A NEW SPECIES OF THE GENUS *LOPHOZIA* (LOPHOZIACEAE) FROM THE SVALBARD ARCHIPELAGO

НОВЫЙ ВИД ИЗ РОДА *LOPHOZIA* (LOPHOZIACEAE) С АРХИПЕЛАГА ШПИЦБЕРГЕН

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Abstract

A new species of liverwort *Lophozia svalbardensis* (Marchantiophyta, Jungermanniopsida) collected in the Nordaustlandet (Svalbard Archipelago) is described. It is characterized by heteroicous inflorescence, presence of low perigynium, crenulate-ciliate perianth mouth, thick walled cells near perianth mouth; colourless to slightly pinkish red tinged gemmae contrasting in color with red-brown marginal cells of the uppermost leaves, two-layer thick base of leaves. A detailed description including illustrations of the species is given. The phylogenetic position of the species is considered, and morphological differences from similar species are discussed.

KEYWORDS: molecular markers, ITS1-2, *trnL*-F, liverworts, taxonomy

INTRODUCTION

In the course of the study of the liverwort flora of Nordaustlandet (Svalbard Archipelago) we collected a species of *Lophozia* with a very peculiar appearance. This bright green and purple red *Lophozia* with numerous large perianth and sporophytes grows abundantly on nonsorted circles among crushed rocks in the arctic desert in Gustav V Land (Figs. 1-2). Based on heteroicous (partly just paroicous) inflorescences we provisionally assigned it to *Lophoziopsis excisa* (Dicks.) Konstant. & Vilnet. Subsequent thorough examination of the samples under a microscope showed that the species differs from *L. excisa* both in the color and shape of gemmae, as well as in the characters of the cell network and a number of other features. Molecular study has shown that the species clearly diverged from phylogenetically allied species. Together with the significant morphological differences identified after a thorough study of the sample, this allowed us to describe the new species – *Lophozia svalbardensis* sp. nov.

MATERIAL AND METHODS

The species was collected on the north-west coast of Nordvika Bay (Murchisonfjorden, Gustav V Land, Nordaustlandet, Svalbard). It covered up to 20-25% of nonsorted circles (Fig. 2) and was collected in a large number of mats since it was intended to be published in a set of Hepaticae Svalbardensia Exsiccatae. The coordinates of locality were measured using GPS.

The samples were re-examined several times in order to clarify and identify the variability of different characters. Some of them were difficult to describe e.g. it was very hard to find and take a picture of the mouth of the perianth, since they were destroyed at most of them. Only after a thorough study of most of the collected samples was it possible to find gemmae on smaller shoots hidden among perianth bearing shoots. To illustrate the quite characteristic appearance and the most important morphological features we took pictures using Nikon SMZ 800 or they were depicted in drawings. The specimens are deposited in Herbarium of Polar-Alpine Botanical Garden.
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Garden-Institute of the Kola Scientific Center, Russian Academy of Science, duplicates will be sent to LE, MW, MHA, VBGI.

MOLECULAR DATA

To reveal the affinity of collected species we implemented phylogenetic analyses based on ITS1-2 nrDNA and trnL-F cpDNA. Newly sequenced data were obtained for nine specimens, sequences were taken from our previous studies for 30 specimens (Vilnet et al., 2008, 2010; Bakalin & Vilnet, 2019). The newly produced dataset contains the majority of molecularly studied specimens of the genera Lophozia and Lophoziopsis, a number of other key genera from family Lophoziaceae and Scapaniaceae; the outgroup was represented by Anastrepta orchadensis (Hook.) Schiffn. from Anastrophyllaceae. All specimens included in the current study are listed in Appendix 1 with GenBank accession numbers and voucher details.

DNA isolation, amplification and sequencing

DNA was extracted from dried liverwort tissue using the DNeasy Plant Mini Kit (Qiagen, Germany). The primers given by White et al. (1990) for ITS1-2 and Taberlet et al. (1991) for trnL-F were used for amplification and sequencing reactions.

PCR was carried out in 20 μl volumes with the following amplification cycles: 3 min at 94°C, 30 cycles (30 s 94°C, 40 s 56°C, 60 s 72°C) and 2 min of final extension time at 72°C. Amplified fragments were visualized on 1% agarose TAE gels by EthBr staining, purified using the QIAquick Gel Extraction Kit (Qiagen, Germany), and then used as a template in sequencing reactions with the ABI Prism BigDye Terminator Cycle Sequencing Ready Reaction Kit (Applied Biosystems, U.S.A.) following the standard protocol provided for 3100 Avant Genetic Analyzer (Applied Biosystems, USA).

Phylogenetic analyses

The newly obtained ITS1-2 and trnL-F nucleotide sequences were assembled and then included in the newly produced dataset in BioEdit 7.0.1 (Hall, 1999). The automatic alignment procedure was done with option of full multiple alignment with default settings for gaps and extension weights in the ClustalW tool. The obtained dataset was manually corrected. The absence of incongruence between two studied loci was shown in preliminary phylogenetic estimation. The combined ITS1-2+trnL-F was used in subsequent analyses with inclusion of all positions, absent data at the ends of regions were coded as missing.

Three criteria were implemented to the reconstruction of phylogeny: maximum parsimony (MP) with TNT v. 1.5 (Goloboff & Catalano, 2016), maximum likelihood (ML) with PhyML v. 3.0 (Guindon et al., 2010) and Bayesian reconstruction with MrBayes v. 3.2.1 (Ronquist et al., 2012). The parsimony analysis with TNT involved a New Technology Search for the minimal length tree by five iteration and 1000 bootstrap replicates, default settings were used for other parameters, gaps were treated as missing. The program ModelGenerator (Keane et al., 2006) identified TN+I+Γ as the best-fitting evolutionary model for the ITS1-2+trnL-F dataset. This model, gamma distribution with four rate categories to estimate among-site rate heterogeneity were used in the maximum likelihood estimation. Bootstrap support (BS) for individual nodes was assessed using a resampling procedure with 500 replicates. According to the stopping frequency criterion (FC) for the bootstrap (Pattengale et al., 2010) our dataset should require only 250 replicates to reach convergence with Pearson average c100 = 0.994960 as estimated by RAxML v. 7.2.6 (Stamatakis, 2006).

For the Bayesian analyses each partition of the combined alignment (ITS1-2, trnL-F) was separately assigned the GTR+I+Γ model that recommended by authors of the program; gamma distributions were approximated using four rate categories. Two independent runs of the Metropolis-coupled MCMC were used to sample parameter values in proportion to their posterior probability. Each run included three heated chains and one unheated, and two starting trees were chosen randomly. Chains were run for ten million generations and trees were sampled every 100th generation. The software tool Tracer (Rambaut & Drummond, 2007) revealed effective sample size (ESS) as 29112.555 and auto-correlation time (ACT) as 618.2968 for our data. As determined by Tracer, the first 10 000 trees in each run were discarded as burn-in, thereafter 180 000 trees were sampled from both runs. The average standard deviation of split frequencies between two runs was 0.001357. Bayesian posterior probabilities were calculated from trees sampled after burn-in.

The infrageneric and infraspecific variability of ITS1-2 and trnL-F for the genus Lophozia was calculated as

![Fig. 1. Map of Svalbard, collecting locality is indicated.](image-url)
the average pairwise \( p \)-distances in Mega 5.1 (Tamura et al., 2011) using the pairwise deletion option for counting gaps.

RESULTS

In total, ITS1-2 and \( trnL-F \) nucleotide sequences were newly obtained for nine specimens and deposited into GenBank. The combined ITS1-2+\( trnL-F \) alignment for 39 specimens consists of 1409 sites, among them 894 sites belong to ITS1-2 and 515 sites to \( trnL-F \). The number of conservative positions in ITS1-2 and \( trnL-F \) is 497 (55.59%) and 360 (69.90%), respectively, the number of variable positions is 360 (40.27%) and 145 (28.16%), and the number of parsimony-informative positions is 226 (25.28%) and 86 (16.70%). In the combined alignment there are 857 (60.82%) conservative sites, 505 (35.84%) variable sites and 312 (22.14%) parsimony informative positions.

The MP analysis with TNT yielded 19 equally parsimonious trees with a length of 1636 steps, with CI = 0.619224 and RI = 0.709245. The ML criterion recovered a tree with a Log likelihood of -7703.55. Arithmetic means of Log likelihoods in Bayesian analysis for each sampling run were -7505.17 and -7505.48.

The tree topologies achieved in all estimations became highly congruent. On the Fig. 3 the tree topology from ML analysis is presented with ML and MP bootstrap support values (BS) and Bayesian posterior probabilities (PP) for each node. In common, tree topology is congruent with those published in our previous studies (Vilnet et al., 2008, 2010; Bakalin & Vilnet, 2019). The tested specimen from Svalbard was found in sister relation to specimen of \( Lophozia ascendens \) (Warnst.) R.M.Schust. from Buryatiya Republic without support in MP, BS = 61% in ML, PP = 0.7 in BA or -/61/0.70. This clade is related to \( Lophozia lantratovae \) Bakalin (-/84/1.00) and then to a clade with specimens related to \( L. wenzelii \) (Nees) Steph. – \( L. ventricosa \) (Dicks.) Dumort. – \( L. austrohibrica \) Bakalin (/-70/0.99). The last relation in the genus \( Lophozia \) (-/81/1.00) belongs to clade of \( L. silvicoloides \) N. Kitag. and recently described \( L. fuscovires \) Bakalin & Vilnet (-/89/1.00).

To support taxonomic treatment of tested specimen, the infraspecific and infrageneric \( p \)-distances for ITS1-2/\( trnL-F \) loci were calculated for species of the genus \( Lophozia \) (Table 1). The level of infraspecific distances among majority of species did not exceed 1%, with ex-
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Fig. 3. Phylogram obtained in a maximum likelihood analysis for the families Lophoziacae and Scapaniaceae based on combined nucleotide sequences dataset of ITS1-2+trnL-F. Bootstrap support values of maximum parsimony, maximum likelihood analyses and Bayesian posterior probabilities more than 50% (0.50) are indicated.

exception of L. lantratovae (1.1/0.2%). The variability in the complex of allied taxa from the clade of L. wenzelli-ventricosa-astrosibirica was agreed with infraspecific, which again sharply raises the question of revision of this complex. The tested sample from Svalbard differed from the all species of Lophozia in 4.4 – 5.9/1.9 – 4.0%, which corresponded to the level of differentiation of species in this group being evaluated 4.9-7.5/1.7–5.1%. (Table 1). The phylogenetic affinity and level of sequence divergence allow us to attend Svalbard’s specimen to a species new to science – Lophozia svalbardensis sp. nov.

TAXONOMY

Lophozia svalbardensis Konstant., Vilnet & Mamonov sp. nov.

Type: Norway, Svalbard, Nordaustlandet, Gustav V Land, Murchisonfjorden, south-east slope on north-west coast of Nordvika Bay, 80°3”13’N – 18°48”26’E (80.053638 N – 18.807244E), 196 m alt. bank of lake, rock field, on covered by bryophytes nonsorted circles among crushed rocks, 17 August 2007, coll. Konstantinova N.A. & A.N.Savchenko K135-3-07 (Holotype KPABG; Isotypes MHA, MW, LE, VBGI SYKO). Figs. 4-7
**Etymology:** The name refers to the area where the species was collected.

**Diagnosis.** The species is characterized by 1) heteroicous inflorescence; 2) presence of small perigynium; 3) crenulate-ciliate with teeth up to 4 cells long perianth mouth; 4) slightly to distinctly thick walled cells of perianth mouth; 5) colorless to slightly pinkish red tinged gemmae contrasting in color with red-brown marginal cells of uppermost leaves; 6) leaves two layer thick near the base.

**Description**

Plants in dense low mats, with abundant perianth and sporophytes, purple to brick-red-brown in upper parts and green below, sterile shoots just 0.5–0.7 mm, near perianth to 1.2 (1.3) mm wide and just 3–4 mm long, with several subfloral innovations that easily became fertile again, branching lateral-terminal or lateral intercalary, stem fleshy, soft textured, dark brown on ventral side and light brown to dark green on dorsal side especially in upper part, cross-section 15–20 cells high, almost round to subelliptical, 300–400 × 400–450 μm with fungi infections up to 0.5–0.75 high, cells in ventral side of cross-section ca. (12)15–20(25) μm in upper part 25–35(40) μm. Rhizoids numerous in very dense mats, colorless to slightly brownish, very long. Leaves purple or red-brown to almost black distally and light-green or colorless to slightly brownish, very long. Leaves purple or red-brown to almost black distally and light-green or colorless proximally, on sterile shoots imbricate distinctly concave, brown to almost black distally and light-green or colorless again, branching lateral-terminal or lateral intercalary, stem fleshy, soft textured, dark brown on ventral side and light brown to dark green on dorsal side especially in upper part, cross-section 15–20 cells high, almost round to subelliptical, 300–400 × 400–450 μm with fungi infections up to 0.5–0.75 high, cells in ventral side of cross-section ca. (12)15–20(25) μm in upper part 25–35(40) μm. Rhizoids numerous in very dense mats, colorless to slightly brownish, very long. Leaves purple or red-brown to almost black distally and light-green or colorless proximally, on sterile shoots imbricate distinctly concave, subquadrat 480 × 480 μm as wide as long or slightly wider than long, 450–480 × 400–430 μm with broadly obtuse-triangular to shallow lunate sinus ca. 0.15–0.3 of leaf length, lobes with dorsal lobes slightly smaller, obtuse to subacute, rarely acute. Cells of leaves with distinct rather large trigones and slightly thick-walled, in upper part of leaves with red-brown colored walls, along the margin approximately the same size as in the middle 20–25 μm, at base slightly larger, elongated to 22 × 32–37 (42) μm, at leaf base and sometimes up to 0.3 leaf length two layers thick. Cuticle smooth. Gemmae on juvenile small leaves hidden in uppermost leaves or on small sometimes androecious branches or sporadic on plants with young perianth, gemmae mostly colorless with admixture of slightly pinkish contrasting with intensely rich red-brown color of the upper parts of the surrounding leaves, very variable in shape and size, ellipsoidal to rounded triangular and rare rectangular with rounded and more or less thickened angles 1–2 (3) celled, 22 × 22 μm, 18–20 × 30 μm, 25 × 25 μm, 25 × 30 μm, 27 × 33 μm, 22 × 37–40 (42) μm. Leaves on small leaved gemmiparous shoots wider than long, ca. 450 × 350 μm, 550 × 350 μm.

Heteroicous. Antheridia just below perianth in female bracts or in 2–3 pairs below gynoecia or on rather small leaved gemmiparous branches, male bracts are slightly larger than leaves, slightly ventricose at the base on dorsal side, 1.1–1.3 mm wide and 0.7–1.1 mm long divided in 2–3 uneven lobes, two-lobed leaves often with large lobe-like teeth at base ca. 5 cells wide and up to half of leaf length, on dorsal side with scattered small teeth on margins, leaf lobe ending by uniseriate 1–3 (5) cells long apices of almost isodiametric and slightly reduced in size to upper cell, sometimes two cell wide in the middle. Antheridia with uniseriate stalk up to 7 cells long.

Young inflorescences look like dense crispate heads. Female bracts larger than leaves, wavy and crispate on margins, much wider than long, to 1700 μm wide and 900 μm long, divided up to 0.4 their length in 3–5 lobes with curved margins of sinuses, lobes end in up to 4-celled teeth, cells of teeth are thick walled, 25 × 25–30 μm, on both sides of bracts there are scattered one-two celled teeth, bracteole small, connate on one side with bract. Perianths large, ca. 1.3 mm wide and 2 mm long, cylindrical, plicate in upper part, almost fully free, slightly contracted to mouth, distinct but short perigynium present in some plants, ca. 0.2–0.25 of perianth length. Mouth destroyed very soon after fertilization, colorless, crenulate-ciliate with scattered teeth 1–4 cells long, cells of teeth slightly elongated 20 × 25 μm apart of distinctly elongated upper cell that to 14 × 35 μm. Cells just below mouth thick-walled, dark red-brown apart uppermost that are hyaline and very soon destroyed after fertilization. Cells in upper part of perianth very variable in shape and size, from 12–14 × 25 μm and 14 × 14 μm to 20 × 32 μm, 25–30 × 30–35 (38) μm in the middle, gradually became much longer below to 25–37 × 45–75 (100) μm. Spores dark red-brown, fine granulate. ca. 13–15 μm in diameter. Elaters 2–spiral, 8–13 μm wide, with band ca. 1.5–2 μm wide.

**Differentiation**

*Lophozia svalbardensis* differ from the somewhat similar paroicous *Lophoziosis excisa* in shape and color of

| Taxon | Within species/clade, ITS1-2/trnL-F, % | Between species/clade, ITS1-2/trnL-F, % |
|-------|----------------------------------|----------------------------------------|
| 1 wenzeli-ventricosa-austrosibirica clade | 0.9/0.3 | 1 2 3 4 5 6 |
| 2 lantratovae | 1.1/0.2 | 6.1/4.6 |
| 3 svalbardensis | n/c/n/c | 5.3/3.2 4.3/4.0 |
| 4 ascendens | n/c/n/c | 7.2/3.2 6.2/3.5 5.4/1.9 |
| 5 fuscovirens | 0.6/0.0 | 6.9/2.7 6.4/4.2 5.9/3.9 7.5/3.8 |
| 6 silvicoloides | 0.0/0.0 | 5.8/2.8 5.1/5.1 4.2/3.5 5.4/3.6 4.9/1.7 |

Table 1. The value of infrageneric *p*-distances for the genus *Lophozia*, n/c – non calculated value due to single specimen only.
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Fig. 4. A, D, F, G – fertile (paroicous) shoots. B, H, J-M – female bracts. C, E, I – male bracts. K – female bract with bracteole. Scale bars: 1 mm to B, C, E, I-M. 2 mm to A, D, F, G. All from Konstantinova & Savchenko K135-3-07 (KPABG).

gemmae, shape and size of midleaf cells, crenulate-ciliate mouth of perianth, heteroicous inflorescences (Table 2). Based on heteroicous inflorescence, crenulate-ciliate female bracts, decolorate crenulate-ciliate mouth of perianth, thick walled cells of perianth mouth the species may be confused with Isopaches bicrenatus (Schmidel ex Hoffm.) H.Buch. From the latter species Lophozia svalbardensis differs in the shape and color of gemmae, lack of specific smell that is very characteristic for I. bicrenatus, stem cross section which is up to 20 cells high vs. 8–9 cells high in I. bicrenatus. From phylogenetically closely related Lophozia ascendens and L. lantratovae, the species strongly differs in heteroicous inflorescence, shape of female bracts, the color of gemmae, color of leaves (Table 2).

Ecology and distribution

The species is known from the type locality where it is abundant on nonsorted circles in the rocky polar desert, covering up to 25% of the surface of nonsorted circles on which it forms a red-brown crust (Fig. 2). The species grows in almost pure mats with admixture of single shoots of Anthelia juratzkana (Limpr.) Trevis., Cephalozia bicuspidata (L.) Dumort. and Prasanthus suecicus (Gottsche) Lindb. Given that the species produces a lot of spores, it is most likely widespread in the Arctic and adjacent mountains.

Discussion

Lophozia is a small genus of liverworts, with an incredibly confusing interpretation of the most of its species. According to the World checklist of liverworts (Söderström et al., 2016), it includes 18 species, of which
only five are marked as fully accepted, seven species are marked as knowledge problem and six are referred to category "serious doubts". Some of the described entities were tested molecularly, however, the problem is that the interpretations of the species included in different molecular studies differ. Critical revision of the entire genus on an integrative basis has never been done. Moreover, such a study will unavoidably face the need to first understand and relate dozens of described names as well as to check involved in molecular study specimens. Given the very poor preservation of the most type specimens and the fact that they often contain just several individuals, and sometimes only sterile plants, this is a possibly unsolvable problem. A more or less appropriate approach is to gradually unravel the tangle of accumulated problems based on study type specimens and choosing neotypes from the molecularly studied samples. The described new species is, in our opinion, an example of a description of a species that meets these requirements. As shown above, _L. svalbardensis_ differs well both morphologically and molecularly. _Lophozia svalbardensis_ is the only heteroicous species of _Lophozia_ sensu Konstantinova _et al._ (2009), all species of which with the exception of _L. austrosibirica_ are dioicus. The latter species was described as paroicous (Bakalin, 2003) but the species level of this taxon is not supported by our molecular study (Fig.3)

_Lophozia svalbardensis_ is the fifth species of liverworts described from the Svalbard Archipelago along with _Marsupella arctica_ (Berggr.) Bryhnn et Kaal. (described as _Sarcoscyphus emarginatus_ var. _arcticus_ Berggr.), _Scapania spitsbergensis_ (Lindb.) Müll.Frib. (as _Martinelli spitsbergensis_ Lindb.), _Jungermannia polaris_ Lindb., _Scapania obcordata_ (Berggr.) S.W.Arnell (as _Sarcocyphos obcordatus_ Berggr.). All of these species were described from Svalbard in the last third of the 19th century and it took ca. 150 years for it to become clear that they are not rare in most sectors of the arctic and adjacent areas. Most likely, the species described by us is not uncommon in the Arctic, which is still very poorly studied in relation to liverworts.

**ACKNOWLEDGMENTS**

Anders Hagborg is gratefully acknowledged for correction of English and useful suggestions. A. Savchenko is kindly thanked for preparing the map of the studied area and assistance in the preparation of the photos. We are also grateful to the anonymous reviewer for his comments. This study was carried out in the framework of the State Research Program of the Polar-Alpine Botanical Garden and Institute KSC RAS (AAAA-A18-118050490088-0) and was partly supported by RFBR (№18-04-00594).
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Figure 6. A - C – perianth mouth; D – young perianth; E – lobes of female bract; F – male bract with the multicellular tooth on dorsal side; G – stem cross-section; H – apex of male bract; I – leaf margin with gemmae; J – sector of stem cross-section; K – gemmae; F – cells in midleaf. All from Konstantinova & Savchenko K135-3-07 (KPABG).
Table 2. Comparison of several morphological characters of Lophozia svalbardensis with some species.

| Criterion                      | Lophozia svalbardensis Dark brown on ventral side | Lophozia excisa Purple or red-brown to almost black distally and light-green or colourless proximally | Lophozia ascendent Pale yellowish green, colorless proximally do not differ on ventral side | Lophozia lantratovae Pale brown to brownish–red distally parts red to carmine or brownish–red |
|--------------------------------|--------------------------------------------------|-------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|----------------------------------------------------------------------------------|
| Sexuality                      | Heteroicous, copiously fertile                    | Paroicous, copiously fertile                                                                   | Paroicous, copiously fertile                                                     | Paroicous, copiously fertile                                                     |
| Female bract                   | Crispate, 3–5 lobed, edentate or with scattered one-celled teeth | Crispate, irregularly 3–5 lobed, with edentate or finely dentate margins                      | Crispate, irregularly 3–5 lobed, with edentate or finely dentate margins          | Crispate, irregularly 3–5 lobed, with edentate or finely dentate margins          |
| Perianth mouth                 | Crenulate-ciliate, with scattered 1–4 cells long, the teeth with elongated upper cell (20 × 35 μm) | Lobed, with crenulate lobes, with rather elongate thin-walled, finger-shaped marginal cells whose distal ends only are free | Lobulate-laciniate, with laciniae 6–10 cells long, 3–5 cells wide with 1–2 short teeth at base and uniseriate apices 2–5 cells long | With scattered 1(2) celled blunt teeth                                           |
| Leaves                         | 450–480 × 400–430 μm                              | 950 × 1100 μm in smaller phases                                                               | Narrow to ovate rectangular, longer than wide, 560–770 × 750–860 μm             | Ovate to rectangular, as wide as long or longer than wide                         |
| Color of leaves                | Purple or red-brown to almost black distally and light-green or colourless proximally | Pure green or in upper parts red to carmine or brownish-red                                   | Pale to yellowish green                                                          | Light to bright green                                                            |
| Cells in the middle of leaves  | 23–25 × 25–27 μm                                 | (27)28–30(32) × 30–35(40) μm                                                                  | (20)24–27 × 27–30(35)μm                                                         | (18)20–27(30) × 25(27–40(45) μm                                               |
| Cell walls                     | Slightly thick walled especially at perianth mouth | Always thin walled                                                                            | Thin walled                                                                      | Thin walled                                                                      |
| Trigones                       | Distinct, rather large, bulging                  | Very small                                                                                   | Distinct                                                                         | Distinct                                                                         |
| Gemmae                         | In amorphous masses on juvenile leaves, hidden in uppermost leaves, never form a globules      | Sparse on uppermost leaves                                                                   | Abundant, in globules like masses at apices of uppermost leaves                  | Abundant, in globules like masses at apices of uppermost leaves                  |
| Shape and color of gemmae      | Mostly colourless to slightly pinkish 1–2 celled, elliptoidal to rounded triangular and rectangular with rounded and more or less thickened angles | Vinaceous to purplish or purplish brownish, pyramidal to polyhedral-polyangulate           | Yellowish green, angular to stellate                                              | Pale brown to brown with admixture of colour less, 3–4, rare 5 angulate, 10–16 × 13–18 μm |

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CARGILL, D.P. COSTA, B.J. CRANDALL-STOTLER, E.D. COOPER, G. DAUPHIN, J.J. ENGEL, K. FELDBERG, D. GLENNY, S.R. GRADSTEIN, X. HE, J. HEINRICHS, J. HENTSCHEL, A.L. ILKIV, BORGES, T. KATAGIRI, N.A. KONSTANTINOVA, J. LARRAIN, D.G. LONG, M. NEBEL, T. POCS, F. FELISA PUCHE, E. REINER DREWALD, M.A.M. RENNER, A. SCHÄFER-VERM, J.G.S. MORAGUES, R.E. STOTLER, P. SUKH KhARAK, B.M. THIERS, J. URIBE, J. VÁŇA, J.C. VILLARREAL, M. WIGGINTON, L. ZHANG & R.-L. ZHU. 2015. World checklist of hornworts and liverworts. – PhytoKeys 59: 1–828.

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Appendix 1. The list of tested specimens with voucher details and GenBank accession numbers, accessions start with MW obtained in this study.

| Taxon                        | Specimen voucher | GenBank accession number |
|------------------------------|------------------|--------------------------|
| Anastropta orcadensis (Hook.) Schaff. | Russia: Buryatiya Rep., N. Konstantinova, 59-1-01, 102486 (KAPBG) | ITS1-2 nrDNA: DQ875126, trnL-F cpDNA: DQ875088 |
| Diplophyllum taxifolium (Wahlenb.) Dumort. | Russia: Kariyapi Rep., V. Bakalin, 28-Jul-1998 | EU791772, AY327762 |
| Heterogemma capitata (Hook.) Konstant. & Vilnet | Russia: Nizhny Novgorod Prov., N. Konstantinova, 132-03, 106019 (KAPBG) | DQ875119, DQ875080 |
| Lophozia ascends (Warnst.) R.M. Schust. | Russia: Buryatiya Rep., N. Konstantinova, 109-3-01, 104300 (KAPBG) | DQ875089, DQ875054 |
| L. austrosibirica Bakalin | Russia: Buryatiya Rep., V. Bakalin, 15-9-99, 109664 (KAPBG) | DQ875105, DQ875069 |
| L. fuscovirens Bakalin & Vilnet | Norway: Svalbard, A. Savchenko, CA16-12-1, 12143 (KAPBG) | MK774737, MK779914 |
| L. lantratovae Bakalin | Russia: Magadan Prov., V. Bakalin, Mag-50-16-11, 122642 (KAPBG) | MK007092, MK012212 |
| L. lantratovae Bakalin | China: Sichuan Prov., V. Bakalin, China-3-9-17, 122581 (KAPBG), 37536 (VBGI) | MK007086, MK012020 |
| L. lantratovae Bakalin | Russia: Buryatiya Rep., V. Bakalin, 76-7-01, 102544 (KAPBG) | DQ875090, DQ875055 |
| L. silicicoloides N. Kitag. | Norway: Svalbard, N. Konstantinova, K241-1b-12 (KAPBG) | MW298767, MW297148 |
| L. spitsbergensis Konstant. & Vilnet | Russia: Svalbard, N. Konstantinova, K-135-3a-07 (KAPBG) | MW298768, MW297149 |
| L. ventricosa (Dicks.) Dumort. | Russia: Arkhangelsk Prov., Franz Josef Land, Ziegler Island, A. Savchenko, CA19-29-10a-1 (KAPBG) | MT422262, MT431406 |
| L. ventricosa var. guttulata (Lindb. & Arnell) Bakalin | Russia: Buryatiya Rep., N. Konstantinova, 81-1-01, 104253 (KAPBG) | DQ875108, DQ875072 |
| L. wenzeli var. groenlandica (Nees) Bakalin | Russia: Murmansk Prov., N. Konstantinova, G9329 (KAPBG) | DQ875109, DQ875073 |
| L. wenzeli var. lapponica H. Buch & S.W. Arnell | Norway: Svalbard, N. Konstantinova, 124-2-04 (KAPBG) | DQ875112, DQ875076 |
| L. wenzeli var. massularioides Bakalin | Russia: Perm Terr., A. Bezgodov, MW298769, AB 206-09 (KAPBG) | MW297150 |
| Lophoziopsis excisa (Dicks.) Konstant. & Vilnet | Russia: Svalbard, A. Savchenko, CA 364-2a-11 (KAPBG) | MW298770, MW297151 |
| L. excisa (R.M. Schust.) Konstant. & Vilnet | Russia: Murmansk Prov., N. Konstantinova, 41-2-97, 6146 (KAPBG) | DQ875092, DQ875057 |
| Species                      | Collecting Details                                           | Accession Numbers          |
|------------------------------|--------------------------------------------------------------|-----------------------------|
| L. excisa (Dicks.) Konstant.& Vilnet | Russia: Maryi-El Rep., N. Konstantinova, K437-2-04, 108028 (KPABG) | EF065691, EF065684         |
| L. excisa (Dicks.) Konstant.& Vilnet | Antarctica, L. Kurbatova, L125 (KPABG)                       | MW298771, MW297152         |
| L. excisa var. elegans       | Russia: Murmansk Prov., N. Konstantinova, K129-7-19 (KPABG)  | MW298772, MW297153         |
| L. jurensis (Meyl. ex Muell. Frib.) Mamontov & Vilnet | Russia: Altai Terr., 1, Yu. Mamontov, YuSM-214-7 (KPABG) | MF803151, MF803153         |
| L. jurensis (Meyl. ex Müll. Frib.) Mamontov & Vilnet | Russia: Altai Terr., 2, Yu. Mamontov, YuSM-214-8 (KPABG) | MF803150, MF803152         |
| L. longidens (Lindb.) Konstant.& Vilnet | Russia: Murmansk Prov., N. Konstantinova, 360-2-00, 8110 (KPABG) | DQ875094, DQ875059         |
| L. pellucida (R.M. Schust.) Konstant. & Vilnet | Russia: Trans-Baikal Terr., Yu. Mamontov, 356-3-6 (KPABG) | MW298773, MW297154         |
| L. polaris (R.M. Schust.) Konstant. & Vilnet | Norway: Svalbard, 1, A. Savchenko, CA 19-29-3 (KPABG) | MW298774, MW297155         |
| L. polaris (R.M. Schust.) Konstant. & Vilnet | Norway: Svalbard, 2, A. Savchenko, CA 367-2b-11 (KPABG) | MW298775, MW297156         |
| L. polaris (R.M. Schust.) Konstant. & Vilnet | Norway: Svalbard, 3, N. Konstantinova, K129-1-07 (KPABG) | MT334459, MT338482         |
| L. polaris (R.M. Schust.) Konstant. & Vilnet | Russia: Arkhangelsk Prov., Franz Josef Land, MT422257, MT431401 (KPABG) | EU791805, EU791686         |
| L. polaris (R.M. Schust.) Konstant. & Vilnet | Ziegler Island, A. Savchenko, CA 19-29-12 (KPABG) | EU791807, EU791688         |
| Pseudotritomaria heterophylla (R.M. Schust.) Konstant. & Vilnet | Russia: Yakutiya Rep., V. Zolotov, E. Sofronova, 13-Jul-2003 (KPABG) | EU791807, EU791688         |
| Scaccobasis polymorpha (R.M. Schust.) Schljakov | Russia: Murmansk Prov., N. Konstantinova, 21-3b-96, 6189 (KPABG) | EU791735, EU791627         |
| Scapania aspera M. Bernet & Bernet | Belgium, N. Konstantinova, 2-20-3-99 (KPABG) | EU791807, EU791688         |
| Schistochilopsis grandiretis (Lindb. ex Kaal.) Konstant. | Russia: Kamchatka Terr., V. Bakalin, 99-5-01-VB, 102125 (KPABG) | DQ875120, DQ875081         |
| Trilophozia quinquedentata (Huds.) Bakalin | Russia: Kareliya Rep., V. Bakalin, 02-Jul-1997 (KPABG) | EU791804, AY327786         |
| T. quinquedentata fo. gracilis (R.M.Schust.) Konstant. | Norway: Svalbard, N. Konstantinova, K 118-2-06 (KPABG) | EU791802, EU791684         |
| Tritomaria exsecta (Schmidel) Schiffn. ex Loeske | Russia: Nizhny Novgorod Prov., N. Konstantinova, 103-1-03, 105966 (KPABG) | EU791800, EU791682         |
| T. scitula (Taylor) Joerg. | Russia: Komi Rep., M. Dulin, 101301 (KPABG) | EU791799, EU791681         |