

A provisional checklist of mosses (Bryophyta) of Friendship Park (Finland)

Margarita A. Boychuk & Gergely Várkonyi

Boychuk, M. A., Institute of Biology, Karelian Research Centre of RAS, 11 Pushkinskaya St., 185910 Petrozavodsk, Russia, boychuk@krc.karelia.ru. Várkonyi, G., Friendship Park Research Centre, Finnish Environment Institute SYKE, Lentiirantie 342B, FI-88900 Kuhmo, Finland, gergely.varkonyi@syke.fi

We provide the first moss checklist of Friendship Park (Kainuu Region, Finland). Data from both own field collections and the literature are compiled. 164 species are listed in total, of which 79 are representing new species records for Friendship Park. *Hedwigia mollis* and *Plagiothecium rossicum* are reported for the first time from Finland. Most encountered moss species (75%) are widespread in Finland. Seven species occurring in Friendship Park are listed in the 2019 Red List of Finnish Species: *Buxbaumia viridis* (EN), *Callicladium haldanianum* (NT), *Hamatocaulis vernicosus* (NT), *Schistostega pennata* (VU), *Sphagnum contortum* (NT), *S. inundatum* (EN) and *S. subnitens* (NT). Further five species, *Fontinalis dalecarlica* (NT), *Helodium blandowii* (NT), *Scorpidium scorpioides* (NT), *Splachnum ampullaceum* (NT) and *Tomentypnum nitens* (NT), are included in the 2019 European Red List. The moss species diversity of Friendship Park is compared with that of the adjacent Kostomuksha Strict Nature Reserve (Russia). The total moss species richness of Friendship Park is assessed using nonparametric estimators. It is concluded that the moss species diversity of Friendship Park is relatively well known.

Introduction

Established in 1990, Friendship Park is located in the area of the municipalities of Kuhmo and Suomussalmi in Kainuu Region, eastern Finland (Metsähallitus 2009; Fig. 1). Friendship Park consists of five protected areas: Juortanansalo–Lapinsuo Mire Reserve (hereinafter Juortanansalo–Lapinsuo MR; 54.4 km²), Iso-Palonen–Maariansärkät Nature Reserve (Iso-Palonen–Maariansärkät NR; 40.5 km²), Lentua Nature Reserve (Lentua NR; 65.9 km²), Elimyssalo Nature Reserve, including the nearby Riihivaara area (Elimyssalo NR; 92.4 km²), and Ulvinsalo Strict Nature Reserve (Ulvinsalo SNR; 39.5

km²). With a total area of 292.7 km², Friendship Park comprises the Finnish part of the Finnish–Russian Friendship Nature Reserve. The Russian part consists of a single protected area, Kostomuksha Strict Nature Reserve (Kostomuksha SNR; 492.8 km²), which is 1.7 times larger than combined parts of Friendship Park (Fig. 1). Situated on both sides of the national border between Finland and Russia, Friendship Nature Reserve is part of the Green Belt of Fennoscandia (e.g. Titov et al. 1995; Bakhmet et al. 2021).

One of the main aims of these protected areas is to ensure long-term survival of species and their habitats, occurring in the area. Therefore, there is a fundamental need to survey bio-

logical diversity of various groups of organisms in Friendship Nature Reserve.

The moss flora of Friendship Park has been studied mostly sporadically during the past 25 years. In a study of the biotopes of Ulvinsalo SNR, Teeriaho & Tolvanen (1997) found 58 species. In addition, the endangered species *Buxbaumia viridis* was recently reported from Ulvinsalo SNR (Pihlaja et al. 2022). In a series of mire studies, mosses were identified in Elimyssalo NR (total 62 species: Heikkilä et al. 1997; Tahvanainen et al. 2002; Galanina & Heikkilä 2007; Boyчук 2012) and Juortanansalo–Lapinsuo MR (total 67 species: Galanina 2012; Boyчук 2012). No records of mosses of Iso-Palonen–Maariansärkät NR and Lentua NR have been previously published. The aims of present study are to (i) supplement and summarise moss species occurrence data from the area, (ii) compile a preliminary checklist of moss species of Friendship Park and (iii) compare the moss floras of Friendship Park and Kostomuksha SNR. In addition, we (iv) aim at assessing the total moss species richness of Friendship Park and its parts, using nonparametric estimators.

Study area

Geologically, Friendship Park is located on the Fennoscandian (Baltic) shield consisting predominantly of the oldest Archaean and Proterozoic rocks (Gorkovets & Raevskaya 2003, 2009). The study area lies in the middle boreal vegetation zone (Ahti et al. 1968).

Juortanansalo–Lapinsuo MR is dominated by Archaean migmatites. Most of the area is occupied by mires (the largest being Isosuo) in natural state. The mire system includes aapa mires, bogs, as well as poor and intermediate fens (Kuznetsov et al. 1999; Galanina 2012). Forest is formed on mineral ground on islets surrounded by mires and patches between mires; they are mesic old-growth spruce forests and pine stands. There are many ponds in the area but no lakes.

Iso-Palonen–Maariansärkät NR is located in the distribution field of tonalite gneisses with migmatites. There is plagiomicrocline granite in the eastern part. The hydrographic network is well developed. The largest waterbodies are Lake

Iso-Palonen and the River Viiksimo (Viiksimojoki in Finnish). Most of the forests in the protected area are pine stands. In the Maariansärkät area they occupy east–west orientated eskers.

Lentua NR is dominated by Archaean rocks such as plagiomicrocline gneissose granites and tonalite gneisses. In the northeastern part of the area, amphibole-bearing and mica schists occur. Most of the area (75%) is covered by open water, Lake Lentua, which is the largest unregulated lake in Kainuu Region. It has sandy and rocky shores. The surface water outflow of the lake is channeled through the Lentua rapids (Lentuankosket). The rest of the area (25%) consists of islands and shores mostly covered by pine forests.

Elimyssalo NR is dominated by Archaean plagiomicrocline granites. Proterozoic rocks (komatiites and basalts) are widespread in the southern parts. There are small lakes and brooks, old-growth (>120-year-old) spruce stands, paludified forests and mires. The mire Härkösuu, consisting of various biotopes – e.g., aapa mires, spring fens and pine bogs – has been studied intensively (Tahvanainen et al. 2002; Galanina & Heikkilä 2007). There are two old wilderness tenant farms (Latvavaara and Levävaara) in the area, covered by hilltop meadows.

Ulvinsalo SNR is geologically homogeneous and consists of microcline granites. There are pristine spruce forests, various mires, small lakes and watercourses. The diversity of biotopes is high (Teeriaho & Tolvanen 1997).

In the biogeographic zonation scheme of Finland (Cajander 1906), Friendship Park is part of the province Ostrobothnia kajanaensis, which corresponds the biological province Kainuu. The moss species richness of province Kainuu has been assessed several times, e.g., Ulvinen & Syrjänen (2009): 369 species; Pihlaja & Ulvinen (2021) and Pihlaja et al. (2022): total 383 species.

Sampling

This study is based mainly on the first author's field collections. Moss flora surveys during short field trips (1–8 days) were carried out in Friendship Park in the years 1995–1997, 2001, 2008–2009, 2015, 2018 and 2019, using a total of 45 person-days (Table 1). Over 1 200 moss samples

Figure 1. Map of Friendship Park (Finland) indicating collecting localities.

Juortanansalo–Lapinsuo MR

- 1. Isosuo
- 2. Lokkipuro

Iso-Palonen–Maariansärkät NR

- 3. Matokangas
- 4. Viiksimonjoki
- 5. Särkkälampi and Pieni Joutenlampi

Lentua NR

- 6. Vetotaipaleenkangas
- 7. Laajalahdenkangas
- 8. Lentuankoski

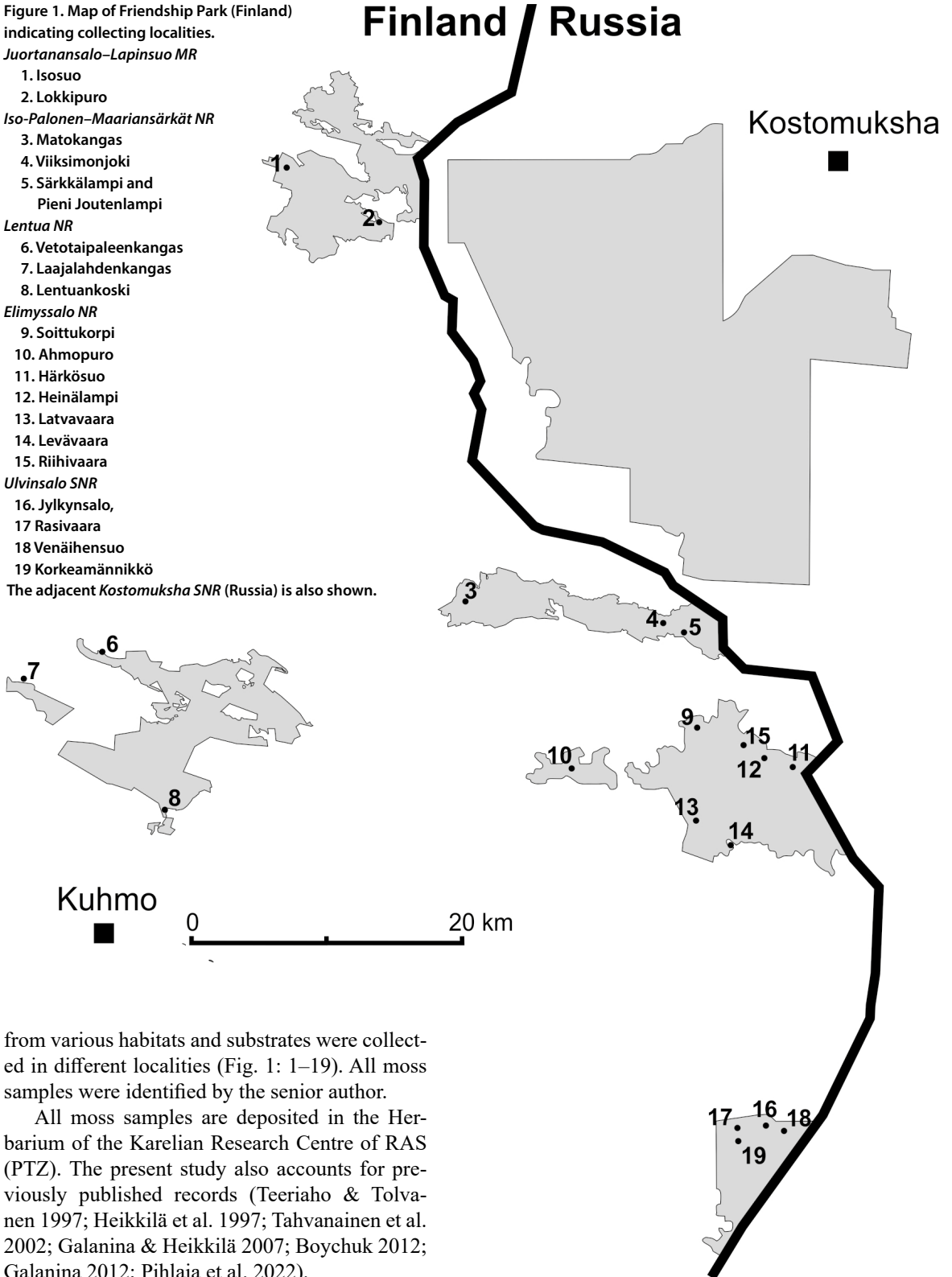
Elimyssalo NR

- 9. Soittukorpi
- 10. Ahmopuro
- 11. Härkösuu
- 12. Heinälampi
- 13. Latvavaara
- 14. Levävaara
- 15. Riihivaara

Ulvinsalo SNR

- 16. Jylkynsalo,
- 17 Rasivaara
- 18 Venäihensuo
- 19 Korkeamännikkö

The adjacent *Kostomuksha SNR* (Russia) is also shown.



from various habitats and substrates were collected in different localities (Fig. 1: 1–19). All moss samples were identified by the senior author.

All moss samples are deposited in the Herbarium of the Karelian Research Centre of RAS (PTZ). The present study also accounts for previously published records (Teeriaho & Tolvanen 1997; Heikkilä et al. 1997; Tahvanainen et al. 2002; Galanina & Heikkilä 2007; Boychuk 2012; Galanina 2012; Pihlaja et al. 2022).

Estimation of species richness

Studying species richness of biotopes, communities or ecosystems inevitably involves sampling error. Checklists of species of a geographical area are therefore incomplete by definition. Increasing sampling effort will decrease the number of undetected species but the additional effort needed to sample rare species is typically high. To estimate the total number of species of a target area or community, one can use the frequency distribution of the detected species and estimate the number of species with zero encounters, i.e., species that have remained undetected by sampling. We are using two nonparametric approaches to account for undetected species. Estimator Chao1 was originally derived as a lower bound of species richness (Chao 1984) but subsequently shown to offer a reasonably good point estimator of the total species richness (e.g. Chao et al. 2006). To estimate the number of undetected species, it only uses the information of species encountered in the sample once (singletons) or twice (doubletons). Our second nonparametric approach provides jackknife estimators developed by Burnham and Overton (1978). In this method, the bias of the observed species richness is assessed by using information on how the estimator changes when individuals are successively deleted from the original data. Again, only information of rarely encountered species is used; their first-order estimator only considers information of singletons, and their second-order estimator on singletons and doubletons. All estimations were implemented in program SPADE (Chao & Shen 2010).

Species checklist

The moss species are arranged in alphabetical order. The nomenclature follows Hodgetts et al. (2020). The names of protected areas are marked as follows (see Fig. 1): **I** – Juortansalo–Lapinsuo MR, **II** – Iso-Palonen–Maariansärkät NR, **III** – Lentua NR, **IV** – Elimyssalo NR, **V** – Ulvinsalo SNR. Localities of moss collecting (Fig. 1: 1–19) are indicated by Arabic numerals. In cases the exact location is not known, they are marked with a plus sign (+). The checklist accounts for

literature data with the following abbreviations in square brackets: [H] – Heikkilä et al. (1997); [TT] – Teeriaho & Tolvanen (1997); [T] – Tahvanainen et al. (2002); [GH] – Galanina & Heikkilä (2007); [B] – Boyčuk (2012); [G] – Galanina (2012); [P] – Pihlaja et al. (2022). Species included in the Red List of Finland (Juutinen et al. 2019) are marked with an 'F', those in the Red List of Europe (Hodgetts et al. 2019) with an 'E', along with their conservation status categories. New species records for Friendship Park are marked with an asterisk (*).

- **Amblystegium serpens* (Hedw.) Schimp. – **III**: 8; **V**: 16.
- **Andreaea rupestris* Hedw. – **I**: 1; **II**: 3, 4; **III**: 8; **IV**: 14; **V**: (+).
- **Atrichum undulatum* (Hedw.) P. Beauv. – **III**: 8; **IV**: 13.
- Aulacomnium palustre* (Hedw.) Schwägr. – **I**: [B], 1; **II**: 3, 4, 5; **III**: 6, 7, 8; **IV**: [B, T], 9, 10, 11, 14, 15; **V**: [TT], 16, 18, 19.
- **Bartramia pomiformis* Hedw. – **IV**: 10; **V**: (+).
- **Brachytheciastrum velutinum* (Hedw.) Ignatov & Huttunen – **IV**: 12; **V**: 16.
- **Brachythecium albicans* (Hedw.) Schimp. – **III**: 8.
- Brachythecium rivulare* Schimp. – **IV**: [B], 10, 11, 12; **V**: [TT], 16.
- **Brachythecium salebrosum* (Hoffm. ex F. Weber & D. Mohr) Schimp. – **I**: 2; **II**: 4, 5; **III**: 8; **IV**: 13, 14; **V**: 16, 18.
- Buxbaumia viridis* (Moug. ex Lam. & DC.) Brid. ex Moug. & Nestl. – **V**: [P]. F (EN).
- **Callicladium haldanianum* (Grev.) H.A. Crum – **II**: 4. F (NT).
- Calliargon cordifolium* (Hedw.) Kindb. – **I**: [B], 1, 2; **II**: 3, 4; **III**: 8; **IV**: 9, 10, 12, 14, 15; **V**: [TT], 16, 18.
- Calliargon giganteum* (Schimp.) Kindb. – **I**: [B], 1.
- **Calliargon megalophyllum* Mikut. – **III**: 7; **IV**: 10.
- Calliargon richardsonii* (Mitt.) Kindb. – **I**: [B], 1; **III**: 8; **IV**: 12; **V**: 16.
- Calliargonella cuspidata* (Hedw.) Loeske – **IV**: [B, T], 11, 12.
- **Calliargonella lindbergii* (Mitt.) Hedenäs – **II**: 3; **III**: 6, 7, 8; **IV**: 14.

- Campylium stellatum* (Hedw.) Lange & C.E.O.
Jensen – I: [B], 1; II: 3; III: 7; IV: [B, T, GH], 11; V: [TT].
- **Ceratodon purpureus* (Hedw.) Brid. – III: 6; IV: 12, 13.
- Cinclidium stygium* Sw. – I: [B], 1; IV: [B, T], 11, 12.
- **Cirriphyllum piliferum* (Hedw.) Grout – III: 8; IV: 13.
- **Climacium dendroides* (Hedw.) F. Weber & D. Mohr – III: 6, 8; IV: 10, 13, 14; V: 16.
- **Cynodontium strumiferum* (Hedw.) Lindb. – I: (+); II: (+).
- **Dichelyma falcatum* (Hedw.) Myrin – II: 4; III: 6, 7, 8; IV: 14.
- Dicranella cerviculata* (Hedw.) Schimp. – I: [B], 1, 2.
- **Dicranum angustum* Lindb. – III: 6.
- Dicranum bonjeanii* De Not. – I: [B], 1; IV: [B, T], 11.
- **Dicranum drummondii* Müll. Hal. – I: (+); II: 4; IV: 10, 14, 15; V: 19.
- **Dicranum flexicaule* Brid. – I: 1; II: 3, 4; III: 6; IV: 14, 15; V: (+).
- **Dicranum fragilifolium* Lindb. – III: 6; IV: 9, 10, 15.
- Dicranum fuscescens* Sm. – I: [B], 1; II: 3, 4, 5; III: 6, 7; IV: 9, 10, 13, 14, 15; V: 17, 18, 19.
- Dicranum leioneuron* Kindb. – I: [B], 1; IV: [B], 11.
- Dicranum majus* Sm. – I: [B], 1; II: 3; III: 7, 8; IV: [B], 9, 10, 11, 12, 14, 15; V: [TT], 18, 19.
- **Dicranum montanum* Hedw. – I: (+); II: 5; III: 8; IV: 10; V: (+).
- Dicranum polysetum* Sw. ex anon. – I: [B], 1; II: 3, 4, 5; III: 7; IV: [B], 10, 11, 14; V: [TT], 18.
- Dicranum scoparium* Hedw. – I: [B], 1; II: 3, 4, 5; III: 6, 7, 8; IV: [B], 9, 10, 11, 13, 14, 15; V: [TT], 18, 19.
- Dicranum undulatum* Schrad. ex Brid. – I: [B, G], 1; II: 5; III: 7; IV: [B, T], 10, 11, 14; V: [TT], 19.
- **Ditrichum heteromallum* (Hedw.) E. Britton – II: 4.
- **Ditrichum pusillum* (Hedw.) Hampe – I: (+).
- **Drepanocladus polygamus* (Schimp.) Hedenäs – III: 8.
- Drepanocladus trifarius* (F. Weber & D. Mohr) Broth. ex Paris – IV: [B, T], 11.
- **Fissidens adianthoides* Hedw. – III: 6.
- **Fissidens osmundoides* Hedw. – III: (+).
- **Fontinalis antipyretica* Hedw. – I: 2; II: (+); III: 6, 8; IV: 10, 14, 15; V: 16, 18, 19.
- **Fontinalis dalecarlica* Schimp. – II (+); III: 8; IV: 12, 14, 15; V: 19. E (NT).
- **Grimmia longirostris* Hook. – III: 8.
- **Grimmia muehlenbeckii* Schimp. – III: 8.
- **Hamatocaulis vernicosus* (Mitt.) Hedenäs – IV: 12. F (NT).
- **Hedwigia mollis* Ignatova, Ignatov & Fedosov – I: 1; II: (+); IV: (+).
- Helodium blandowii* (F. Weber & D. Mohr) Warnst. – I: [B], 1; IV: [B, T], 9, 11. E (NT).
- **Heterocладиella dimorpha* (Brid.) Ignatov & Fedosov – I: (+); IV: (+).
- **Hygroamblystegium fluviatile* (Hedw.) Loeske – III: 8.
- **Hygrohypnella ochracea* (Turner ex Wilson) Ignatov & Ignatova – I: 2; IV: 10; V: 19.
- Hylocomiadelphus triquetrus* (Hedw.) Ochyra & Stebel – I: [B], 1; II: 4; III: 6, 7; IV: [B], 10, 11, 12, 13, 14; V: [TT], 18, 19.
- Hylocomiastrum umbratum* (Hedw.) M. Fleisch. – IV: [B], 11, 14; V: 18.
- Hylocomium splendens* (Hedw.) Schimp. – I: [B], 1; II: 3, 4, 5; III: 6, 7; IV: [B], 9, 10, 11, 12, 13, 14, 15; V: [TT], 18, 19.
- **Hymenoloma crispulum* (Hedw.) Ochyra – III: 8; IV: 12.
- **Hypnum cupressiforme* Hedw. – II: (+); III: 8.
- **Isopterygiopsis pulchella* (Hedw.) Z. Iwats. – V: 16.
- **Leptodictyum riparium* (Hedw.) Warnst. – III: 6; V: 18.
- **Lescurea saxicola* (Schimp.) Molendo – III: 8.
- **Lewinskya elegans* (Schwägr. ex Hook. & Grev.) F. Lara, Garilleti & Goffinet – V: 16.
- Loeskypnum badium* (Hartm.) H.K.G. Paul – I: [B, G], 1; II: 5; III: 6, 7; IV: [B, GH, T], 11; V: [TT], 17.
- **Nyholmia obtusifolia* (Brid.) Holmen & E. Warncke – I: (+).
- **Oligotrichum hercynicum* (Hedw.) Lam. & DC. – II: 4; IV: 10.
- **Oncophorus wahlenbergii* Brid. – III: 6, 8; IV: 10.
- Paludella squarrosa* (Hedw.) Brid. – I: [B, G], 1; IV: [B, T], 9, 11; V: [TT], 17, 19.
- **Paraleucobryum longifolium* (Hedw.) Loeske – I: 1; II: (+); III: 6; IV: 10, 14; V: (+).

- **Philonotis caespitosa* Jur. – **III**: 8; **V**: 16.
Philonotis fontana (Hedw.) Brid. – **I**: [B], 1; **III**: 8; **IV**: [B, T], 9, 10, 11, 12; **V**: 18, 19.
Plagiomnium cuspidatum (Hedw.) T.J. Kop. – **III**: 8; **V**: [TT], 16.
Plagiomnium ellipticum (Brid.) T.J. Kop. – **I**: [B], 1; **III**: 8; **IV**: [B, T], 11, 13, 14; **V**: [TT].
 Plagiomnium medium* (Bruch & Schimp.) T.J. Kop. – **III: 8.
 Plagiothecium denticulatum* (Hedw.) Schimp. – **III: 7, 8; **V**: 16.
 Plagiothecium rossicum* Ignatov & Ignatova – **I: 1; **II**: (+); **III**: 7, 8; **IV**: 9, 10, 12, 14, 15; **V**: 17, 18, 19.
Pleurozium schreberi (Willd. ex Brid.) Mitt. – **I**: [B], 1, 2; **II**: 3, 4, 5; **III**: 6, 7, 8; **IV**: [H, GH, B], 9, 10, 11, 12, 13, 14, 15; **V**: [TT], 16, 17, 18, 19.
 Pogonatum dentatum* (Menzies ex Brid.) Brid. – **I: 1; **IV**: 14.
 Pogonatum urnigerum* (Hedw.) P. Beauv. – **I: 1; **II**: 4; **III**: 8; **IV**: 14; **V**: 18.
 Pohlia bulbifera* (Warnst.) Warnst. – **II: 4; **III**: 8; **IV**: (+); **V**: 16.
 Pohlia cruda* (Hedw.) Lindb. – **II: (+); **IV**: 10.
Pohlia nutans (Hedw.) Lindb. – **I**: [B], 1; **II**: 3, 4, 5; **III**: 8; **IV**: [H, B], 9, 10, 11, 12, 14, 15; **V**: 16, 17, 18, 19.
 Polytrichastrum alpinum* (Hedw.) G.L. Sm – **I: 1; **V**: (+).
Polytrichum commune Hedw. – **I**: [B], 1; **II**: 3, 4; **III**: 6, 7; **IV**: [B, T], 9, 10, 11, 13, 14, 15; **V**: [TT], 18, 19.
Polytrichum juniperinum Hedw. – **I**: 1; **II**: 3, 4; **III**: 8; **IV**: 10, 12, 13, 14; **V**: [TT], 19.
 Polytrichum longisetum* Sw. ex Brid. – **I: 2; **II**: 4; **III**: 6, 7, 8; **IV**: 9, 12, 14, 15; **V**: 17, 19.
 Polytrichum piliferum* Hedw. – **I: 1; **II**: (+); **III**: 8; **IV**: 14.
Polytrichum strictum Mensies ex Brid. – **I**: [B, G], 1; **II**: 4, 5; **III**: 7, 8; **IV**: [H, B, T], 9, 10, 11, 14, 15; **V**: [TT], 16, 17, 18, 19.
Polytrichum swartzii Hartm. – **I**: [B], 1.
Pseudobryum cinclidioides (Huebener) T.J. Kop. – **I**: [B], 1, 2; **III**: 7; **IV**: 9, 10, 12, 14, 15; **V**: [TT], 16, 18.
Ptilium crista-castrensis (Hedw.) De Not. – **I**: 1; **II**: 4; **III**: 7, 8; **IV**: 9, 10, 14, 15; **V**: [TT], 18, 19.
 Ptychostomum moravicum* (Podp.) Ros & Mazimpaka – **III: 8.
Ptychostomum pseudotriquetrum (Hedw.) J.R. Spence & H.P. Ramsay ex Holyoak & N. Pedersen – **I**: [B], 1; **II**: 4; **III**: 8; **IV**: 10; **V**: [TT], 16, 18.
Ptychostomum weigeli (Biehler) J.R. Spence – **I**: [B], 1; **IV**: [B, T], 9, 11; **V**: [TT], 16.
 Pylaisia polyantha* (Hedw.) Schimp. – **IV: 10; **V**: 16.
 Racomitrium aciculare* (Hedw.) Brid. – **IV: 14.
 Racomitrium canescens* (Hedw.) Brid. – **III: 8.
Racomitrium microcarpon (Hedw.) Brid. – **I**: 1; **II**: 3, 4; **III**: 6, 8; **IV**: 10, 13, 14; **V**: [TT].
Rhizomnium magnifolium (Horik.) T.J. Kop. – **IV**: [B, T], 10, 11; **V**: [TT], 16, 18.
Rhizomnium pseudopunctatum (Bruch & Schimp.) T.J. Kop. – **I**: [B], 1, 2; **III**: 8; **IV**: [B], 9, 11, 12, 14; **V**: [TT], 16, 18, 19.
 Rhizomnium punctatum* (Hedw.) T.J. Kop. – **II: 4; **III**: 8; **IV**: 10; **V**: 18, 19.
 Rhodobryum roseum* (Hedw.) Limpr. – **I: 2; **III**: 6.
 Rhytidiadelphus squarrosus* (Hedw.) Warnst. – **III: 8; **IV**: 13, 14.
Rhytidiadelphus subpinnatus (Lindb.) T.J. Kop. – **III**: 8; **IV**: [B], 10, 11.
Sanionia uncinata (Hedw.) Loeske – **I**: [B], 1, 2; **II**: 3, 4; **III**: 6, 7, 8; **IV**: 10, 14; **V**: 16, 18.
Sarmentypnum exannulatum (Schimp.) Hedenäs – **I**: [B], 1; **II**: 3, 4, 5; **III**: 8; **IV**: [H, GH, B], 9, 10, 11, 12, 14; **V**: [TT], 17, 18, 19.
Sarmentypnum procerum (Renauld & Arnell) Hedenäs – **II**: 3, 5; **IV**: [B, T], 11; **V**: [TT], 17, 19.
Sarmentypnum sarmentosum (Wahlenb.) Tuom. & T.J. Kop. – **I**: [G]; **II**: 5; **IV**: [B, T], 11; **V**: [TT], 17, 19.
 Sarmentypnum trichophyllum* (Warnst.) Hedenäs – **II: 3; **III**: 7; **IV**: 12, 14.
 Schistidium agassizii* Sull. & Lesq. – **III: 8.
 Schistidium apocarpum* (Hedw.) Bruch & Schimp. – **I: 2; **III**: 6, 8.
 Schistostega pennata* (Hedw.) F. Weber & D. Mohr – **IV: 9, 12, 14; **V**: 17, 19. F (VU).
 Sciuro-hypnum curtum* (Lindb.) Ignatov – **I: 2; **III**: 8; **IV**: 14; **V**: 16.
 Sciuro-hypnum plumosum* (Hedw.) Ignatov & Huttunen – **III: 8; **IV**: 10, 14.

- **Sciuro-hypnum populeum* (Hedw.) Ignatov & Huttunen – **III**: 6.
- **Sciuro-hypnum reflexum* (Starke) Ignatov & Huttunen – **I**: 1; **II**: 5, **III**: 8; **IV**: 9, 12, 13, 14.
- Scorpidium cossonii* (Schimp.) Hedenäs – **V**: [TT].
- Scorpidium revolvens* (Sw. ex anon.) Rubers – **I**: [B, G], 1; **II**: 3, 4; **IV**: [T, GH, B], 9, 11; **V**: [TT], 19.
- Scorpidium scorpioides* (Hedw.) Limpr. – **III**: 8; **IV**: [T, GH, B], 11; **V**: [TT], 17. E (NT).
- Sphagnum angustifolium* (C.E.O. Jensen ex Russow) C.E.O. Jensen – **I**: [B], 1; **II**: 3, 4, 5; **III**: 7, 8; **IV**: [H, T, GH, B], 9, 10, 11, 14, 15; **V**: [TT], 16, 17, 18, 19.
- Sphagnum annulatum* H. Lindb. ex Warnst. – **III**: 7; **IV**: [H, B, T], 11.
- Sphagnum aongstroemii* C. Hartm. – **I**: [B], 1; **IV**: [B, T], 9, 11, 12, 15; **V**: 18.
- Sphagnum balticum* (Russow) C.E.O. Jensen – **I**: [B], 1; **IV**: [H, T, GH, B], 11, 14; **V**: 18, 19.
- Sphagnum capillifolium* (Ehrh.) Hedw. – **I**: [B], 1; **II**: 3; **III**: 6, 7, 8; **IV**: 9, 10, 14, 15; **V**: [TT], 18.
- Sphagnum centrale* C.E.O. Jensen – **I**: [B], 1; **II**: 3, 4; **III**: 6, 7; **IV**: [B], 9, 10, 11, 12, 14; **V**: [TT], 18, 19.
- Sphagnum compactum* Lam. & DC. – **I**: [B, G], 1; **II**: 3; **III**: 6, 7, 8; **IV**: [H, B, T], 11; **V**: [TT], 16, 19.
- Sphagnum contortum* Schultz – **IV**: [B, T], 11, 12. F (NT).
- **Sphagnum cuspidatum* Ehrh. ex Hoffm. – **V**: 18.
- Sphagnum divinum* Flatberg & Hassel
[=*Sphagnum magellanicum* auct. eur. p.p., non Brid.] – **I**: [B], 1; **II**: 4, 5; **III**: 7, 8; **IV**: [H, B, T], 9, 10, 11, 12, 14, 15; **V**: [TT], 16, 17, 18, 19.
- Sphagnum fallax* (H. Klinggr.) H. Klinggr. – **I**: [B, G], 1; **II**: 3, 4; **III**: 7; **IV**: [H, GH, B], 9, 10, 11, 14, 15; **V**: [TT], 18, 19.
- Sphagnum fimbriatum* Wilson – **I**: [B], 1; **II**: 3; **III**: 7; **IV**: 9, 10, 14, 15; **V**: [TT], 16.
- Sphagnum flexuosum* Dozy & Molk. – **I**: [B], 1; **IV**: [B, T], 9, 11, 15; **V**: 18.
- Sphagnum fuscum* (Schimp.) H. Klinggr. – **I**: [B, G], 1; **II**: 4, 5; **III**: 7; **IV**: [H, T, GH, B], 9, 10, 11, 14, 15; **V**: [TT], 16, 17, 18, 19.
- Sphagnum girgensohnii* Russow – **I**: [B], 1; **II**: 3, 4, 5; **III**: 7, 8; **IV**: [GH, B], 9, 10, 11, 12, 14, 15; **V**: [TT], 16, 18.
- **Sphagnum inundatum* Russow – **IV**: 14. F (EN).
- Sphagnum jensenii* H. Lindb. – **I**: [B], 1; **III**: 7; **IV**: [B, T], 9, 10, 11, 14; **V**: 16, 18, 19.
- Sphagnum lindbergii* Schimp. – **I**: [B], 1; **IV**: [H, B, T], 9, 11, 14, 15; **V**: 16, 17, 19.
- Sphagnum majus* (Russow) C.E.O. Jensen – **I**: [B], 1; **II**: 3, 5; **IV**: [H, T, GH, B], 9, 11; **V**: [TT], 16, 17.
- Sphagnum obtusum* Warnst. – **I**: [B], 1; **II**: 4; **IV**: 11, 12; **V**: [TT].
- Sphagnum papillosum* Lindb. – **I**: [B, G], 1; **II**: 3, 4, 5; **III**: 7; **IV**: [H, T, GH, B], 11, 15; **V**: [TT], 16, 18, 19.
- Sphagnum platyphyllum* (Lindb. ex Braithw.) Warnst. – **I**: (+); **II**: 3, 4, 5; **III**: 6, 7; **IV**: [H, T, GH, B], 11; **V**: [TT].
- Sphagnum pulchrum* (Lindb. ex Braithw.) Warnst. – **I**: 1; **III**: (+); **IV**: [H, B, T], 11; **V**: 16, 18.
- **Sphagnum quinquefarium* (Braithw.) Warnst. – **III**: 7; **IV**: 15; **V**: 19.
- Sphagnum riparium* Ångstr. – **I**: [B], 1; **II**: 5; **III**: 7, 8; **IV**: [T, GH, B], 9, 10, 11, 12, 14, 15; **V**: [TT], 16, 18, 19.
- Sphagnum rubellum* Wilson – **I**: [B], 1; **II**: 5; **IV**: [H, B], 11; **V**: [TT].
- Sphagnum russowii* Warnst. – **I**: [B], 1; **II**: 3, 4, 5; **III**: 6, 7, 8; **IV**: [T, GH, B], 9, 10, 11, 12, 14, 15; **V**: [TT], 16, 18, 19.
- Sphagnum squarrosus* Crome – **I**: [B], 1; **II**: 3; **III**: 6, 7, 8; **IV**: 9, 10, 14, 15; **V**: [TT], 16, 18, 19.
- Sphagnum subfulvum* Sjors – **I**: [B, G]; **II**: 3, 4; **III**: 6, 7, 8; **IV**: [T, GH, B], 10, 11; **V**: [TT].
- Sphagnum subnitens* Russow & Warnst. – **I**: [G]; **II**: (+); **V**: [TT]. F (NT).
- Sphagnum subsecundum* Nees – **I**: [B], 1; **II**: 3, 4, 5; **III**: 6, 7, 8; **IV**: [T, GH, B], 9, 10, 11, 12, 14; **V**: [TT], 17, 18, 19.
- Sphagnum tenellum* (Brid.) Pers. ex Brid. – **I**: [B], 1; **II**: 5; **IV**: [H, B], 11; **V**: 16, 18.
- Sphagnum teres* (Schimp.) Ångstr. – **I**: [B], 1; **IV**: [B, T], 9, 11, 15; **V**: [TT], 18.
- Sphagnum warnstorffii* Russow – **I**: [B, G], 1; **II**: 3, 4, 5; **III**: 6, 7; **IV**: [T, GH, B], 9, 11, 12; **V**: [TT], 16, 17, 18, 19.
- Sphagnum wulfianum* Girg. – **II**: 3, 4; **III**: 6, 7, 8; **V**: [TT].

- Splachnum ampullaceum* Hedw. – I [B]. E (NT).
Splachnum luteum Hedw. – I: [B], 1; V: [TT], 18.
 **Splachnum rubrum* Hedw. – I: (+).
 **Splachnum vasculosum* Hedw. – I: (+).
Straminergon stramineum (Dicks. ex Brid.)
 Hedenäs – I: [B], 1; II: 4, 5; III: 8; IV: [GH,
 B], 9, 11, 14, 15; V: [TT], 16, 17, 18, 19.
 **Tetraphis pellucida* Hedw. – I: 1; II: 3, 4, 5; III:
 7, 8; IV: 9, 12, 14, 15; V: 16, 18, 19.
 **Tetraplodon angustatus* (Hedw.) Bruch &
 Schimp. – II: 5.
 **Thuidium recognitum* (Hedw.) Lindb. – III: 8.
Tomentypnum nitens (Hedw.) Loeske – I: [B], 1;
 IV: [T, GH, B], 9, 11; V: [TT]. E (NT).
Warnstorfia fluitans (Hedw.) Loeske – I: [B], 1;
 II: 4; III: 6, 7, 8; IV: [H, B, T], 10, 11, 12, 14,
 15; V: [TT], 16, 17, 19.
 **Warnstorfia pseudostraminea* (Müll. Hal.)
 Tuom. & T.J. Kop. – V: 18.

Estimation of total species richness

Observed species richness and total moss species number estimates separately for each subarea of Friendship Park, as well as for the entire park area, are summarised in Table 1. For reference, also total person-days used for field surveys during 1995–2019 are given.

The moss flora of Friendship Park

The moss species of Friendship Park are listed for the first time. In the territory of Juortanansalo – Lapinsuo MR, 97 moss species were found (30 new species records), in Elimyssalo NR, 119 species and 57 new species records and, in Ulvinsalo SNR, 103 species and 44 new species records. Data on moss species richness of Iso-Palonen – Maariansärkät NR (76 species) and Lentua NR (104 species) are presented for the first time. A total of 164 moss species were recorded in the five subareas of Friendship Park. This species richness equals 23% of the total Finnish moss flora (698 species: Pihlaja & Ulvinen 2021 and Pihlaja et al. 2022), encountered in a small area (ca. 0.09% of the total area of Finland). 79 moss species (48%) are recorded for the first time in Friendship Park. *Lewinskya elegans* was very recently added to the Finnish list of mosses (Pihlaja et al. 2022). Our find of *L. elegans* from Jylkynsalo (Ulvinsalo SNR) is the first authentic record of the species from the biological province of Kainuu. See Pihlaja et al. (2022) for a discussion of earlier Finnish records under this name (e.g. Pihlaja & Ulvinen 2021). Two species (*Hedwigia mollis* and *Plagiothecium rossicum*) are discovered as new for the flora of Finland and, consequently, Kainuu biological province.

Table 1. Species richness of mosses recorded in Friendship Park. Abbreviations of the names of study areas: JUO = Juortanansalo–Lapinsuo MR, ISO = Iso-Palonen–Maariansärkät NR, LEN = Lentua NR, ELI = Elimyssalo NR, ULV = Ulvinsalo SNR. Person-days refer to total person-days used by experts for field survey of mosses in 1995–2019. S_{obs} denotes observed species richness. Chao1, as well as first- and second-order jackknives, are estimators of true species richness, i.e., S_{obs} plus the number of undetected species, all given as point estimators (with 95% confidence intervals). All computations were performed using the program SPADE (Chao & Shen 2010). For further details, see text.

	JUO	ISO	LEN	ELI	ULV	Friendship Park
Person-days	12	6	8	11	8	45
S_{obs}	97	76	104	119	103	164
Chao1	110.5 (102.1–132.7)	104.0 (86.7–149.4)	128.7 (114.5–161.7)	129.5 (123.2–148.4)	124.5 (110.7–160.1)	175.5 (167.7–196.6)
First-order jackknife	121.9 (111.5–139.9)	101.9 (91.2–120.1)	136.9 (124.4–156.9)	139.0 (130.2–155.2)	127.9 (117.2–146.2)	187.0 (176.8–204.8)
Second-order jackknife	124.0 (108.6–159.8)	115.8 (97.9–148.3)	147.9 (127.8–184.8)	139.0 (126.8–172.9)	138.9 (121.4–172.2)	188.0 (173.2–224.0)

The discovery of the new species is based on recent taxonomic changes prompted by integrative molecular and morphological studies. In a revision of the genus *Hedwigia* (Ignatova et al. 2016), three new species, including *H. mollis* Ignatova, Ignatov & Fedosov, were described. Morphologically, *H. mollis* differs from *Hedwigia ciliata* (Hedw.) P. Beauv. by its narrowly and shortly recurved leaf margins, smaller spores and smaller papillae. All of our *H. ciliata* specimens collected before 2016 have been re-identified as *H. mollis*. *Hedwigia mollis* has already been recorded from Karelian Republic and Murmansk Region of Russia (Ignatova et al. 2016), hence its discovery in eastern Finland was not unexpected.

Plagiothecium rossicum Ignatov & Ignatova was recently described in a study on the taxonomy of the *Plagiothecium laetum* complex (Ignatova et al. 2019). *Plagiothecium rossicum* is distinguished from *P. laetum* by its flat leaf margins (the latter has narrowly recurved leaf margins) and by more asymmetrical leaves. After a critical check, all of our samples, previously identified as *P. laetum*, turned out to be *P. rossicum*. The new species is known to occur in Northeast Europe and the Russian Far East (Ignatova et al. 2019). A critical check of *Hedwigia* and *Plagiothecium* specimens in Finnish herbariums (H, JYV, KUO, OULU, TUR) may shed light on the true distribution of the two newly recorded species in Finland.

Most species (75%) are found in all (21) or almost all (20) biological provinces of Finland (Pihlaja & Ulvinen 2021). Some others are less widespread: *Callicladium haldanianum*, *Dicranum fragilifolium*, *Drepanocladus trifarius*, *Sphagnum pulchrum* and *S. subnitens* are found in 17, *Hygroamblystegium fluviatile* and *Warnstorfia pseudostraminea* in 16, while *Sphagnum cuspidatum* and *S. inundatum* in 15 biological provinces. Some species (*Dicranum angustum*, *Lescuraea saxicola*, *Sphagnum aongstroemii*) are less common to the south, others (*Atrichum undulatum*, *Rhytidiadelphus squarrosus*, *Sphagnum quinquefarium*) are less common to the north of Friendship Park. Seven moss species recorded from Friendship Park are red-listed in Finland (Juutinen et al. 2019). These are *Buxbaumia viridis* (EN), *Callicladium haldanianum* (NT), *Hamatocaulis vernicosus* (NT), *Schistostega pennata* (VU), *Sphagnum contortum* (NT), *S. inundatum*

(EN), and *S. subnitens* (NT). Five species, *Fontinalis dalecarlica* (NT), *Helodium blandowii* (NT), *Scorpidium scorpioides* (NT), *Splachnum ampullaceum* (NT), and *Tomentypnum nitens* (NT), are included in the European Red List (Hodgetts et al. 2019).

Comparison of the moss floras of Friendship Park and Kostomuksha SNR

The observed moss diversity of Friendship Park (164 species) and Kostomuksha SNR (180 species: Boychuk 2021), showed great similarity (141 common species), in spite of the difference in the area of the reserves (292.7 km² and 492.8 km², respectively). This can be explained by the similar natural conditions (dominance of felsic rocks and acid soils, shared climate, pine and spruce forests as the main forest types, as well as oligotrophic mires and lakes) on both sides of the Finnish – Russian border.

Twenty-three species found in Friendship Park have not been encountered in Kostomuksha SNR (cf. Boychuk 2021). Some of them, dwelling in wet habitats, e.g., bogs (*Dicranum leioneuron*, *Sphagnum cuspidatum*), transitional mires (*Sphagnum annulatum*, *S. aongstroemii*), shores of Lake Lentua (*Calliergon megalophyllum*, *Sciuropygium populeum*, *Cirriphyllum piliferum*, *Philonotis caespitosa*), are likely to be found in similar mires and the shores of Lake Kamenoye in Kostomuksha SNR. But some other species (*Calliergonella cuspidata*, *Cinclidium stygium*, *Drepanocladus trifarius*, *Hamatocaulis vernicosus*), found in rich fens in Elimyssalo NR, are probably missing from Kostomuksha SNR due to the lack of such habitats (Kolomytsev & Kuznetsov 1997).

Thirty-nine moss species recorded from Kostomuksha SNR have yet not been found in Friendship Park. Most of these 'missing' moss species are likely to occur in the area because the majority of them (35 out of 39) are recorded from Kainuu biological province (Pihlaja & Ulvinen 2021). Some others may be truly missing. For instance, there is a bryologically interesting locality in Kostomuksha SNR called 'Tzar Porog' (Tzar Rapids) of River Kamennaya. *Blindia acu-*

ta, *Campyliadelphus elodes*, *Platyhypnum alpestre* and *P. smithii* were found on the wet boulders of Tsar Rapids but they were missing from Lentua Rapids in Lentua NR. Moreover, *Amphidium lapponicum*, *Neckera oligocarpa* and *Ulota curvifolia* were encountered on calcium-bearing bedrock exposures near Tzar Porog but not found in Elimyssalo NR nor in other parts of Friendship Park.

Estimation of total species richness

Our results (Table 1) strongly suggest that our moss checklist of Friendship Park is incomplete. Results of all nonparametric estimators demonstrate that further species are to be discovered in each protected subarea of Friendship Park. The minimum species deficit, calculated as the lowest total species richness estimate minus the observed species richness, of the individual protected areas was smallest in Elimyssalo NR (10 'missing' species and 119 observed species), second smallest in Juortanansalo – Lapinsuo MR (14 and 97) and largest in Iso-Palonen – Maariansärkät NR (26 and 76), while Ulvinsalo SNR (22 and 103) and Lentua NR (25 and 104) were intermediate. As expected, the smallest species deficit figures were found in areas with highest sampling effort (expressed as the number of field days). In the analysis of the pooled material, the observed moss species richness of Friendship Park (164 spp.) was found to be close to the Chao1 estimator value (175.5 spp.) and the species deficit estimate was relatively low (12 spp.). Therefore, one can argue that the moss flora of Friendship Park as a whole is reasonably well known. That said, further surveys especially in rare (micro)biotopes are likely to yield further additions to the moss checklist of Friendship Park.

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