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Sphagnum mosses of West Iceland

Länsi-Islannin rahkasammalista

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The unique characteristics of some of the main environmental gradients – pH and nutrient availability, as well as wetness and aeration – suggest that the environment for *Sphagnum* species in Iceland is different than that of most other European mires. This makes Icelandic *Sphagna* an interesting topic to study. Our course studied vegetation, especially *Sphagnum* species, in West Iceland on three mire sites and at two hot spring sites. Each mire site averaged about 60% coverage of *Sphagnum*, and *S. papillosum* was the dominating species in every site, followed by a noticeable presence of *S. subnitens*. However, there were differences in the number of species found and the coverage distributions between species. *Sphagnum subnitens* and *S. teres* were common in both hot spring sites, but otherwise the species composition differed. The diversity of *Sphagnum* species was lower on the hot spring sites than on the three study sites. In total, we found 20 different *Sphagnum* species during our stay in Iceland.

Introduction

Most soils in Iceland are formed of volcanic material deposited from an active mantle plume, hotspot of volcanic activity, underlying the island. This makes the landscape very distinct from other European soils (Arnalds 2015). Small particles are porous, fine-grained, and very prone to erosion. Strong aeolian deposition of volcanic loess and tephra has a considerable influence on the properties of Icelandic mires (Arnalds et al. 2016; Þórhallsdóttir & Óskarsson 2017). Inland fen wetlands are relatively high in pH and nutrient availability, having made them attractive to widespread drainage and agricultural use in the twentieth century (Arnalds et al. 2016). While wetlands are estimated to cover about 23 000 km^2, organic histosols add up to only 1300 km^2 or approximately 5.7% of the total land area (Arnalds 2015). The organic carbon content of surface soil horizons in inland wetlands is most often <25%, i.e., lower than the average of other northern peatlands (Arnalds et al. 2016).

The lack of truly ombrotrophic and nutrient-poor mires in Iceland shows as the mires being inherently more dominated by vascular plants than *Sphagnum* mosses (Arnalds 2015). This could also be due to the young age of peatlands; they have mostly started forming around 7000 years ago (Lammers et al. 2021), but peat accumulation is inconsistent due to volcanic activity and changes in climate (Hellqvist *et al.* 2020).

These unique characteristics of some of the main environmental gradients – pH and nutrient availability, as well as wetness and aeration (Rydin & Jeglum 2013) – suggest that the environment for *Sphagnum* species in Iceland is different than that of most other European mires. This makes Icelandic *Sphagna* an interesting topic to study. The presence of *Sphagnum* species in mires is especially important for peat formation (Rydin & Jeglum 2013). *Sphagnum* has an acidifying effect on its surroundings, restricting the growth of many vascular plants (Rydin & Jeglum 2013). On the other hand, volcanic tephra distributed periodically is high in pH and decreases soil

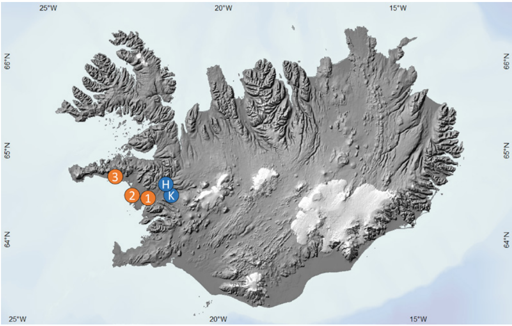

Fig. 1. Study sites 1-Stangarholt, 2-Hundastapi, 3-Stakkhamar, and hot spring sites K (Kleppjárnsreykjum) and H (Hurðarbak) on a map. Map based on data from: https://gatt.lmi.is/geonetwork/srv/eng/catalog.search#/metadata/6dc71751-5fbe-4464-9743-231700e09e48

Kuva 1. Tutkimuskohteemme 1–3 ja kaksi kuumaa lähdettä K (Kleppjárnsreykjum) ja H (Hurðarbak), joista keräsimme rahkasammalia.

acidity. Whenever a thick layer of tephra covers the mire, soil processes are returned to a new starting point (Bonatotsky et al. 2019). This lack of truly ombrotrophic mires should be visible in the species composition of *Sphagna* in Iceland and is our motivation for this study.

Material and methods

Sites

Our study sites were located in West Iceland, as shown on the map (Fig. 1). Site 1 was an oligotrophic pristine mire located in Stangarholt (64°39'41.4"N; 21°52'58.1"W). This site was near the Langá river but separated by a road. Common vascular plants on the site included *Betula nana*, *Empetrum nigrum* and *Eriophorum angustifolium*. Site 2 was a drained peatland located in Hundastapi (64°36'20.0"N; 22°13'33.0"W). This site had a similar nutrient level to site one and common vascular plants were like those of site 1. Site 3 was a mesotrophic mire in Stakkhamar (64°49'07.6"N; 22°46'38.8"W). The edges of this mire were drained, but the area near our sample plots was undrained. This was the most nutrient-rich of the sites, and vascular plants included different *Carex* species and bryophytes, but also substantial amounts of *Eriophorum angustifolium* and *Empetrum nigrum* like on sites 1 and 2. All three sites are located in the western lowlands. Sites 2 and 3 are in a 5-kilometer proximity from the ocean, while site 1 is furthest away from the shore at a 10-kilometer distance. Fig. 2 shows photos of all study sites.

In addition to the three study sites, we visited two sites with hot springs (Fig. 3), where we did not measure coverage sample plots, but gathered *Sphagnum* samples to be identified with a microscope. The first hot spring site was in Kleppjárnsreykjum (64°39'12.557"N; 21°24'36.148"W). The site has been harnessed for geothermal heating purposes of nearby housing. Common vascular plants on the sides of the spring included *Hydrocotule vulgaris* and *Equisetum fluviatile*. Ground temperature at 0.5 meters distance on the side of the spring was measured at +42 °C.

Fig. 2. Study sites 1, 2 and 3, respectively from left to right. Photos: Jemina Djupsjöbacka.

Kuva 2. Tutkimusalueemme 1, 2 ja 3 vasemmalta oikealle. Kuvat: Jemina Djupsjöbacka.

Fig. 3. Hot spring sites K (Kleppjárnsreykjum) and H (Hurðarbak), respectively from left to right. Photos: Jemina Djupsjöbacka.

Kuva 3. Kuumat lähteet K (Kleppjárnsreykjum) ja H (Hurðarbak vasemmalta oikealle. Kuvat: Jemina Djupsjöbacka.

Fig. 4 a) Identifying vascular plants at a sampling plot. 13.6.2022. b) Identifying Sphagnum species in the laboratory. 14.6.2022. Photos: Jemina Djupsjöbacka.

Kuva 4. a) Putkilokasvien määritystä maastossa 13.6.2022. b) Rahkasammalten määritystä laboratoriossa 14.6.2022. Kuvat: Jemina Djupsjöbacka.

The second hot spring site was in Hurðarbak (64°41'10.1"N; 21°24'18.6"W). The hot spring was used to heat a farmhouse and located on fields grazed by sheep. Common vascular plants near the hot spring included *Hydrocotule vulgaris, Cardamine pratensis* and *Ranunculus sp.* Ground temperature at 0.5 meters distance on the side of the spring was measured at +36 °C.

Sampling and identification

Students worked in four groups of three people each. At all research sites, sampling plots were semi-randomly selected by choosing a direction and number of steps or by tossing a frame in a random direction. The number of steps and direction varied at each sampling spot. A grid of 0.25 m^2 in area was used to frame the area to be studied (Fig. 4 a). At each plot, vascular plants and mosses were identified and their coverage estimated. All *Sphagnum* species were sampled. Each study site consisted of three sampling plots, so the total amount of plots sampled for all groups at all sites was 36 grids, equivalent to 9 m^2 in area. In addition, *Sphagnum* species new to the study were also sampled outside the plots as they were found, to gain as comprehensive a list of *Sphagna* as possible.

In the laboratory at The Agricultural University of Iceland in Hvanneyri, all *Sphagnum* species were examined, and their identification confirmed using a stereo microscope and a compound microscope (Fig. 4 b).

Results and discussion

Species at study sites

In this chapter we present the combined results of all four groups to form averaged coverages of all *Sphagnum* species found on each site (Table 1). The species are listed in alphabetical order. We also list all the species found outside the plots, but due to not being included in the sample plots, they lack coverage estimates.

The results between sites are overall similar in terms of total *Sphagnum* coverage and dominating species. Each site averaged around 60% coverage of *Sphagnum*, and S. *papillosum* was the dominating species in every site, followed by a noticeable presence of *S. subnitens*. However, there are differences in the number of species found and the coverage distributions between species. Site 3 has the most diverse species composition overall, which is not surprising as it was also the most nutrient-rich of all the sites. The coverage distribution on this site was more evenly spread out between all the species, though *S. papillosum* was still clearly the most dominant *Sphagnum*. Site 2 had the smallest number of species found and its total *Sphagnum* coverage was the lowest of the three sites, though it was close to site 1 in its nutrient level. This could be explained by drainage, as site 2 had drainage ditches, whereas site 1 was an undrained mire. Drainage negatively affects the *Sphagnum* coverage in peatlands (Laine et al. 1995; Paal et al. 2016).

Seventeen of the plots were placed on hummock surfaces, ten on lawns and nine on hollows. The distribution for each site is presented in Table 2. The distribution is clearly uneven, as site 1 only has one hollow grid and site 2 only has two lawn grids. Even so, observations can be made from the

Table 1. The averaged *Sphagnum*-coverage results of all the groups' sample plots for the three study sites.

Taulukko 1. Keskiarvoistetut kaikkien ryhmien rahkasammalten peittävyydet kolmella tutkimusalueella.

Coverage, %			
Species	**Site 1**	**Site 2**	**Site 3**
S. angustifolium	1.1	1.17	-
S. capillifolium	-	2.1	-
S. compactum	-	8.4	-
S. contortum	0.02	-	2.9
S. flexuosum	0.2	-	-
S. palustre	-	-	0.2
S. papillosum	55.3	44.0	27.4
S. russowii	0.7	0.1	-
S. subnitens	5.3	3.4	19.7
S. subsecundum	-	-	8.2
S. teres	0.9	-	7.5
S. warnstorfii	-	-	0.5
Outside plots	*S. balticum*		*S. auriculatum*
	S. lindbergii		*S. flexuosum*
	S. subsecundum		*S. rubellum*
			S. russowii
			S. squarrosum

Table 2. The sample grid placement distribution for each site.

Taulukko 2. Kasviruutujen jakauma mättäisiin, välipintoihin ja painannepintoihin eri tutkimuskohteilla.

	Hummock	Lawn	Hollow
Site 1	7	4	1
Site 2	6	2	4
Site 3	4	4	4

data. Site 1 had the highest *Sphagnum* coverage on hummocks (79%), while site 2 had the highest *Sphagnum* coverage on lawns (69%), and site 3 had the highest *Sphagnum* coverage on hollows (78%). It must be noted that site 2 only had two lawn plots, and the next highest coverage was on hummock surfaces at 59%. *S. papillosum* was found dominating on all surfaces, except in the hollows of site 3, where *S. subnitens* had a slightly higher coverage. Interestingly, *S. papillosum* often formed hummocks, whereas in Finland, *S. papillosum* usually prefers moister conditions provided by hollows or lawns and is rarely found on hummocks.

Species at hot springs

The two hot spring sites were sampled by searching for *Sphagnum* species specifically. Coverage estimates were not calculated for the sites. Table 3 below presents the species found near hot springs. The species are listed in alphabetical order due to the lack of estimates on coverage.

Sphagnum subnitens (Fig. 5) and *S. teres* were common in both sites, but otherwise the species composition differed. The diversity of *Sphagnum* species was lower than on the three study sites. This contrasts with an earlier study by Lange (1973), suggesting that species richness is

Table 3. *Sphagnum* species found at the hot spring sites.

Taulukko 3. Kuumien lähteiden ympäristön rahkasammalet.

Kleppjárnsreykjum	Hurðarbak
S. flexuosum	*S. centrale*
S. squarrosum	*S. medium*
S. subnitens	*S. subnitens*
S. teres	*S. teres*
S. warnstorfii	

Fig. 5. Plentiful of sporophytes of *Sphagnum subnitens* appeared along the hot springs in Hurðarbak. Photo: Kari Minkkinen.

Kuva 5. Kirjorahkasammalen (Sphagnum subnitens) Itiöpesäkkeet olivat hyvin runsaslukuisia Hurðarbakin kuumilla lähteillä.

greater in the geothermal sites than in other mires of Iceland due to differences in water chemical composition. Her research, however, lists dominant species at hot springs to include *Sphagnum teres* and *S. subnitens.* These species were also found at both the sites we visited. *S. papillosum* or *S. palustre*, also listed in her research, were not seen at these sites.

Conclusions

Due to the lack of truly ombrotrophic mires and forested mires in Iceland, most *Sphagnum* species are those that thrive in nutrient-rich and open conditions. *S. papillosum* and *S. subnitens* were the most common species inhabiting the mires of West Iceland, though many other species were found as well. It is interesting that *S. papillosum* thrives on hummock surfaces in West Iceland, where in Finland it is usually found on wetter surfaces. The cause for this could be higher annual precipitation and the nearby presence of the ocean facilitating moist conditions even on hummocks.

The lack of ombrotrophic *Sphagnum* species such as *Sphagnum fuscum* was evident at all sites. *S. fuscum* is considered the dominant species in ombrotrophic conditions (Laine et al. 2018) and was not found at any of the sites we visited during our excursion. Other species that can be found in ombrotrophic conditions include *S. russowii, S. rubellum* and *S. capillifolium*. They were found at the study sites in small or moderate numbers, but they do not indicate ombrotrophic conditions on their own.

Hot springs provide a nutritious habitat for *Sphagna*, and we found many *Sphagnum* species benefitting from the hot springs' presence, but surprisingly, we did not find as many species near the hot springs as we did in the other study sites. This could be due to the significantly smaller area that is habitable by *Sphagnum* species near the hot spring compared to the vast area provided by entire mires.

In the end, we found a total of 20 different *Sphagnum* species during our stay in Iceland. In addition to the mentioned ones, *S. fimbriatum* was found from a Southern mire with a high concentration of tephra in the peat (63°27'02.1"N; 19°02'16.5"W).

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Tiivistelmä

Islannin maaperä on pääasiassa muodostunut tulivuorten toiminnan seurauksena maanpinnalle kerrostuneesta vulkaanisesta materiaalista eli tefrasta. Tämä tekee Islannin maaperästä poikkeuksellisen muuhun Eurooppaan verrattuna. Maa-aines on hienojakoista ja huokoista, ja siten altista eroosiolle.

Tuulen kuljettamalla tefralla on merkittävä vaikutus Islannin soiden ominaisuuksiin. Tefra tuo mukanaan ravinteita tavallisesti karuillekin soille, ja sillä on myös soiden pH:ta nostava vaikutus. Islannin suot ovat alkaneet muodostua noin 7000 vuotta sitten, joten ne ovat myös selvästi nuorempia kuin suot muualla Euroopassa. Merellisen vaikutuksen ja suurten sademäärien vuoksi Islannin suot ovat huomattavan kosteita. Näiden seikkojen takia Islannin suoluonto ja erityisesti sen rahkasammalpopulaatio ovat mielenkiintoinen tutkimusaihe.

Kartoitimme Länsi-Islannin rahkasammallajistoa kolmella eri suolla, sijoittamalla soille kasviruutuja satunnaisotannalla. Etsimme rahkasammalia myös kasviruutujen ulkopuolelta, jotta saisimme mahdollisimman kattavan lajilistan. Lisäksi tutkimme kahden eri kuuman lähteen läheisyydessä kasvavia rahkasammalia, mutta näille koealoille emme tehneet kasviruutuotantaa. Kaikista löytämistämme rahkasammallajeista otettiin näytteet, ja lajimääritys varmistettiin mikroskoopilla.

Kartoituksemme perusteella Länsi-Islannissa kalvakkarahkasammal (*S. papillosum*) on yleisin laji, ja kirjorahkasammalta (*S. subnitens*) esiintyy huomattavan paljon. Kuumien lähteiden ravinteet tarjosivat otolliset kasvupaikat ravinnetarpeiltaan vaativimmille lajeille, kuten lettorahkasammaleelle (*S. teres*), okarahkasammaleelle (*S. squarrosum*) ja heterahkasammaleelle (*S. warnstorfii*). Myös muualla yleinen *S. subnitens* löytyi kuumilta lähteiltä, mutta kaikkialla muualla dominoivaa *S. papillosumia* ei esiintynyt lähteiden läheisyydessä edes vähäisenä.

On mielenkiintoista, että *S. papillosum* kasvoi Länsi-Islannissa mätäspinnoilla, ollen usein myös mättäiden ainoa rahkasammallaji. Suomessa *S. papillosum* viihtyy parhaiten kosteilla välipinnoilla ja painanteissa. Syynä kasvupaikkojen eroihin voi olla Islannin merellinen ilmasto ja Suomea suuremmat vuosittaiset sademäärät, jotka luovat mätäspinnoillekin otollisen kosteat olosuhteet, joissa *S. papillosum* viihtyy. Yhteensä löysimme Islannista 20 rahkasammallajia matkamme aikana.