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A Snapshot of Restored Bogs in Southeastern Norway: Short Term Vegetation Change After Rewetting of Ombrotrophic Mires

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Preface

This study is my master thesis in Natural Resource Management, written at the Norwegian University of Life Sciences at the Faculty of Environment Sciences and Natural Resource Management.

I would like to thank my main supervisor Jan Vermaat and co-supervisors Jonathan Edward Colman and Marte Fandrem. It has been motivating having you as supervisors! Jan and Jonathan, I appreciate your help with the field work preparations, statistics and the writing process. Especially, thank you Marte Fandrem for the assistance and feedback on the statistical analyses. Thanks to the Norwegian Nature Inspectorate (SNO) for initiating this master project, to Pål Martin Eid (SNO) for providing information about SNO's rewetted bogs, and to the Norwegian Environment Agency (MD) for granting funding.

I am grateful to have worked at this project with Hanna Utseth, Eirik Walle and Ola Eian. You have been resourceful, creative and enthusiastic. I have enjoyed working on this project with you, together with Jan, Jonathan and Marte!

Finally, I want to thank my roommates for all the study sessions and the good company during lock down when campus was closed.

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Abstract

Drained peatlands are affected by altered hydrological conditions. Rewetting by ditch blocking and deforestation is conducted to improve ecological conditions of drained peatlands. This study maps the vegetation communities and frequency of specific species in drained, rewetted and pristine ombrotrophic bogs in SE Norway, in addition to differences in species frequencies with distance to ditches. The aim was to evaluate the short-term response one to five years after rewetting of bogs. Data were collected by registering species with a point-intercept method along 250 cm long "species lines" placed perpendicular every 10th m along transects of various lengths, crossing drainage ditches where relevant. A non-metric multidimensional scaling (NMDS) indicated differences among the species communities, where drained and rewetted sites were more similar to each other than pristine ones. The species *Calluna vulgaris, Pleurozium schreberi, Trichophorum cespitosum* and *Sphagnum* spp contributed most to the differences among the treatments observed in the NMDS. *C. vulgaris* was the only single species that had a significantly lower frequency in rewetted than in drained sites, and thereby resembled the frequency in pristine sites. The frequency of *Sphagnum* spp increased with distance to the ditch in both drained and rewetted sites, with no significant differences between the treatments. The results suggest that restoration efforts have not yet achieved reversing the overall species composition towards a pristine community, although the lower frequency of the heather *C. vulgaris* in rewetted sites indicated a response to rewetting. *C. vulgaris* is suggested to be an indicator species when monitoring the development of rewetted bogs in Norway.

Sammendrag

En konsekvens av grøfting av myrer er endrede hydrologiske forhold. Restaurering i form av avskoging og tetting av grøfter kan utføres for å forbedre den økologiske tilstanden av grøftede myrer. Denne studien undersøker plantesamfunnene og frekvensen av enkeltarter i grøftet, restaurert og uberørte ombrotrofe myrer i Sørøst-Norge, i tillegg til å studere forskjeller i artsfrekvens med hensyn til avstand til nærmeste grøft. Målet med studien var å evaluere korttidsresponsen for vegetasjon, ett til fem år etter myrrestaurering. Data ble samlet inn ved bruk av pin-punkt langs en 250 cm lang «artslinje», plassert hver tiende meter langs transekter. Transektene varierte i lengde, og for myrer med åpne eller tettede grøfter, ble de plassert vinkelrett på grøftene. En ikke-metrisk multidimensjonal skalering (NMDS) indikerte forskjeller mellom artssamfunnene, hvor grøftet og restaurerte lokaliteter hadde større likheter med hverandre enn de uberørte lokalitetene. Artene som bidro til de største forskjellene mellom de tre kategoriene var *Calluna vulgaris, Pleurozium schreberi, Trichophorum cespitosum* og *Sphagnum* spp. *C. vulgaris* var den eneste arten med signifikant lavere frekvens i restaurerte enn i drenerte lokaliteter, tilsvarende frekvensen i uberørte lokaliteter. *Sphagnum* spp var den eneste arten som økte i frekvens med avstand til nærmeste grøft i både drenerte og restaurerte lokaliteter, men hadde ikke signifikante forskjeller mellom behandlingene. Resultatene indikerer at restaurering ikke har reversert det samlede plantesamfunnet i drenerte myrer til å tilsvare samfunn i uberørte myrer enda, til tross for at frekvensen av *C. vulgaris* tydet på at restaurering har hatt noe effekt. *C. vulgaris* foreslås å være en indikatorart ved overvåking av utvikling av restaurerte myrer i Norge.

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1. Introduction

Loss of species and ecosystem functions are consequences of pollution, invasive species and land use (Chapin Iii et al., 2000). The threats against ecosystem functioning can affect ecosystem services fundamental to humans, such as food and clean water (Gann et al., 2019). Securing healthy ecosystems by establishing protected areas is considered insufficient, and it is argued that ecological restoration is necessary in addition to protection to counteract the degradation of ecosystems (Gann et al., 2019). Actively restoring nature results in a more rapid recovery, than if degraded nature were to recover by itself (Dobson et al., 1997). However, reducing or modifying the cause of degradation might also be enough to assist the recovery of natural processes at a site (Dobson et al., 1997).

Degraded mires are often restored by rewetting, as many suffer from drainage. In Europe, peat has been exploited and used as fuel for thousands of years (Hallingbäck, 2016). As well as a source of fuel, mires were important in forestry and agriculture, where drainage made new areas available for cultivation (Vasander et al., 2003). Approximately 11 % of Norway is covered in mires, whereas a quarter of the original mire area in Norway is estimated to be drained (Joosten & Clarke, 2002; Moen et al., 2011; Tanneberger et al., 2017). The aims for restoring wetlands in Norway, such as mires, are to reduce greenhouse gas emissions, adapt to increasing risk of flooding due to climate change, and improve the ecological state (Miljødirektoratet, 2016; Miljødirektoratet, 2021). To rewet drained mires, water loss is reduced by removing trees and plugging drainage ditches, using locally available peat or logs (Hagen et al., 2015). The overall aim is for the degraded mire to evolve back towards an earlier, approximately pristine condition, both in terms of biodiversity and ecological functioning (Gorham & Rochefort, 2003).

Nutrients and hydrological conditions influence plant communities in mires (Laine et al., 1995; Martikainen et al., 1995). Intact mires produce peat under anaerobic conditions, as organic matter accumulates due to low decomposition at high water levels (Kuhry & Vitt, 1996). Based on their main supply of water and nutrients, mires can be divided into two main categories. Ombrotrophic mires, hereafter bogs, receive nutrients primarily from rainfall, and not from the soil as minerotrophic mires that receives water and nutrients from ground water or run-off. As ombrotrophic bogs are nutrient poor, they have a slower succession than minerotrophic mires, and the vegetation community is characterized by species adapted to nutrient limitations (Joosten & Clarke, 2002; Komulainen et al., 1999; Moen et al., 2011). However, drainage alters hydrological conditions in terms of a lower water table, whereas the area closest to a ditch is impacted the most (Stewart & Lance, 1991). Changed hydrological conditions lead to mineralization and increased nutrient availability, which in turn affects the plant community (Heller et al., 2015; Laine et al., 1995; Martikainen et al., 1995).

Drier conditions drive the species composition toward that of a forest community, yet this transition can vary between sites and can be reversed through rewetting of mires (Hancock et al., 2018; Laine et al., 1995). For example, *Carex lasiocarpa* and *Carex rostrata* are found to disappear shortly after drainage, while *Betula nana* is considered one of the most sensitive species towards reforestation and is replaced with *Vaccinium myrtillus* and *Vaccinium vitis-idaea* approximately 50 and 20 years, respectively, following drainage of a mire (Laine et al., 1995). Lower abundance of *Carex limosa*, *Drosera longifolia* and *Rhynchospora alba* are also related to drier conditions (Moen et al., 2011). A decline in *Sphagnum* spp cover happen simultaneously with the expansion of the forest species *Pleurozium schreberi* after negative hydrological changes in drained mires (Martikainen et al., 1995). Species tolerant to lower water tables may also have higher transpiration rates, and thus, have an additive effect to drainage (Sarkkola et al., 2010). Dry tolerant species, such as forest mosses and heathers, usually decrease after rewetting (Haapalehto et al., 2011; Hancock et al., 2018). Contrary, rewetting is shown to increase the abundance of species such as *Eriophorum vaginatum* two years after rewetting, and *Eriophorum angustifolium* and *Sphagnum* spp ten years after rewetting (Haapalehto et al., 2011; Hancock et al., 2018; Komulainen et al., 1999). Revegetation of *Sphagnum* spp is central in restoration, since it contributes to an acidic environment and storing water (Poulin et al., 2013; Van Breemen, 1995).

As vegetation responds to drainage and rewetting, plant species are used as indicators for monitoring the success of mire restoration by the Norwegian Nature Inspectorate (Miljødirektoratet, 2016; Miljødirektoratet, 2021). Indicator species are chosen depending on the mires' succession stage and whether they indicate wet or dry conditions. The selected indicator species often have high abundance in pristine mires and respond to changes caused by, for instance, drainage. The frequency of the registered species gives an indication of the mires' condition, related to the conservation goals, and is registered in the new tool NatStat (Miljødirektoratet, n.d).

The first major Norwegian restoration project started in 2015, and in 2020, more than 30 mires were rewetted in Oslo, Viken and Vestfold and Telemark (Miljødirektoratet, 2015; Miljødirektoratet, 2016; *Myrrestaurering-innsynskart*, n.d). In addition to monitoring rewetted mires, more studies investigating the effects on biodiversity after the rewetting of mires in

Norway are needed (Byrkjeland, 2020; Moen et al., 2011). This study provides an analysis of the status per 2020 of eight rewetted ombrotrophic bogs in Viken, Oslo and Vestfold and Telemark, rewetted one to five years ago. The species frequencies and species composition among drained, rewetted and pristine sites were compared. Specifically, the aim of this study was to investigate differences among vegetation communities, the frequency of plant species in drained, rewetted and pristine sites, and whether rewetting affected species frequencies related to distance to a ditch. The results can be used as guidance for mire management and give a first indication of short-term recovery after rewetting.

1.1 Expected outcomes

- By comparing species communities in drained, rewetted and pristine sites, I expected to find the species community in rewetted sites to have recovered and be more similar to the species community in pristine sites.
- For the frequency of species among drained, rewetted and pristine bogs, I expected the frequencies of species in rewetted sites to resemble the frequencies in pristine sites.
- By comparing the frequency of species at different distances to a ditch, I expected drought tolerant species to have higher frequencies closer to the ditch, and wet tolerant species to have higher frequencies further from the ditch, based on the ditch’s impact on the water table. I assumed rewetting would reduce the impact of the ditch, resulting in species frequencies not impacted by the ditches.

2. Method

We were four master students, including Hanna Utseth, Eirik Walle and Ola Eian, that studied insects, water and vegetation in bogs, respectively, together at NMBU during 2020-2021. We cooperated to select mires and transects for the project, and two or more students conducted the fieldwork together. The planning and sampling of vegetation was mainly coordinated between Ola Eian and I, as both of us studied vegetation. All four master students used the same locations and transects, except for location L6, Midtfjellmåsan, which was sampled for the vegetation theses only (Appendix 1).

2.1 Locations

Data were collected from eight locations, each containing a drained, rewetted and pristine ombrotrophic bog in Viken, Oslo and Vestfold and Telemark, from 02.06.2020 to 06.09.2020 (Figure 1, Appendix 1). Locations with both a drained, pristine and rewetted site in proximity were selected based on the Norwegian Nature Inspectorate´s rewetted bogs (*Myrrestaurering-innsynskart*, n.d). The selected mires were all ombrotrophic, and to confirm whether the bogs were intact or drained, near the rewetted site and nutrient poor, “Norge i bilder”, “Høydedata” and “Naturbase” were used (*Høydedata*, n.d; *Naturbase*, 2020; *Norge i Bilder*, n.d). Rewetting of the selected bogs occurred between 2015 and 2019 (appendix 1). In four bogs, we could locate both pristine and rewetted sites within the same bog, as the rewetted bogs were large enough to still contain intact areas (Boelter, 1972). Each rewetted bog had individual restoration goals, in accordance with the five year plan for restoration of wetlands, “Plan for restaurering av våtmark i Norge (2021-2025)” (Miljødirektoratet, 2016; Miljødirektoratet, 2021). In this thesis, the individual goals of the government plan were not considered, as all rewetted bogs were treated similarly with vegetation as the factor indicating effects of rewetting.

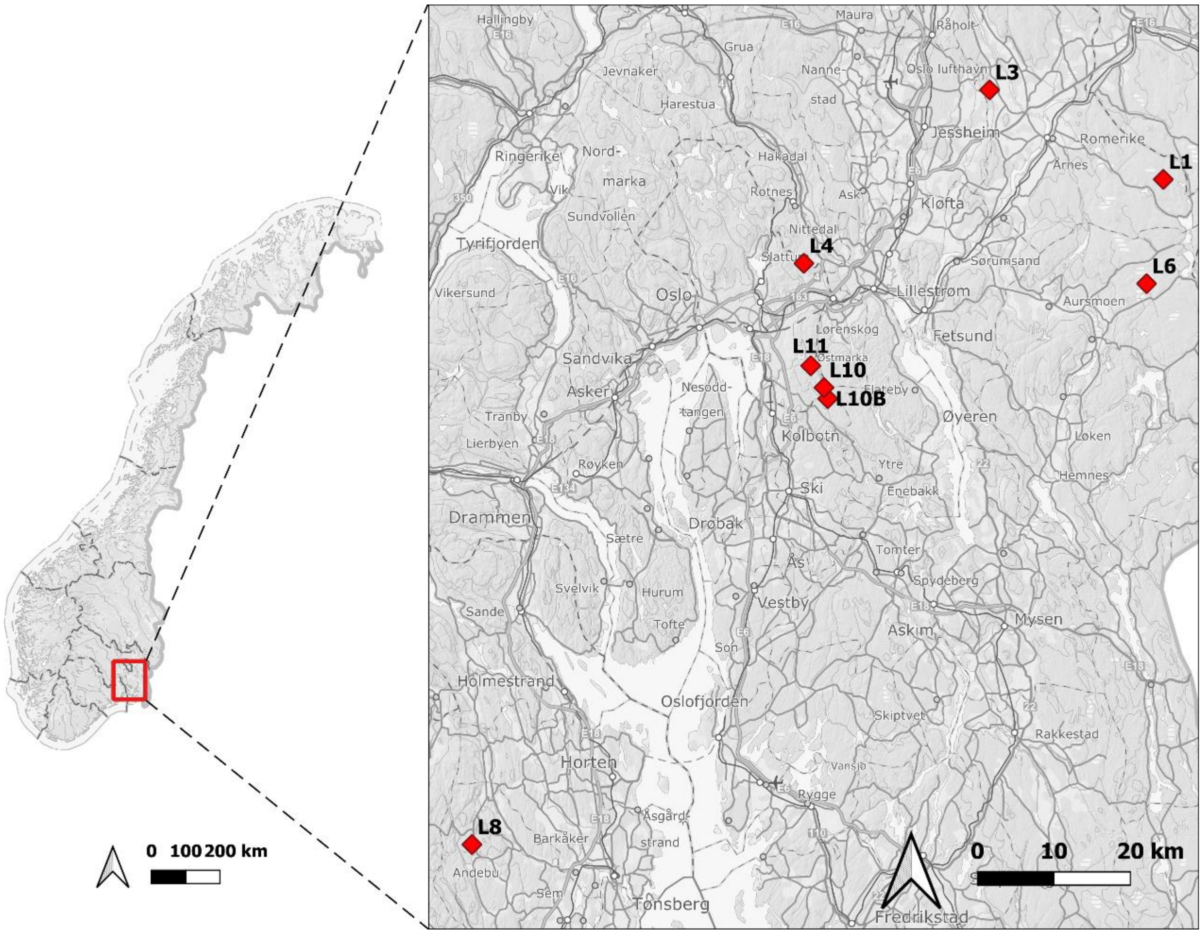

Figure 1: Map of the study area. The rewetted bogs are named and marked in red. The pristine and drained sites are not marked in this map since they are located in close proximity to the rewetted bogs. L1=Sakkhusmåsan, L3=Aurstadmåsan, L4=Romsmåsan, L6=Midtfjellmåsan, L8=Veggermyra, L10=Fjøsmåsan, L10B=Eriksvannmåsan, L11=Ødegårdsmåsan.

2.2 Fieldwork

The survey method in this study was adapted from "NINA Rapport 1576" (Kyrkjeeide et al., 2018). Placement of transects was representative for the bog, in that the length and width of the bog was covered. In the bogs with open or plugged ditches, the transects were placed perpendicular to a ditch. Length (30-50 metres) and number of transects varied between bogs, depending on the bogs' size and characteristics (Appendix 1). A line of 2.5 m, called a "species line" in Kyrkjeeide et al. (2018) was placed every 10th metre of the transect, parallel to the ditch and perpendicular to the transect (Figure 2). Thus, the total number of species lines varied with the length and number of transects for each bog. The species lines where consistently placed with 1.25 m at each side of the transect.

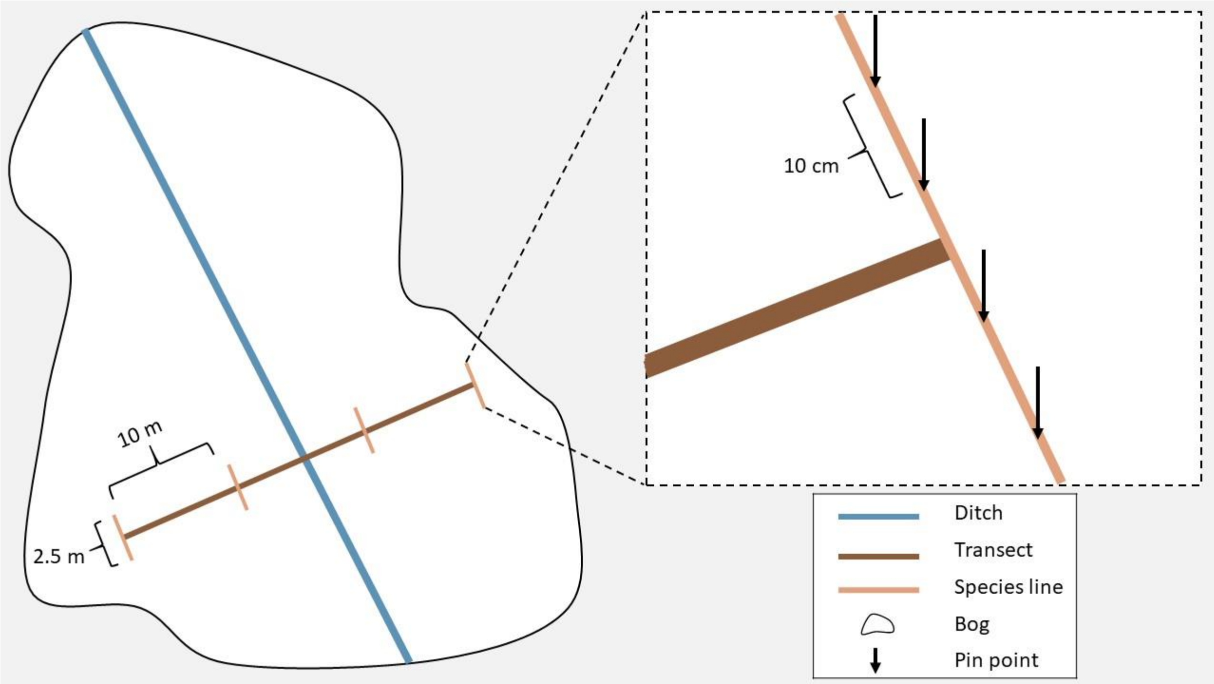

Figure 2: A stylized illustration of the sampling method in drained and rewetted sites. Transects were placed perpendicular to a ditch in drained and rewetted mires. A 2.5 m long species line was then placed across every 10th metre of the transect. A pin was placed every 10th cm along the species line to register species. The same method was used for pristine sites, although transects were placed in areas without ditches.

Data on species cover and presence were collected with a point-intercept method along the species lines (Figure 2, Appendix 2) For every 10th cm along the species line a pin was placed in the ground, and all species in contact with the pin (hits) were registered, providing 25 points per species line. "NA" was noted where it was not possible to register species, for instance due to rocks, logs or water in the species line. Dead species or debris were not registered. Registered species were sorted into three vegetation categories: Tree and bush layer, field layer and ground layer (Appendix 3). In the tree and bush layer, all vascular plants were registered to species level, if being 30 centimetres or taller. Vascular plants in the field layer were classified to species level, except for species of *Eriophorum, Drosera* and *Oxycoccus* that were classified to genus. *Eriophorum* consisted mainly of *E. vaginatum.* Species in Cyperaceae were classified to family, except from *Eriophorum* spp and *Trichophorum cespitosum*. Species in the ground layer were classified to species level, except from species of *Cladonia*, *Dicranum*, *Sphagnum* and *Polytrichum,* classified to genus. Remaining lichens, mosses and livermosses were grouped separately (Appendix 3).

2.3 Data analysis

Data were structured in Microsoft Excel (Microsoft Corporation, 2008) before being analysed in R Studio version 1.4.1103 (RStudioTeam, 2021). In all statistical tests, 0.05 was used as significance level.

2.3.1 Species communities

To visualize the possible differences in species communities between treatments, a non-metric multidimensional scaling (NMDS) from the vegan package was plotted (Oksanen, 2017). The data were aggregated to show the species frequency for each location and its treatments. Bray-Curtis distance was used to calculate the distance between the treatments' species communities. Two dimensions were used as the low stress allowed it. To test whether there was a difference between the treatments, an adonis test from the vegan package was performed (Oksanen, 2017). The adonis test was performed with 999 permutations and location as blocking factor. A permutation test assessed whether the assumption of similar dispersion in the adonis test were met. The permutation test was performed with 99 999 permutations to get a more secure p-value, since the p-value varied around the significant level when performing the test with lower permutations. The function envit was used to find the centroids for each treatment in the NMDS plot, to interpret whether there was a difference among the species communities (Oksanen, 2017).

2.3.2 Assessing species frequency variation among treatments

Species with less than 100 observations in total were excluded in this analysis. The frequency of each species (hits/total number of pins) compared among treatments were modelled using a generalized linear mixed model with the package glmmTMB, where the package DHARMa was used to test the model for zero inflation and over- and underdispersion (Brooks et al., 2017; Hartig, 2020). To account for the number of zeros in the dataset, a beta distribution was used in the model rather than a gaussian distribution. The frequency of each species was the response variable, and treatment was the predictor and fixed effect. Transect ID was nested within locations (L1, L3, L6 et cetera), as a random effect (see Appendix 1). Nesting with more levels led to over-parametrization. Finally, the best model was selected based on the lowest AIC, from the function AIC in the package stats (R-core, 1970; Zuur et al., 2009). Plots were designed using the package ggpubr (Kassambara, n.d).

2.3.3 Changing species frequency with distance from ditch

Data were aggregated to show the species frequency for each species per registered metre to the closest ditch. The package glmmTMB was used, with a beta distribution to fit the data (Brooks et al., 2017). DHARMa was used to test the fit of the model (Hartig, 2020). Data from pristine mires were excluded in this test since they have no ditches, and species with less than 100 observations were excluded. The frequency of each species was the response variable, and treatment and distance from a ditch were fixed effects. Random effects were transect ID nested within location. More levels nested would result in over-parametrization. The lowest AIC score selected the best model, resulting in a model with no interaction between treatment and distance from ditch for all species (R-core, 1970; Zuur et al., 2009). However, models with interactions included were separately tested as well. None of the interactions of ditches were significant, supporting the current model selection based on AIC. Plots were designed with the package ggplot2 (Wickham et al., 2016).

3. Results

3.1 Species communities

The species communities inhabiting the drained, rewetted and pristine sites differed (R^2 = 0.227, Pr(>F) = 0.013). The calculated centroids for the drained, rewetted and pristine communities had different locations in the NMDS plot, indicating that these treatments to some extent differed from each other (Figure 3).

The species contributing the most to the differences seen among the treatments were *Sphagnum* spp, *P. schreberi*, *Calluna vulgaris*, *V. myrtillus*, *Vaccinium uliginosum*, *T. cespitosum* and Cyperaceae (Appendix 4), which is in line with the results of single species in the next section (Figure 4).

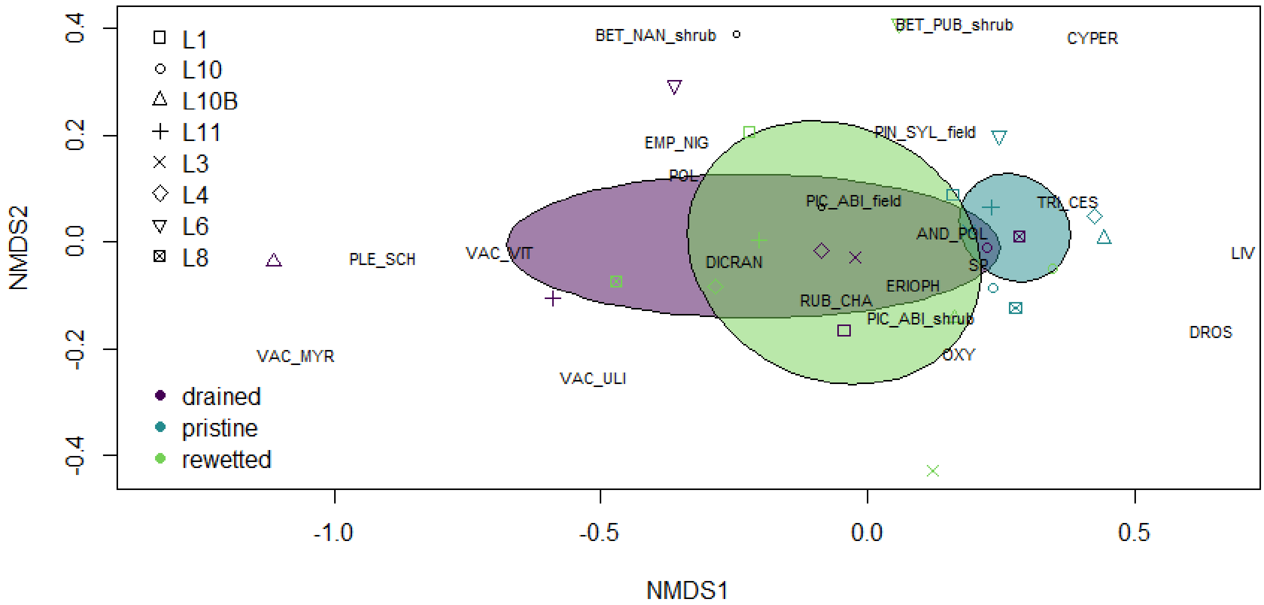

Figure 3: NMDS ordination of all species registered using Bray-Curtis distance of square root transformed data with 2 dimensions (stress=0.101). Symbols refer to locations, colours show the bogs' treatment, and species are named with abbreviations. The ellipses are plotted based on the centroid (SE, confident limit for ellipses= 0.98) for each treatment (NMDS1, NMDS2): drained (-0.2140, -0.0075), rewetted (-0.0621, -0.0200), pristine (0.2760, 0.0275). Note that not all species are possible to observe in the figure, as some species overlap.
Betula nana subsp. nana=BET_NAN, Betula pubescens*=BET_PUB, Picea abies*=PIC_ABI, Pinus sylvestris*=PIN_SYL, Cyperaceae=CYPER, Oxycoccus=OXY, Drosera=DROS, Eriophorum=ERIOPH, Calluna vulgaris=CAL_VUL, Empetrum nigrum=EMP_NIG, Trichophorum cespitosum=TRI_CES, Vaccinium myrtillus=VAC_MYR, Vaccinium uliginosum=VAC_ULI, Vaccinium vitis-idea=VAC_VIT, Rubus chamaemorus= RUB_CHA, Andromeda polifolia=AND_POL, Cladonia=CLAD, Dicranum=DICRAN, Sphagnum=SP, Polytrichum=POL, Hylocomium splendens= HYL_SPL, Pleurozium schreberi=PLE_SCH, Lichen=LICH, Liverworths=LIV, Other mosses=MOS. Species marked with * are found in both in bush and field layer.*

3.2 Species frequency among treatments

Six species had a significant difference in plant frequency between two or more of the treatments (Figure 4, Appendix 5). *Sphagnum* spp, *T. cespitosum* and *Andromeda polifolia* had significantly higher frequencies in pristine sites than in drained and rewetted sites (Figure 4 a, e, f). *P. schreberi* had a lower cover in pristine than in drained and rewetted sites, and had also the highest plant frequency in drained sites, while a frequency close to zero in pristine sites (Figure 4 b). Pristine bogs differed significantly from rewetted sites for *Empetrum nigrum* only, where the mean plant frequency was almost seven times lower in pristine sites than rewetted sites (Figure 4 d). *C. vulgaris* was the only species showing a significant difference in frequency between drained and rewetted sites only, where the highest plant frequency was found in drained sites (Figure 4 c).

Cladonia spp, *Eripophorum* spp, *Oxycoccus* spp, Cyperaceae, *V. myrtillus, V. uliginosum, V. vitis-idaea* and *Rubus chamaemorus* did not differ significantly in frequency among the treatments (Appendix 5).

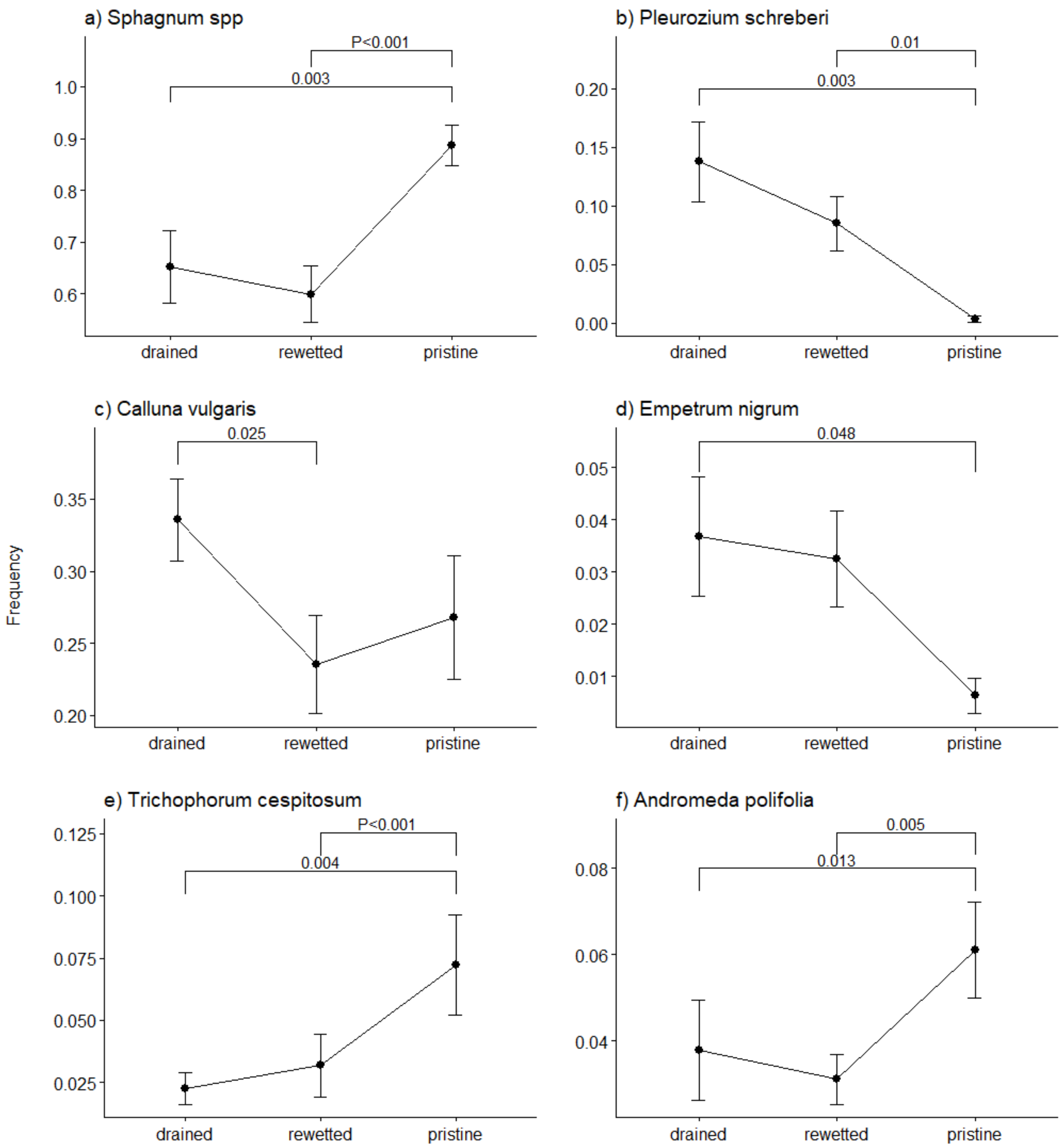

Figure 4: Species with a significant difference in species frequency (mean ± SE) between two or more treatments. Note that the y-axes have different offsets.

3.3 Species frequency with distance from ditch

C. vulgaris differed significantly in frequency between drained and rewetted sites, but distance to the nearest ditch did not have a significant impact on plant frequency (Figure 5 a, Appendix

6). Plant frequency of *C. vulgaris* was higher in drained than restored sites at zero metres from a ditch. Plant frequency of *Sphagnum* spp increased with distance to the ditch (Figure 5 b, Appendix 6). *Sphagnum* spp did not differ significantly between drained and rewetted sites in terms of plant frequency, although the frequency seemed to be higher in drained than restored bogs.

Cladonia spp, *Eriophorum* spp, *E. nigrum*, *Oxycoccus* spp, *T. cespitosum*, *V. uliginosum*, *V. vitis-idea*, Cyperaceae, *A. polifolia*, *V. myrtillus*, *P. schreberi and R. chamaemorus* did not show significant effects of distance from a ditch (Appendix 6).

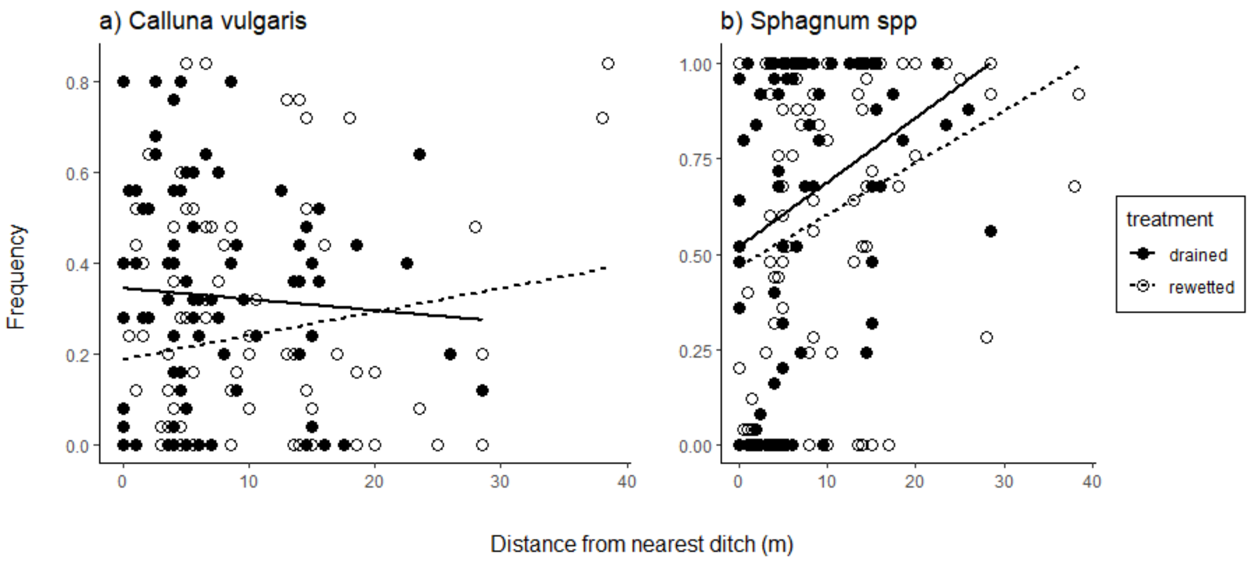

Figure 5: Mean frequency of species with distance to the nearest ditch (metres), for drained and rewetted bogs. Each circle represents the mean frequency of plant cover of the given species in a species line. Note that the y-axes have different offsets. Only species showing significance for either distance to ditch or between the treatments are shown. a) Frequency of C. vulgaris. b) Frequency of Sphagnum spp.

4. Discussion

Overall, the species community in rewetted sites still resembles the drained community more than the pristine community, lending little to my first expectation. No response of rewetting was observed for specific species either, other than *C. vulgaris* which was the only species supporting my second expectation. Contrary to the third expectation, effects of rewetting related to distance to plugged ditches were not observed.

4.1 Species communities

In this study, the species communities in drained, rewetted and pristine bogs differed only slightly from each other (Figure 3), similar to findings by McCarter and Price (2013) and Poulin et al. (2013) at the bog Bois-des-Bel in Quebec in Canada. In my study, the main species contributing to the differences among the species communities were *P. schreberi, C. vulgaris, V. myrtillus, V. uliginosum, Sphagnum* spp., Cyperaceae and *T. cespitosum* (Appendix 4). In Bois-des-Bel, the rewetted site had a higher *Sphagnum* cover and more characteristic pristine bog species compared to the drained site, but still differed from the pristine site by having a higher species diversity (McCarter & Price, 2013; Poulin et al., 2013). As drained and rewetted sites in Bois-des-Bel were characterized by forest and ruderal species, drier conditions and succession were believed to cause the differences between pristine and restored sites (McCarter & Price, 2013). The findings by McCarter and Price (2013) and Poulin et al. (2013) show that species communities respond to rewetting, but not to the extent where pristine and rewetted sites fully resemble each other. This is similar to my findings that rewetting of drained bogs in SE Norway has not yet reversed the species community to fully resemble pristine sites.

Differences in species communities among the three treatments in my study may be explained by the available seed bank in the rewetted bogs, as drainage degrades the original seed bank (Stroh et al., 2012). Stroh et al. (2012) found that seeds characterizing pristine mires were missing in the seed bank of rewetted sites, hence no resemblance between rewetted and pristine sites were observed, even 60 years post rewetting. The available seed bank may have contributed to the differences observed among the bog communities in my study.

The rewetting of mires in my study occurred five years ago or less, with just one bog restored in 2015, two in 2016, two in 2018 and three in 2019 (Appendix 1). It is unlikely that the plant communities would change after just one year, and thus, the three sites rewetted in 2019 likely skewed my results towards "still closer to drained" than "rewetted". Hancock et al. (2018) found that a plant community developed towards the desired bog reference within the first six years after rewetting. The development halted after 14 years, resulting in a plant community not fully similar to the pristine control (Hancock et al., 2018). A similar trend was found by Anderson and Peace (2017), where the vegetation rapidly developed towards pristine conditions during the first three to four years after rewetting. Ten years after, the species communities remained only partly similar to the pristine sites (Anderson & Peace, 2017). Haapalehto et al. (2011) found that despite rewetting reversed the effects of drainage on the species community, key species typical for intact mires were not found ten years after rewetting. The findings of

Haapalehto et al. (2011) show that the development towards a pristine plant community is slow, and that some species need more than a decade to re-establish after rewetting. Only monitoring the species community over a time interval longer than five years allows registering changes of species with slow recovery (Choi, 2007; Haapalehto et al., 2011). The findings of Anderson and Peace (2017), Haapalehto et al. (2011) and Hancock et al. (2018) supports the findings in my study, that the species community in rewetted sites need more than one to five years to become more similar to pristine sites.

4.2 Specific species

In terms of specific species, drained and rewetted sites differed from pristine sites for *Sphagnum* spp*, P. schreberi, T. cespitosum* and *A. polifolia,* while *E. nigrum* in drained sites differed from pristine sites (Figure 4 a, b, d, e, f). Since drainage was conducted, the vegetation of the sites in this study may have had more than 50 years to adapt to changed water availability and soil mineralization (Malmer et al., 1994; Miljødirektoratet, 2021). For example, studies have found the species *A. polifolia*, *C. vulgaris* and *P. schreberi* to increase after drainage, and *T. cespitosum* to decrease due to drier conditions (Laine et al., 1995; Stewart & Lance, 1991; Stivrins et al., 2017; Wilson et al., 2011). As rewetting aims to reduce water loss from the bogs, specific plant species in my study were expected to respond to an increased water table. Hence, nonsignificant results between drained and rewetted sites may be explained by poor hydrological conditions in rewetted sites.

The species *E. nigrum* favour the driest parts of the bog, and if drained, it is often found in areas impacted by drainage (Bell & Tallis, 1974; Maanavilja et al., 2014). With raised water tables, the conditions no longer favour *E. nigrum,* at which stage it decreases in abundance (Bell & Tallis, 1974; Maanavilja et al., 2014). As *E. nigrum* prefer the driest areas in the bog, cover of *E. nigrum* has been considered an indicator of restoration failure for a 4 to 11 year period after restoration (González et al., 2013). As *E. nigrum* did not differ significantly from drained nor pristine sites in my study, the water table might be too low to have impacted the frequency of *E. nigrum* yet. Like *E. nigrum*, *P. schreberi* prefer drier conditions, but does to some extent tolerate higher water levels (Maanavilja et al., 2014). Tolerance to different water tables combined with the short time since rewetting may explain why the frequency of *P. schreberi* in rewetted sites still remains higher than the frequency in pristine sites (Maanavilja et al., 2014). If the water level is tolerable or not high enough over time, it may explain why rewetted sites did not differ significantly from drained and pristine sites for some species in my study.

C. vulgaris had a lower frequency at rewetted sites, compared to drained sites (Figure 4 c, Figure 5 a, Appendix 6). Even if the pin-intercept method may have favoured *C. vulgaris*, as it has a bigger biomass and thereby higher probability to touch the pin, my findings are similar to other studies (Frank & McNaughton, 1990; Hancock et al., 2018). Increased water tables may negatively affect *C. vulgaris*, as their root system with mycorrhizal symbiosis do not tolerate wet conditions (Bragazza & Gerdol, 1996). Yet, Jauhiainen et al. (2002) found *C. vulgaris* to increase in cover within the first three years after rewetting. Similarly, Hancock et al. (2018) found high abundances of *C. vulgaris* shortly after rewetting, but contrary observed that five years later it declined and gave space for *Sphagnum* spp, sedges and grasses. Although rewetting of the bogs in my study are relatively recent, no more than five years at its longest and for three sites one year only, the decline of *C. vulgaris* may indicate wetter conditions in rewetted sites, compared to drained. This assumption is in line with Walle (2021), who for the same bogs as in my study, found the water table in rewetted sites to be significantly higher than in drained sites.

Sphagnum did not respond to rewetting in my study, which may also indicate poor hydrological conditions and short recovery time since rewetting. Neither Howie et al. (2009), two years post rewetting, nor Punttila et al. (2016), one to three years post rewetting, found differences in *Sphagnum* cover in drained and rewetted sites. The *Sphagnum* cover found by Punttila et al. (2016) was lower in both drained and rewetted sites than in my study, although the pristine sites with 90 % *Sphagnum* cover resemble the findings of *Sphagnum* frequency in my study. Even with a longer time perspective of ten years post rewetting, Haapalehto et al. (2011) did not find the cover of *Sphagnum* to increase to the level of intact bogs. However, Haapalehto et al. (2011) found *Sphagnum* cover in rewetted sites to increase compared to drained sites, parallel with an increased water table. As *Sphagnum* recovery in rewetted sites are slow and related to wet conditions, more than a decade is required for peat to gain the same hydrological properties and to restore *Sphagnum* spp similar to pristine sites (Howie et al., 2009; McCarter & Price, 2013). The recovery of *Sphagnum* is important for other bog species to recover, as *Sphagnum* spp are key species in a bog, influencing factors such as hydrology and acidity (Poulin et al., 2013; Rochefort, 2000; Van Breemen, 1995). In my study, *Sphagnum* spp did not display a significant response to rewetting, similar to findings by Eian (2021), indicating that *Sphagnum* spp may not yet have responded to the rewetting or that the rewetting efforts failed to increase the water level. As some species in the *Sphagnum* taxa respond more rapidly to restoration, collecting individual species, instead of the *Sphagnum* taxa, may have shown more distinct differences between drained and rewetted sites (González et al., 2014). Given more time to increase the water level and growth, it might be possible to observe an effect of rewetting for the frequency of *Sphagnum* spp in the future.

In this study, the frequency of *Eriophorum* spp did not differ among any of the treatments (Appendix 5). *Eriophorum* spp was expected to increase in frequency after rewetting, similar to studies focusing on short time effects of rewetting (Anderson & Peace, 2017; Haapalehto et al., 2011; Hancock et al., 2018; Komulainen et al., 1999). The reason for the nonsignificant results could be that drained, rewetted and pristine sites were too similar in terms of growing conditions for *Eriophorum* spp. A higher water table is known to stimulate growth of *Eripohorum*, to the extent where raised water levels can indicate an acceleration of *Eriophorum* growth (Lavoie et al., 2005). A high cover of *Eriophorum* is found to be achieved two to five years after rewetting, before it starts declining (Haapalehto et al., 2017; Haapalehto et al., 2011; Komulainen et al., 1999). If the succession of *Eriophorum* had passed, not yet occurred or there were too low differences in water tables among drained, rewetted and pristine sites, it may explain why *Eriophorum* was not observed to differ among the sites in this study.

The lack of significant results of rewetting for specific species may also have been impacted by factors other than the water table. An example is for *E. nigrum* and *A. polifolia* which have been found to increase in abundance the first three years after rewetting, even though the overall species community evolved towards a pristine reference (Jauhiainen et al., 2002). It was hypothesised that improved light availability after tree removal especially benefited *E. nigrum* (Jauhiainen et al., 2002). The decreased cover of lichen was also hypothesized to benefit *E. nigrum* growth, even if the rewetting led to increased water levels (Jauhiainen et al., 2002). Without higher or lower frequencies in rewetted sites compared to drained and pristine, it is not possible to evaluate whether *E. nigrum* indicates restoration failure or success in my study. It can be hypothesised that neither the change in water level nor light availability due to tree removal have been strong enough environmental changes to increase or decrease the frequency of *E. nigrum* nor *A. polifolia.* This show that rewetting efforts impact more than just the water table and can, for some species, have both negative and positive impacts the first one to five years following rewetting.

In my study, a positive correlation between *Sphagnum* spp and Cyperaceae was observed (Appendix 7). Cyperaceae did not differ among any of the treatments, although interactions between species are important when species communities change after rewetting (Pouliot et al., 2011). Cover of *Sphagnum* spp are found to increase with vascular plants, such as Cyperaceae, *Eriophorum* spp and small trees, as they work as scaffolds for *Sphagnum* spp, until they start competing for resources (Pouliot et al., 2011). If the vascular species that stimulate *Sphagnum* growth are present in moderate cover, it can be expected improved cover of *Sphagnum* at the rewetted sites in the future. In contrast to my findings, Eian (2021) found significantly higher cover of Cyperaceae in rewetted sites than in drained and pristine. The presence of Cyperaceae spp at rewetted sites may improve future *Sphagnum* growth, even if their frequency did not differ among the treatments in my study.

Differences among the treatments may also be explained by the intensity of drainage. If the drained or rewetted bogs in my study were heavily drained, the species communities may have been more impacted than if the bogs were moderately drained (Braekke, 1983; Stivrins et al., 2017). Stivrins et al. (2017) found that peat accumulation was lower in sites with high drainage intensity than in sites with low drainage intensity, and that the species composition responded differently to moderate and high intensity drainage. Low drainage increased the cover of *Oxycoccus* and *A. polifolia* (Stivrins et al., 2017). More intense drainage caused hollows to dry out, causing *Sphagnum cuspidatum* and *Sphagnum majus* to disapper (Stivrins et al., 2017). However, great rainfall is found to reduce the impact of ditches, since the water lost by drainage may not be enough to negatively impact the water level as more water is added continuously (Coulson et al., 1990). The drainage intensity has not been investigated in my study. Although, it can be hypothesized that if the drained sites were not heavily drained or rainfall did not reduce the rate of draining, drainage would not have impacted the vegetation substantially. Drained and rewetted bogs with low impact of drainage could have led to low differences among drained, rewetted and pristine sites.

4.3 Distance to a ditch

No effects of rewetting were observed in proximity of the plugged ditch (Figure 5 a, b) as *Sphagnum* spp decreased in frequency closer to the ditch both in drained and rewetted sites, and no significant difference between the two treatments was observed (Appendix 6). The findings of increasing *Sphagnum* spp frequencies in drained sites may be explained by the water table, as the water table can be influenced by drainage up to 50 metres from the ditch, where the water table increases with distance to the ditch (Boelter, 1972). Yet, Maanavilja et al. (2015) found that rewetting did not make the water level rise to a level that promoted *Sphagnum* growth, similarly to my study. Although low water tables are disadvantageous for *Sphagnum*, chemical factors may make up for some of the negative impact of dry conditions, depending on the development of the peat after drainage (Grosvernier et al., 1997). The combination of the peat properties and possible low differences in the water level due to the intensity of ditching in drained and rewetted sites may explain the nonsignificant difference between the treatments in terms of *Sphagnum* frequency related to distance to a ditch.

The lack of significant impact of the distance to a ditch, and no differences in frequency between drained and pristine sites might be due to the lack of differences between water tables in the treatments at this stage in time (one to five years post rewetting) (Appendix 6). Similarly to my findings, Williamson et al. (2017) found most of the species, including *Sphagnum* spp, to have no differences in plant cover next to nor further from a ditch. The lack of differences were believed to be related to altered peat properties caused by drying (Holden et al., 2017; Williamson et al., 2017). Holden et al. (2017) found that peat affected by drainage over time is compressed and will sink to the extent that it gets closer to the water table. Ditch blocking would then have had minimal effect on raising the water table near the ditch and minimizing the differences of the water tables in drained and rewetted sites (Holden et al., 2017). The findings by Holden et al. (2017) may explain why distance to a ditch did not impact the plant frequencies, and why drained and rewetted sites did not differ in my study, as the water table may be high relative to the surface pre rewetting.

Several of the species lines in my study were located in between two ditches, but only distance to the nearest ditch was registered in the model testing frequencies related to distance to ditches. The presence of more than one ditch may have impacted the frequency and composition of species, as the density of ditches results in drier conditions (Braekke, 1983; Stivrins et al., 2017). Hancock et al. (2018) found a poorer effect of rewetting in the driest bog areas, such as on plough-ridges. Thus, accounting for that some species may have been impacted of drainage from more than one ditch could have given a more realistic result when investigating the effect of rewetting in relation to the distance to the drainage ditch.

4.4 Conclusion and implications for management

The results in this study indicate that rewetting have not yet had the desired effect of altering the vegetation to resemble pristine rather than drained sites. Rewetting did not impact species in close proximity nor further away from the drainage ditch. Neither whole community composition nor single species frequencies showed a clear effect of rewetting. An exception was *C. vulgaris,* which did show a decline in frequency after rewetting. As suggested earlier, the short time since rewetting, drainage intensity and low water tables may explain the lack of response in rewetted sites. The results in this thesis suggests that *C. vulgaris* can be used as an indicator species in monitoring of newly rewetted bogs. If more species respond in the future, given time and a raised water table, the plant community in rewetted bogs may evolve towards a pristine community. A time scale for this succession ought to be in the order of decades.

Choi (2007) states that future restoration of nature should not focus on the species composition the site had in the past, but rather the recovery of the site’s functions so it can endure in the future. Monitoring rewetted sites over time is necessary to be able to register slow reestablishment of species and changes in abiotic and other biotic factors, where restoration goals need to be specific to fully monitor the effects of restoration (Choi, 2007; Haapalehto et al., 2011; Howie et al., 2009).

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6. Appendices

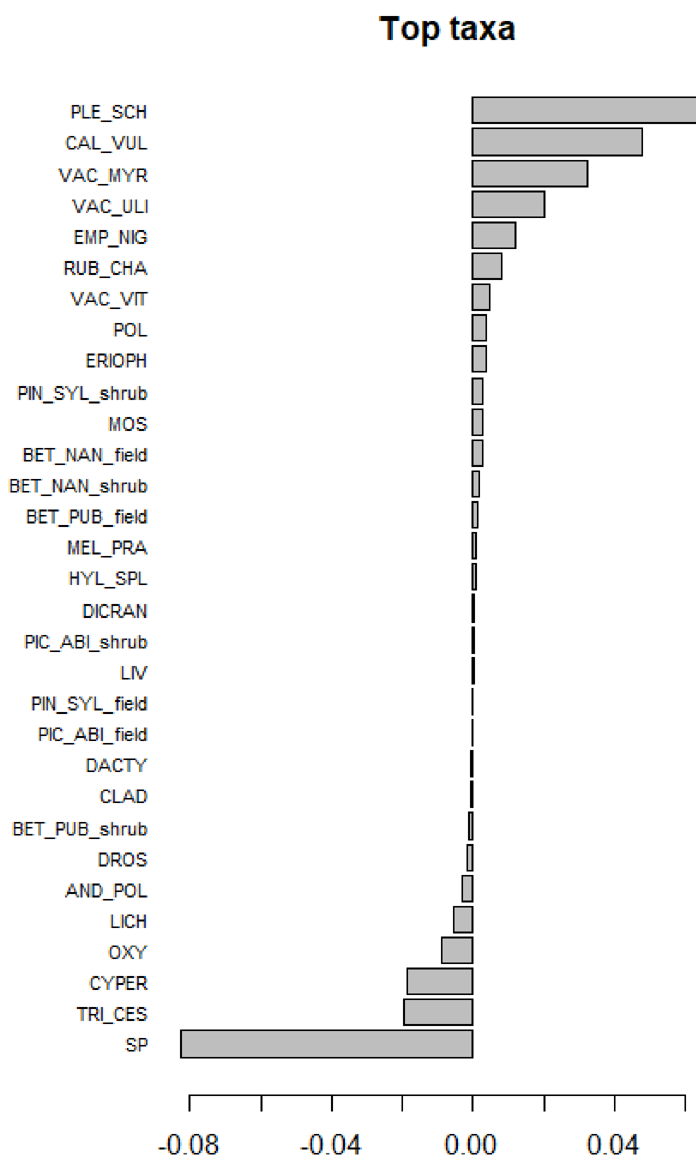
Appendix 1: The location of bogs, their treatment and coordinates, including the number of species lines and transects of each site.

ID	Name	Coordinates	Treatment	Restored (year)	Number of transects	Number of species lines	Date of visit	Municipality
L1	Villpostmyra	60.067385, 11.736947	Drained		2	9	20.08.2020	Nes
	Sakkhusmåsan	60.069704, 11.732560	Rewetted	2015	2	10	20.08.2020	
		60.071156, 11.727700	Pristine		2	9	20.08.2020	
L3	Flakstadmåsan	60.171479, 011.331894	Drained		2	10	14.06.2020	Nes
	Aurstadmåsan	60.184123, 011.344876	Rewetted	2016	3	13	12.06.2020	
		60.186347, 011.339158	Pristine		2	10	12.06.2020	
L4	Anonymous, west for Lomtjern	59.995716, 010.878654	Drained		3	12	11.06.2020	Nittedal
	Romsmåsan	59.984939, 010.884198	Rewetted	2016	3	16	10.06.2020	
	Anonymous, south for Rudsputten	60.002778, 10.866177	Pristine		2	9	11.06.2020	
L6	Tjennshaugmåsan southwest	59.943129, 011.666755	Drained		2	8	06.09.2020	Aurskog-Høland
	Midtfjellmåsan	59.952038, 11.684221	Rewetted	2018	3	13	06.09.2020	
		59.954480, 011.693798	Pristine		3	13	05.09.2020	
L8	Strandemyra	59.312458, 10.076354	Drained		2	9	25.08.2020	Sandefjord
	Veggermyra	59.311034, 10.095132	Rewetted	2018	2	8	25.08.2020	
		59.312337, 10.095082	Pristine		2	8	25.08.2020	
L10	Blåsynmåsan	59.845933, 10.942882	Drained		3	14	04.06.2020	Oslo
	Fjøsmåsan	59.832046, 10.921821	Rewetted	2019	2	10	02.06.2020 - 03.06.2020	
	Anonymous, by Tretjenna	59.844451, 10.913008	Pristine		1	4	04.06.2020	
L10B	Starrmåsan	59.823055, 010.932512	Drained		2	10	08.06.2020	Oslo
	Eriksvannmåsan	59.832735, 10.927911	Rewetted	2019	3	12	03.06.2020	
	Stormyr	59.820552, 10.9284848	Pristine		2	12	08.06.2020	
L11	Skullerudmåsan	59.861692, 010.859518	Drained		2	9	09.06.2020	Oslo
	Ødegårdsmåsan	59.865237, 010.893689	Rewetted	2019	3	12	13.06.2020	
	Skullerudmåsan	59.860759, 010.860219	Pristine		2	8	09.06.2020	

Appendix 2: The pin-intercept method: A pin was placed every 10th cm along the species line. Every species in contact with the pin was registered.

*Appendix 3: Registered species within vegetation layers, the species' abbreviations and in which treatments they were registered. Species marked with * were only observed once and were excluded from the statistical analyses.*

Vegetation layer	**Species**	**Abbreviations**	**Drained**	**Rewetted**	**Pristine**
Tree and bush layer	*Betula nana subsp. nana*	bet_nan	x		
	Betula pubescens	bet_pub	x	x	x
	Picea abies	pic_abi	x		
	Pinus sylvestris	pin_syl	x	x	x
Field layer	Cyperaceae	cyper	x	x	x
	Oxycoccus spp	oxy	x	x	x
	Drosera spp	dros	x	x	x
	Eriophorum spp	erioph	x	x	x
	Calluna vulgaris	cal_vul	x	x	x
	Empetrum nigrum	emp_nig	x	x	x
	Trichophorum cespitosum	tri_ces	x	x	x
	Vaccinium myrtillus	vac_myr	x	x	
	Vaccinium uliginosum	vac_uli	x	x	x
	Vaccinium vitis-idea	vac_vit	x	x	
	Rubus chamaemorus	rub_cha	x	x	x
	Andromeda polifolia	and_pol	x	x	x
	Betula nana subsp. nana	bet_nan	x		
	Betula pubescens	bet_pub	x	x	
	Picea abies	pic_abi		x	
	Pinus sylvestris	pin_syl	x	x	
	*Melampyrum pratense**	mel_pra	x		
	Dactylorhiza spp*	dacty			x
Groundlayer	*Cladonia* spp	clad	x	x	x
	Dicranum spp	dicran	x	x	x
	Sphagnum spp	sp	x	x	x
	Polytrichum spp	pol	x	x	x
	Hylocomium splendens	hyl_spl	x	x	
	Pleurozium schreberi	ple_sch	x	x	x
	Lichen	lich	x	x	x
	Liverworths	liv	x		
	Other mosses	mos	x	x	x



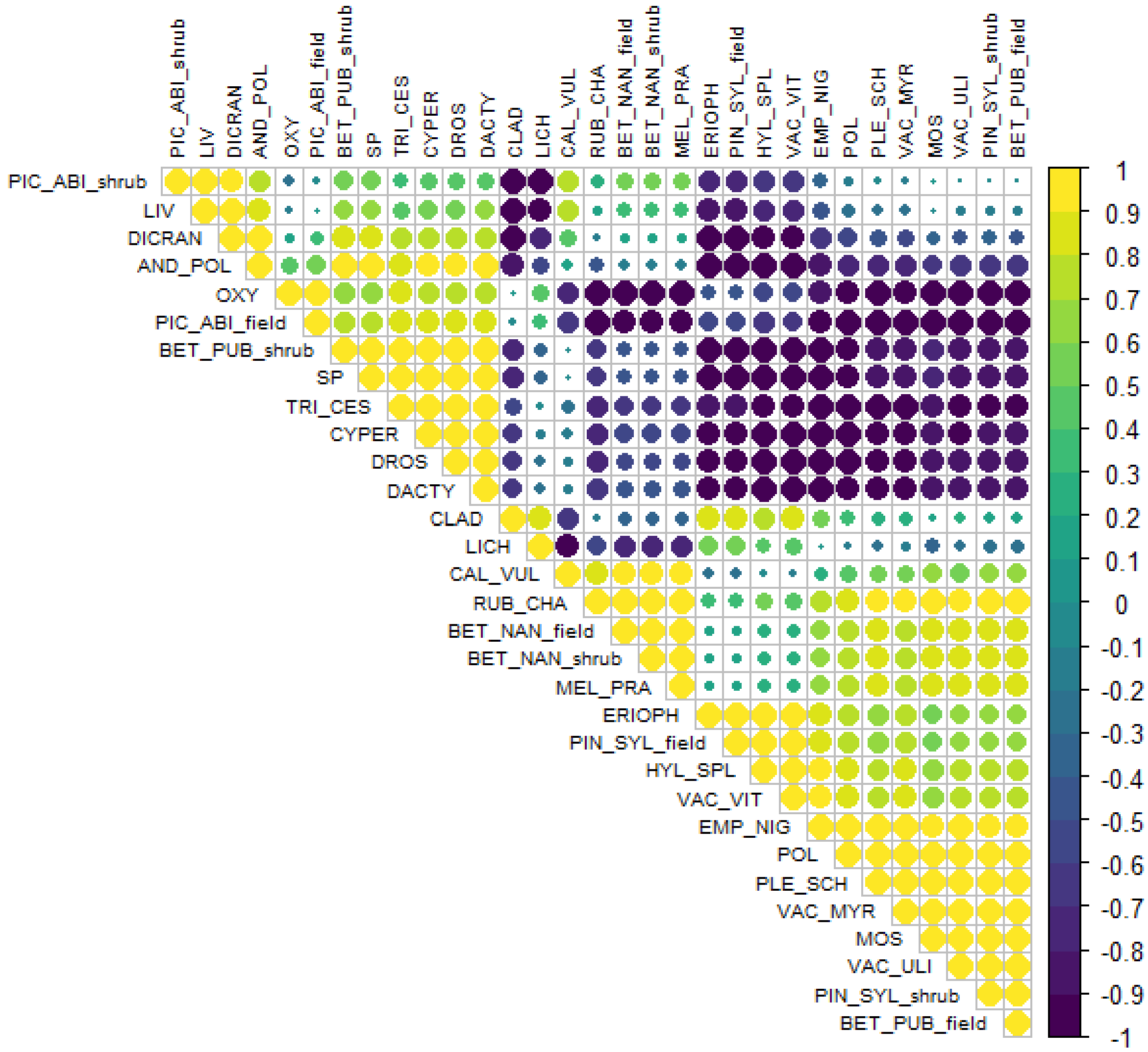
Appendix 4: Barplot of species that contribute the most to either the negative or positive direction of the NMDS plot.
Betula nana subsp. nana=BET_NAN, Betula pubescens*=BET_PUB, Picea abies*=PIC_ABI, Pinus sylvestris*=PIN_SYL, Cyperaceae=CYPER, Oxycoccus=OXY, Drosera=DROS, Eriophorum=ERIOPH, Calluna vulgaris=CAL_VUL, Empetrum nigrum=EMP_NIG, Trichophorum cespitosum=TRI_CES, Vaccinium myrtillus=VAC_MYR, Vaccinium uliginosum=VAC_ULI, Vaccinium vitis-idea=VAC_VIT, Rubus chamaemorus= RUB_CHA, Andromeda polifolia=AND_POL, Cladonia=CLAD, Dicranum=DICRAN, Sphagnum=SP, Polytrichum=POL, Hylocomium splendens= HYL_SPL, Pleurozium schreberi=PLE_SCH, Lichen=LICH, Liverworths=LIV, Other mosses=MOS. Species marked with * are found in both in bush and field layer.*

Appendix 5: Results of the generalized linear mixed model for species frequency tested between the treatments. Significance level is 0.05.

Species	Treatment	Estimate	Std.Error	z value	Pr(>|z|)
Sphagnum spp	pristine-drained	1.108	0.376	2.951	**0.003**
	pristine-rewetted	-1.333	0.359	-3.712	**<0.001**
	drained-rewetted	-0.225	0.322	-0.698	0.485
Cladonia spp	pristine-drained	0.091	0.362	0.251	0.801
	pristine-rewetted	-0.056	0.352	-0.159	0.874
	drained-rewetted	0.035	0.335	0.105	0.916
Pleurozium schreberi	pristine-drained	-1.156	0.396	-2.922	**0.003**
	pristine-rewetted	0.906	0.350	2.591	**0.010**
	drained-rewetted	-0.250	0.348	-0.719	0.472
Eriophorum spp	pristine-drained	-0.034	0.277	-0.122	0.903
	pristine-rewetted	0.140	0.266	0.526	0.599
	drained-rewetted	0.106	0.255	0.417	0.677
Calluna vulgaris	pristine-drained	-0.363	0.272	-1.338	0.181
	pristine-rewetted	-0.211	0.269	-0.785	0.432
	drained-rewetted	-0.575	0.256	-2.243	**0.025**
Empetrum nigrum	pristine-drained	-0.732	0.370	-1.978	**0.048**
	pristine-rewetted	0.499	0.331	1.508	0.132
	drained-rewetted	-0.233	0.335	-0.697	0.486
Oxycoccus spp	pristine-drained	0.396	0.319	1.240	0.215
	pristine-rewetted	0.014	0.289	0.048	0.962
	drained-rewetted	0.409	0.293	1.395	0.163
Trichophorum cespitosum	pristine-drained	0.955	0.331	2.889	**0.004**
	pristine-rewetted	-1.242	0.324	-3.836	**<0.001**
	drained-rewetted	-0.287	0.318	-0.902	0.367
Cyperaceae	pristine-drained	0.595	0.370	1.610	0.107
	pristine-rewetted	-0.559	0.340	-1.644	0.100
	drained-rewetted	0.036	0.334	0.107	0.915
Andromeda polifolia	pristine-drained	0.700	0.282	2.485	**0.013**
	pristine-rewetted	-0.781	0.279	-2.795	**0.005**
	drained-rewetted	-0.080	0.290	-0.276	0.782
Vaccinium myrtillus	pristine-drained	-0.648	0.379	-1.709	0.088
	pristine-rewetted	0.481	0.349	1.377	0.168
	drained-rewetted	-0.166	0.333	-0.50	0.617
Vaccinium uliginosum	pristine-drained	-0.471	0.341	-1.381	0.167
	pristine-rewetted	0.555	0.333	1.685	0.092
	drained-rewetted	0.084	0.315	0.268	0.789
Vaccinium vitis-idaea	pristine-drained	-0.521	0.340	-1.533	0.125
	pristine-rewetted	0.518	0.329	1.577	0.115
	drained-rewetted	-0.003	0.314	-0.009	0.993
Rubus chamaemorus	pristine-drained	-0.642	0.354	-1.814	0.070
	pristine-rewetted	0.378	0.343	1.101	0.271
	drained-rewetted	-0.264	0.313	-0.843	0.399

Appendix 6: Results of the generalized linear mixed model for species frequency with distance to the nearest ditch. Significance level is 0.05.

Species		**Estimate**	**Std.Error**	**z value**	**Pr(>|z|)**
Sphagnum spp	Intercept (drained)	0.087	0.267	0.326	0.744
	Rewetted	-0.193	0.297	-0.650	0.515
	Distance from ditch	0.036	0.015	2.448	**0.014**
Cladonia spp	Intercept (drained)	-3.032	0.234	-12.951	**<0.001**
	Rewetted	0.041	0.159	0.258	0.796
	Distance from ditch	0.008	0.011	0.724	0.469
Pleurozium schreberi	Intercept (drained)	-1.920	0.197	-9.756	**<0.001**
	Rewetted	-0.062	0.182	-0.340	0.734
	Distance from ditch	-0.016	0.0125	-1.282	0.200
Eriophorum spp	Intercept (drained)	-1.425	0.247	-5.777	**<0.001**
	Rewetted	-0.013	0.244	-0.054	0.957
	Distance from ditch	0.021	0.013	1.622	0.105
Calluna vulgaris	Intercept (drained)	-1.014	0.224	-4.533	**<0.001**
	Rewetted	0.509	0.230	-2.215	**0.027**
	Distance from ditch	0.012	0.013	0.937	0.349
Empetrum nigrum	Intercept (drained)	-3.323	0.206	-16.156	**<0.001**
	Rewetted	0.014	0.157	0.087	0.913
	Distance from ditch	0.003	0.011	0.302	0.762
Oxycoccus spp	Intercept (drained)	-2.754	0.185	-14.850	**<0.001**
	Rewetted	0.063	0.157	0.400	0.689
	Distance from ditch	0.017	0.010	1.620	0.105
Trichophorum cespitosum	Intercept (drained)	-3.512	0.204	-17.194	**<0.001**
	Rewetted	-0.070	0.154	-0.453	0.651
	Distance from ditch	0.001	0.010	0.103	0.918
Vaccinium uliginosum	Intercept (drained)	-3.288	0.205	-16.031	**<0.001**
	Rewetted	-0.073	0.154	-0.474	0.635
	Distance from ditch	-0.006	0.011	-0.557	0.577
Vaccinium vitis-idea	Intercept (drained)	-3.588	0.208	-17.249	**<0.001**
	Rewetted	0.019	0.153	0.121	0.903
	Distance from ditch	-0.008	0.011	-0.762	0.446
Cyperaceae	Intercept (drained)	-3.538	0.208	-16.997	**<0.001**
	Rewetted	0.022	0.154	0.145	0.885
	Distance from ditch	0.001	0.010	0.090	0.928
Andromeda polifolia	Intercept (drained)	-3.410	0.205	-16.657	**<0.001**
	Rewetted	-0.014	0.158	-0.899	0.369
	Distance from ditch	0.015	0.010	1.440	0.150
Vaccinium myrtillus	Intercept (drained)	-2.697	0.203	-13.307	**<0.001**
	Rewetted	-0.067	0.157	-0.444	0.657
	Distance from ditch	-0.020	0.012	-1.704	0.088
Rubus chamaemorus	Intercept (drained)	-3.534	0.204	-17.288	**<0.001**
	Rewetted	-0.156	0.154	-1.010	0.313
	Distance from ditch	0.003	0.012	0.268	0.788



Appendix 7: A correlation plot of all species registered across treatments. Yellow and green colours indicate positive correlation (correlation coefficients 1 to 0), while blue and indigo colours represent negative correlation (correlation coefficients from 0 to -1). Species abbreviations: Betula nana subsp. nana=BET_NAN, Betula pubescens*=BET_PUB, Picea abies*=PIC_ABI, Pinus sylvestris*=PIN_SYL, Cyperaceae=CYPER, Oxycoccus=OXY, Drosera=DROS, Eriophorum=ERIOPH, Calluna vulgaris=CAL_VUL, Empetrum nigrum=EMP_NIG, Trichophorum cespitosum=TRI_CES, Vaccinium myrtillus=VAC_MYR, Vaccinium uliginosum=VAC_ULI, Vaccinium vitis-idea=VAC_VIT, Rubus chamaemorus= RUB_CHA, Andromeda polifolia=AND_POL, Cladonia=CLAD, Dicranum=DICRAN, Sphagnum=SP, Polytrichum=POL, Hylocomium splendens= HYL_SPL, Pleurozium schreberi=PLE_SCH, Lichen=LICH, Liverworths=LIV, Other mosses=MOS. Species marked with * are found in both in bush and field layer.*

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