Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Natural Sciences
Department of Biology

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Summary of mire restoration and evaluation of two methods for monitoring mire restoration in Norway

Master's thesis in Natural Resources Management
Supervisor: James Speed
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May 2022

Atnsjømyrene

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ABSTRACT

Intact mires are great carbon stocks but have in many cases historically been drained for forestry and agriculture. Therefore, a restoration plan for wetland was instituted by the Norwegian Environmental Agency [Miljødirektoratet] with the aim of reducing greenhouse gas emissions and biodiversity loss. Two methods for monitoring were introduced, the extensive monitoring method and the intensive monitoring method.

The aims of this study were to summarize the restoration performed during the timeframe of this action plan and explore and evaluate the two monitoring methods in Norway. QGIS was used to summarize the distribution of monitoring, which type of mire was restored, their protection status and restored area, which informed that 60% of restored sites was monitored and that most restoration projects occur in eastern Norway or Trøndelag. Detailed description of the mires was found for approximately half the restored mires.

Data for the intensive method was collected by a simplified point intercept method in four 250 m long species lines with a 10cm distance between points per transect across a restored ditch. In addition, dominating plant groups were registered every 0.5 meters. The extensive method collects data by registering species groups in points with a 0.5 m distance along a transect. To determine the effect of restoration on important plant groups, generalized mixed models were created for *Sphagnum, Eriophorum* and Ericaceous plants for data from the intensive methods species line and transects as well as the extensive method. In addition, the effect of restoration was evaluated by looking at the species composition before and after restoration and compared to a reference transect by using non-metric multidimensional scaling (NMDS). The change in mire margin species to mire expanse species was examined.

I found, through the species line, that there was a slight increase in *Sphagnum* species at some sites after five years. Increase in *Eriophorum* was detected by the other sampling methods while decrease in Ericaceous plants was found by sampling along the transect in the intensive method. The change in species composition indicated that restored transects were more similar to references than unrestored, and in some sites more closely associated with wet mire species like *Sphagnum cuspidatum* and *Sphagnum tenellum.* By exploring how the different sampling methods detected change after restoration, I found that the species lines gave a more detailed perspective on the success of restoration.

SAMMENDRAG

Intakte myrer har store karbonlagre, men har i mange tilfeller tidligere blitt drenerte for skogbruk eller landbruk. Derfor ble det igangsatt en plan for restaurering av våtmark av Miljødirektoratet i 2016, med mål om å redusere utslipp av klimagasser og tap av biodiversitet. To overvåkningsmetoder ble introdusert: den intensive og den ekstensive overvåkningen.

Målet med denne studien er å gi en oppsummering av restoreringen som har blitt gjort i Norge under den første handlingsplanen for restaurering av våtmark og utforske og evaluere de to overvåkningsmetodene som blir brukt på restaurert myr i Norge. For restoreringsoppsummeringen ble QGIS brukt for å finne fordelingen av overvåkede restoreringsprosjekt, myrtype, vernestatus og restaurert areal. Denne undersøkelsen viste at ca. 60% av de restaurerte myrene har overvåkning, og at flertallet av prosjektene er på Østlandet og i Trøndelag. Ca. halvparten av de restaurerte myrene har detaljert beskrivelse av myrtype.

Dataen fra den intensive overvåknings metoden ble samlet inn ved å bruke en forenklet pin-punkt metode i fire 250 m lange linjer med mellomrom på 10cm i tillegg til å registrere dominerende artsgrupper langs transektet som gikk på tvers over en restaurert grøft. I den ekstensive overvåkningsmetoden ble data samlet inn ved å registrere artsgrupper i punkter med 0.5 m avstand langs transektet. For å undersøke effekten av restoreringen på viktige plantegrupper ble generaliserte miksede modeller laget for *Sphagnum, Eriophorum* and lyng for artslinjene og transektene fra den intensive overvåkningsmetoden og for den ekstensive overvåkningsmetoden. I tillegg ble effekten av restoreringen vurdert ved å se på endringen i artssammensetningen før og etter restaurering og sammenlignet med et referansetransekt ved hjelp av en Ikke-metrisk flerdimensjonal skalering (NMDS). I tillegg ble endring fra myrkantarter til myrflatearter undersøkt.

Ved bruk av dataen fra artslinjene, fant denne studien en økning i *Sphagnum* på noen restaurerte myrer etter fem år. De andre innsamlingsmetodene fant en økning i *Eriophorum,* mens innsamling langs transektet i den intensive metoden registrerte en nedgang i lyngarter. Endringer i artssammensetningen indikerte at restaurerte transekter var likere referansene enn før restaurering, og noen områder ble nærmere assosiert med våte myrarter som *Sphagnum cuspidatum* og *Sphagnum tenellum.* Ved å undersøke alle innsamlingsmetodene fant jeg at dataen fra artslinjene ga et klarere bilde av endringene etter restaurering enn de andre metodene.

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Linn Marie Foldnes Lunde

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1. INTRODUCTION

1.1 Nature and climate: efforts must be made

We are currently entering both a climate crisis and a nature crisis. Large cuts in gas emissions are required in order to reduce global warming (IPCC, 2018), while biodiversity and ecosystem services require large conservation actions in order to reduce its escalating decline (Scholes et al., 2018). The biggest driver of biodiversity loss on land is land-use change from pristine lands to agricultural land (Almond et al., 2020; Scholes et al., 2018) and the most important action to halt land degradation and biodiversity loss is to protect and restore nature (Scholes et al., 2018). It is essential that the climate crisis and nature crisis are not treated as two separate events, but as something that is inherently linked (Rusch et al., 2022; Scholes et al., 2018). Land degradation may worsen and accelerate climate change (Scholes et al., 2018), for example by turning peatland carbon sinks into carbon sources (Erkens et al., 2016). In addition, climate change may further damage lands by accelerating soil erosion and increase forest fires (Scholes et al., 2018). The synergies of habitat protection and restoration to biodiversity conservation and climate change mitigation is highlighted by both the Sustainable Development Goals and the Convention on Biodiversity (CBD, 2021).

Natural climate solutions, in addition to energy and industrial mitigation, can be the solution to stabilizing the earth's climate while also benefit nature and ecosystems (Anderson et al., 2019) and can obtain 37% of CO_2 mitigations needed to uphold the Paris agreement (Griscom et al., 2017). Carbon storage in soil is calculated to represent 25% of the potential of natural climate solutions to prevent greenhouse gas emissions, including both the protection of existing soil carbon (40%) and restoration of damaged carbon stocks (60%) (Bossio et al., 2020). Hence, restoration of damaged carbon stocks such as degraded peatlands can be an important measure for climate change mitigation (Bossio et al., 2020) in addition to preservation of biodiversity (Sundberg, 2012). Ecological restoration "is an intentional activity that initiates or accelerates the recovery of an ecosystem with respect to its health, integrity and sustainability" (Society for Ecological Restoration International, 2004). In many cases, the ecosystem has been damaged directly or indirectly by human activities so that its functionality is reduced and cannot recover naturally. Most restoration measures aim to rehabilitate the site to its historically pre-disturbed state; however, this is not always possible (Society for Ecological Restoration International, 2004).

1.2 Mires as climate mitigators and biodiversity hotspots

Peatlands are the world´s most carbon dense ecosystems (Page & Baird, 2016). Even though it covers only 3% of the global land area, peatlands have more carbon storage than all the tropical rainforests in the world (Page & Baird, 2016; Parish et al., 2008). Hence, they play a vital role in carbon sequestration. In addition, peatlands serve as biodiversity hotspots for birds, vascular plants and bryophytes (Sundberg, 2012). Peatlands offer multiple ecosystem services like climate regulation such as flood reduction, water purification and archaeological preservation (Andersen et al., 2017), with the most recognized being greenhouse gas mitigation (Harris et al., 2022). So much carbon is stored by the worlds peatlands that if all carbon was released it would increase the CO_2 level in the atmosphere by 50% (Byrne et al., 2004). While unrealistic, this scenario illustrates the importance of peatlands as a carbon sink. The great potential to store carbon comes from the structure of the mire, where the top layer of a mire, the acrotelm, is exposed to oxygen in the air and consists of both living mosses, some vascular plant roots and decaying organic litter. In boreal peatlands the peat mosses (*Sphagnum*) make up a large part of the living organic material and sequester carbon through photosynthesis. Due to high water level, decomposition and respiration is limited, which leads to an accumulation of carbon rich decaying *Sphagnum* (peat) in the catotelm (Byrne et al., 2004).

1.3 Mire degradation and restoration

Large peatland areas in the temperate and boreal zone have for the past 150 years been drained for land use purposes such as agriculture and forestry (Erkens et al., 2016; Leifeld et al., 2019). When mires are drained, water levels decrease, and the peat is exposed to oxygen (Joosten et al., 2017). This turns the drained peatlands into a carbon source (Wüst-Galley et al., 2016), and peatland drainage contributes to 5% of global annual anthropogenic greenhouse gas emissions. When peatlands are drained the hydrological conditions change as a result of oxidation, subsidence due to peat consolidation and compaction, and these changes can be irreversible without human intervention (Bonn et al., 2016).

Increased knowledge of the importance of a healthy peatland (van Diggelen et al., 2006), has caused a reduction in practices that actively degrades peatlands for forestry and agriculture purposes (Vasander et al., 2003). However, many of the remaining peatlands are partly degraded and may be unable to recover by themselves (Raeymaekers et al., 2000), so efforts are being made to preserve and restore them (Hedberg et al., 2012; Lundin et al., 2017; Mälson et al., 2008). Restoration measures on mires typically aim to rehabilitate the hydrology (rewet), which in turn can recover the species structure (Nellemann & Corcoran, 2010), for example by decreasing mire margin species in favour of mire expanse species (Fremstad, 1997), and to recover the ecosystems functions (Society for Ecological Restoration International, 2004). The rewetting may also reduce loss of carbon to the atmosphere at these sites instantly (Günther et al., 2020), as decomposition rates deaccelerates (Paustian et al., 2016). Other measures, like bryophyte transplantation and cutting trees can also be used in addition to rewetting (Hedberg et al., 2013; Kozlov et al., 2016; Mälson et al., 2008). Rewetting is done by blocking the ditches with for example peat, sawdust or wooden dams (Landry & Rochefort, 2012) to increase the water retention in the peatlands (Shantz & Price, 2006). This allows water to rise to the surface which in turn favours typical mire species as well as decrease the level of undesired plants such as trees and bushes that needs drier conditions to thrive (Tuittila et al., 2009). Typically, ditches are blocked by dams of compacted peat that are spaced along the drainage ditch, allowing pools of water to establish between the dams (Landry & Rochefort, 2012). In some cases, when a more comprehensive filling is needed, backfilling can be used. This restoration method entails filling the drainage ditch with peat, which is very effective to raise the water table, but requires a large amount of peat (Landry & Rochefort, 2012). While this can effectively restore the hydrology, it may cause a great disturbance to the vegetation as peat need to be harvested from the surrounding peatland, such as in figure 1. Hence, some testing to see if the restoration measures have a positive effect, are called for.

Figure 1. Hildremsvatnet in september 2021, 2 years after restoration. Comprehensive restoration measures where bonds of peat are placed in diches as the area was systematically drained. Big patches of bare peat are exposed as well as pools of water in holes from the peat that was used to fill the ditches.

Peatmoss, or *Sphagnum,* is a commonly used proxy on mire health, where increased *Sphagnum* cover may indicate increased ecological health (Rochefort, 2000). Vegetation cover can refer to both canopy cover and foliar cover, which is the proportion of the soil covered by the plant canopy or the proportion of the soil that is covered by the plant parts (Bonham, 1989). Sheathed cottonsedge, *Eriophorum vaginatum*, can also be used as a proxy, as it is often considered a pioneer species in restored peatlands, and establishment of this plant is accommodating for other peatland species to re-establish (Tuittila et al., 2000; Yan et al., 2008). Admittedly, the importance of *Sphagnum* and *Eriophorum* may depend on the type of mire (Moen et al., 2011; Øien, Lyngstad, et al., 2015). Species composition can also be used to evaluate increased ecological condition if compared to a similar healthy ecosystem (Nybø & Evju, 2017).

1.3 Mires in Norway

The biodiversity in Norwegian mires have a large variety of mire types with a substantial and distinct biodiversity (Moen et al., 2011; Øien, Lyngstad, et al., 2015). For example, many rare bryophyte species as well as the strongly threatened red-listed orchid *Epipactis palustris* (Miljødirektoratet, 2020; Solstad & Bratli, 2010), in addition to all but three European

Sphagnum species are present in Norwegian mires (Flatberg, 2002). The distribution of mire types varies geographically: raised bog are more common in eastern Norway and in the northern part of Trøndelag and sloping mires and string bogs are more common in the middle of Norway (Moen, 1998). Nearly 9% of Norway's land area is mires (Bryn et al., 2018; Moen et al., 2011), considerable parts of this have historically been altered by land- use change and especially drainage for agriculture and forestry, like the rest of Europe (Vasander et al., 2003). A plan to protect mire [*Landsplan for myrreservater*] was initiated in 1966 by the Norwegian Council of Nature Conservation [*Statens Naturråd]*, that aimed for the protection to cover as many mire types as possible within the country (Moen, 1973).

1.4 Mire restoration plan in Norway

In 2015, the Norwegian Environmental Agency made an action plan for wetland restoration in Norway from 2015 to 2020 (Miljødirektoratet, 2016). A follow-up for a new five-year period was published in 2020 (Miljødirektoratet, 2020). This action plan highlights three main goals of restoration: reduce greenhouse gas emissions, adapt to climate change and improve the ecological conditions in the mires (Miljødirektoratet, 2020).

Since the Norwegian restoration programme was initiated, 142 restoration projects have been executed on wetlands by 2022 (80 of these by 2020, within the timeframe of the first management plan). Most of these projects were in protected areas, and mires with great potential for climate mitigation, such as raised bogs, have been prioritized in the restoration programme (Miljødirektoratet, 2016). In the renewed management plan from 2020, The Norwegian Environmental Agency reviewed the socio-economic impacts of the restoration. They mention observations of an increased number and variety of dragonflies in one location, as well as observations of an increase in the redlisted black-tailed godwit (*Limosa limosa*). In addition, they present estimates of reduction in annual CO_2 emissions to be between 1.8 to 12.1 tonne per ha each year, based on calculations by Joosten *et al.* (2015) (Miljødirektoratet, 2020).While these observations and estimates give some indication of the positive effects of the restoration, research-based evidence using data collected from the actual restored sites to evaluate the success is lacking.

To measure if restoration is successful, a monitoring programme was developed and executed in a total of five sites, with approximately four transects across a restored ditch which are monitored per site (hereafter called the "intensive" monitoring method) (Hagen et al., 2015). A simplified version of the monitoring programme has been executed on several sites (hereafter called the "extensive" monitoring method), with one monitoring transect. Both surveys measure the level of plant variables. The two survey methods that have been prescribed by The Norwegian Environmental Agency and have been used to monitor pre-restored and rewetted peatlands (Miljødirektoratet et al., 2015). Of the 80 mires that was restored in the time frame of the first management plan, approximately 47 was monitored by the extensive method and 4 by the intensive method by 2020. Since the establishment in 2015, no statistical analyses have been executed on the collected data from either of the monitoring methods, nor is there planned any particular approach for analysing the data from either of the methods.

1.5 Aims

The aims of this thesis are to describe and summarize the restoration and monitoring of mires, from the Norwegian action plan for wetland restoration from 2015-2020, and to explore and evaluate the two monitoring methods on mire restoration in Norway.

Firstly, I will summarize the mire restoration that has been done in Norway, and derive information on elements of the Norwegian mire restoration where there is an information gap, such as:

1. *How many mires have been restored and monitored during the first action plan and what is the geographical distribution in terms of Norwegian counties?*
2. *Are the mire types of restored and monitored mires known? If so, what are the types of mire restored?*
3. *How much area is restored?*

I expect that the counties in the middle and eastern part of Norway to have the most restoration projects, as raised bogs has been prioritised in the restoration programme due to the fact that they often have large carbon stocks (Moen, 1998). I expect an equal proportion of monitoring to restored mires in each county and that counties with more restored area have more monitoring than those with less restored area.

To determine the effects of the restoration measures on the ecological condition and hydrology, and subsequently the success of the restoration, the restored sites need to be monitored. Hence, I will explore ways the data from the different monitoring methods can be analysed to evaluate if restoration measures have been successful and if the data from the monitoring programmes can reveal this, as it was not decided how the data will be tested statistically when the monitoring survey methods was established. Also, I will evaluate if the sampled data can be used as indicators for success in restored mires, and ultimately evaluate the use of the different monitoring methods on the restored mires. I specifically want to answer the following questions:

1. *Does the restoration have an effect on measured indicators of restoration success such as indicator species and species composition?*
2. *How does the different monitoring method capture the effect of these indicators?*
3. *How does the indicators measured by the monitoring methods reflect the objectives of the restoration?*

I expect that there will be an increase of mire-thriving species such as *Eriophorum vaginatum* and *Sphagnum* after restoration at the sites, as well as a decrease of Ericaceous plants (plants from the *Ericacea* family, including *Calluna vulgaris, Andromeda polifolia, Empetrum* ssp. and *Vaccinium* ssp.). How well the data can provide the information needed to measure these proxies may vary depending on monitoring methodology.

2. METHOD

2.1 Monitoring survey methods

The two survey methods collect vegetation data along transects that crosses one or more restored ditches. For both the extensive and the intensive survey, data have been collected before restoration and will be re-analysed in regular time intervals to monitor the effect of the restoration measures.

The intensive survey method collects detailed data of the species composition, mire structure and dominance of plant groups. At each site, four transects of 50 meters (standardized after the monitoring started) were established before restoration actions were implemented (with the exception of Midtfjellmosen, which only have three transects. In addition, all sites have a reference transect in a part of the mire, which is unaffected by a ditch, except for Hildremsvatnet. The transects crosses existing ditches, and the midpoint of 25 meter is typically placed in a ditch (figure 2). Every half meter along the transect, the plant group (such as evergreen or deciduous Ericaceous plants) that dominates, is registered for the bottom and field layer. All plant groups are listed in appendix 1, table A1. This sampling method will hereby be referred to as "transect analysis", as it collects data of the dominating plant groups along the whole transect. Secondly, along each transect a 2.5-meter segment is established every 10 meters and analysed in more detail by using a simplified point-intercept method (Goodall, 1952). At every 10 cm an approximately 4mm diameter pin was lowered, and all species that hit the pin were registered and identified to species level (Jonasson, 1988). This results in four "species-lines" with 25 data points per transect.

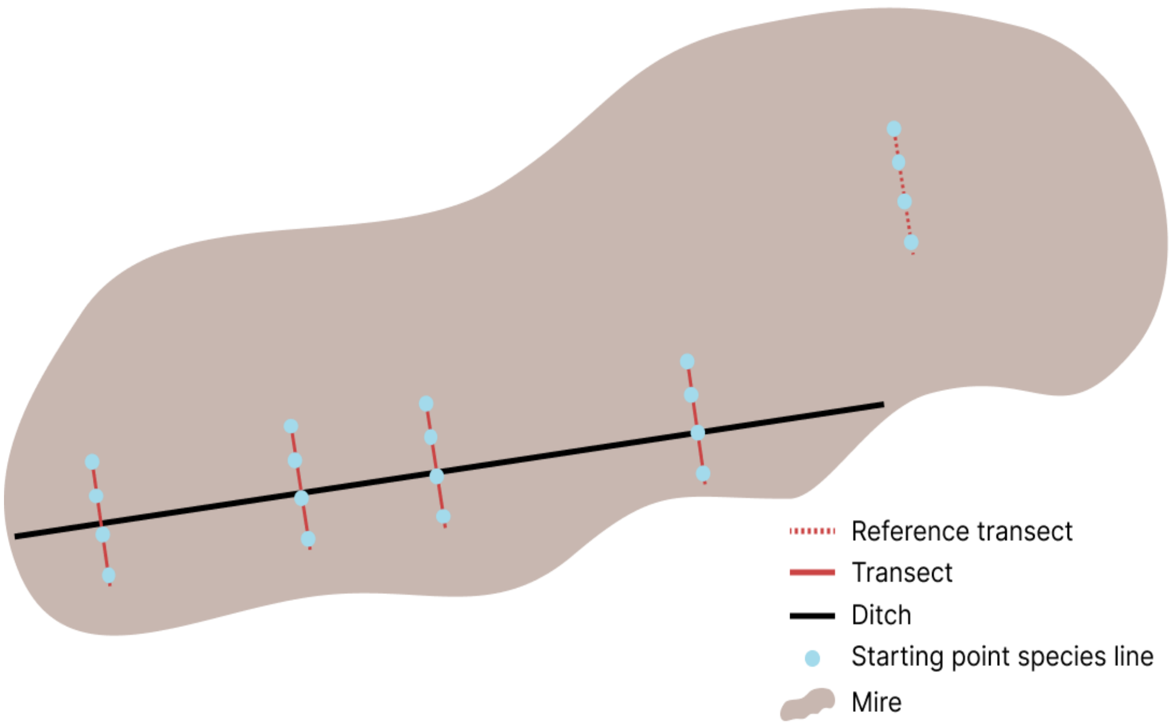

Figure 2. A schematic representation of sampling set up for the intensive monitoring method. Approximately four 50m long transects are placed with a ditch.in the middle, and a reference transect is placed further away from the ditch. Dominating plant groups per vegetation layer are registered along the transect, and species are registered in the species lines that are placed upon the transects every tenth meter. In the species line all species that hits a pin with a 10 cm distance between each sampling point are registered

The extensive survey method is a simplified version of the intensive method. Most locations have one transect, which is 30 meters long. Every 50 cm, the presence of certain species groups is registered in a point of 1x1 cm. The main focus is to register the presence of *Sphagnum*, but other plant groups, such as graminoids, Ericaceous plants, herbs and other may also be registered (appendix 1, table A1.2). This procedure has not been standardized, which means that plant groups that are registered varies depending on the person collecting the data and the presence of that group at the location (Miljødirektoratet, 2020). Therefore, different grouping can be used across sites, and some plant groups may be skipped altogether in some sites.

2.2 GIS Analysis

To get a summary of restored and monitored mires as well as an estimate of restored area, QGIS (Version 3.16.13 Hannover) was used. Data of all mire restoration projects and extensively monitored sites were collected from Norwegian Nature Inspectorate [Statens Natur Oppsyn] (SNO). Coordinates of the intensively monitored sites were provided by NINA. Projects executed after 2020 were excluded. Polygons of mires were made by combining existing polygons of nature reserves that encompassed the restored mires, and further edited against borders of the mires in a topological map of Norway (topo4). Small alterations were preformed against orthophotographs. The final polygons only included the extent of the specific mires that has been restored.

An overview of which of the mires that have extensive monitoring, was created by running an overlap analysis between polygons of mires with restoration projects and endpoints of the extensive monitoring transects. I also added the coordinates of the intensively monitored sites. This gave me an overview of all mire sites which are monitored by either the extensive or the intensive method as well as the sites that lacked monitoring. I added a layer of the counties to better get the distribution of restoration projects and monitoring (Kartverket, 2022).

The mire types, such as “sloping mires” or “minerotroph” were investigated by overlapping polygons of restored mires with areas under nature protection or other area registration. This gave me access to fact sheets with detailed description of each mire, including mire type, protection status and what plan of nature protection the area was protected under, for example plan for mire protection. Mires that did not overlap through this method where checked manually by comparing their location to an official map of protected areas in Norway (Miljødirektoratet, 2022). However, as not all mires were in protected areas, detailed description lacked for some sites through this approach. Hence, an overlap with restoration projects and a map of nature types was performed. “Nature types” refers to the system established in the Directorate for Nature Management’s handbook 13 [Direktoratet for naturforvaltning, handbook 13] (Direktoratet for Naturforvaltning, 2006).

To estimate the area affected by the restoration measures (mainly the filling of ditches), I used data from SNO of filled ditches and bonding dams, and added buffers around these polygons, the area which are affected by restoration was calculated. It is assumed that the impacts of ditches will have an extent on at least 10 m (Miljødirektoratet, 2020). I therefore calculated the minimum area that has been affected by the restoration effort by adding a 10 m buffer around filled ditches on both sides and a 10 m buffer on one side of the bonding dams. These buffer layers were combined and then clipped with the mire polygons. Based on emission factors by Joosten *et al.* (2015) for drained mires to forest (1.8-13.1tonne per ha per year), which the Norwegian Environmental Agency (2020) has deemed to be the emission factor to use for the restored mires in Norway, I calculated the reduction in CO_2 emissions using my calculations on restored area.

2.3 Data collection

Fieldwork was executed during summer 2021. Study locations were chosen at the basis of their proximity to each other and our base location in Trondheim to encompass as many mire locations as possible at the limited time we had (figure 3). We chose locations that had before-data. Most locations which were analysed with the extensive method had only one data collection beforehand, which was before restoration. The mires were examined with the method that had previously been used on that site. In addition, one transect for each location were examined with both monitoring methods, which will enable me to compare if the survey methods measure the proportion of hits per species group equally.

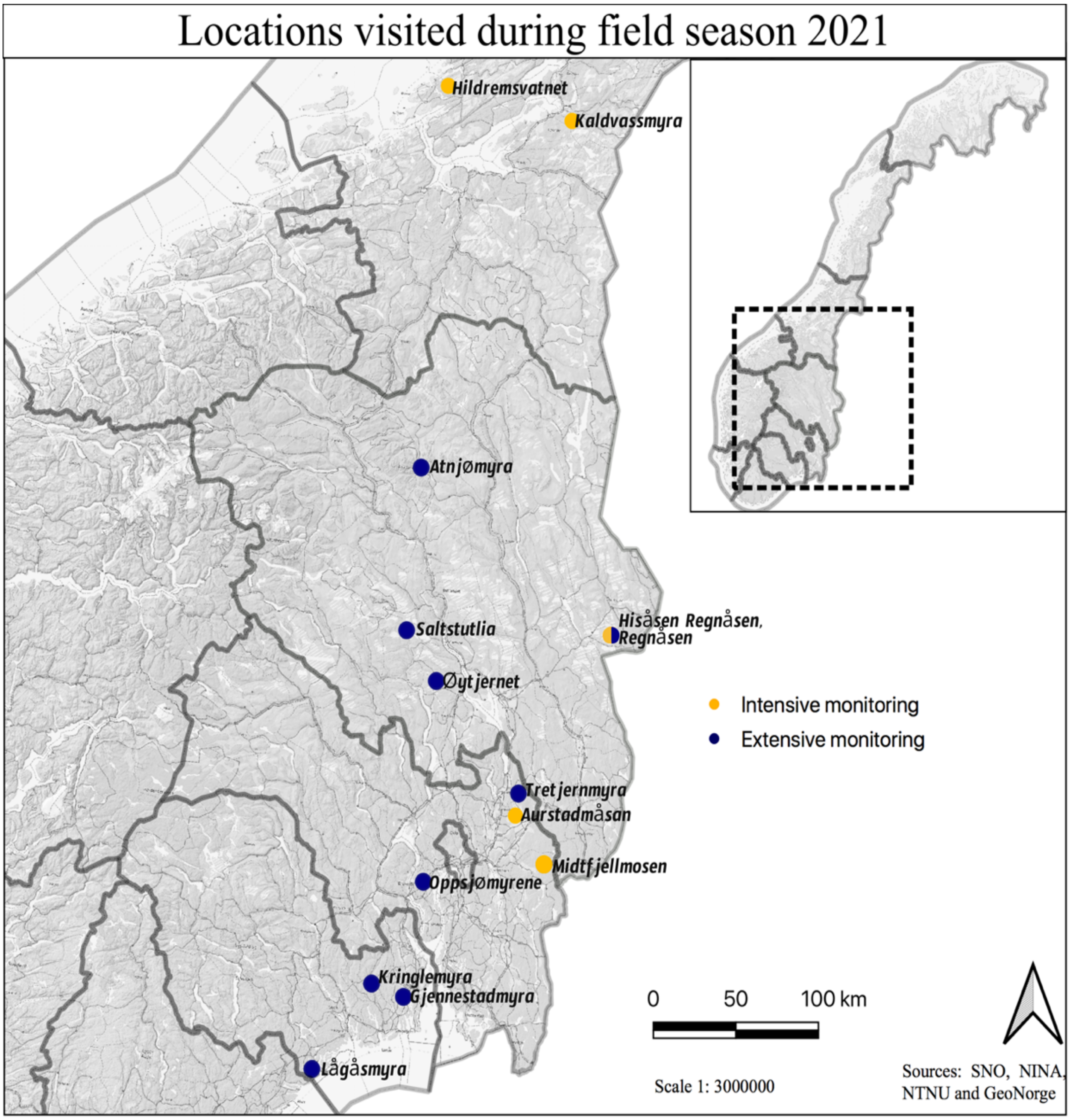

Figure 3 Map of study locations. This map includes all sites visited during field season in 2021 and corespond with table 1. Intensivly monitored sites are illustrated by yellow dots. Extensive sites are illustrated by blue dots. Hisåsen Regnåsen and Regnåsen are closly located and are thus visualized as half dots at the same location.

14 mires were visited in the summer of 2021, eight of which are restored mires that have extensive monitoring and four are restored mires that have intensive monitoring (table 1). These will be used to examine if the vegetation has changed over the study period. The remaining two mires are sites was not restored at the time or lack data from before restoration. These will still be included to compare the proportional cover for each site.

*Table 1. Overview of sites visited in field season 2021, year of first data collection, restoration year as well as year of first reanalysis after restoration (and for relevant sites: years of 2. reanalysis. *sites that are not used in data analysis of vegetation trends but will be used to compare plant group frequency pr transect.*

	Sites	Before restoration	Restoration	1st reanalysis	2nd reanalysis
Intensive monitoring	Aurstadmåsan	2015	2016	2018	2021
	Kaldvassmyra	2018	2017	2018	2021
	Hildremsvatnet	2018	2019	2021	
	Midtfjellmosen	2015	2018	2021	
	Hisåsen Regnåsen*	2021	2021	-	
Extensive monitoring	Atnesjømyra	2017	2017	2021	
	Oppsjømyrene	2017	2017	2021	
	Tretjernmyra	2017	2017	2021	
	Gjennestadmyra	2018	2018	2021	
	Kringlemyra	2018	2018	2021	
	Lågåsmyra	2018	2021	2021	
	Saltstutlia	2018	2018	2021	
	Øytjernet	2018	2018	2021	
	Regnåsen*	-	-	2021	

2.4 Data Analysis

Data were sorted in Excel (version 16.43) into three separate datasets: data from the extensive monitoring, as well as transect data and species data from the intensive monitoring. R Studio (Version 1.3.1093) were used in the statistical analysis. Model diagnostics for all models was executed using the package DHARMa (Hartig, 2022). Plots were created using the package ggplot2 (Wickham, 2016).

2.4.1 Generalized mixed models of plant groups for all sampling methods

Generalized mixed models were created for plant groups *Sphagnum, Eriophorum*(/graminoid) and Ericaceous plants across the three sampling methods.

2.4.1.1 Generalized mixed models for the intensive monitoring method: transects analysis

For the four restored locations monitored by the intensive method, the proportion of dominance by *Sphagnum* ssp*.*, *Eriophorum*, and Ericaceous plants was modelled with generalized linear mixed models (GLMM) (for simplicity, the two Ericaceous plants categories, deciduous and evergreen, were combined). Note that as the data was collected for several layers, the proportion of dominance by bottom species will not affect the proportion of dominance by field species. The aim of this analysis was to look at the change in the vegetation of the transects after vegetations. Therefore, reference transects A5, M4 and K5 was removed from the dataset as to only look at the effect of restoration. Transects were added as a random intercept to account for variation among transects.

The models were created using the package and function glmmTMB (Brooks et al., 2017) with beta distribution. I chose beta distribution because it can be used on data that is U-shaped or skewed, which is often the case of the distribution of plant species as they are spatially aggregated (Damgaard & Irvine, 2019), and also true for my data of *Sphagnum* ssp*.,* *Eriophorum*, and Ericaceous plants. In addition, the beta distribution works with continuous proportions, however it cannot handle proportions that are 0 or 1, so these numbers were transformed to 0.01 and 0.99.

For the three plant categories, five different models were created for each. I used the variable "time" that I created by transforming the years into numbers relative to restoration year. For example, as restoration measures was performed in Aurstadmåsan in 2016, this would be transformed to 0, while the year of pre-analysis, 2015, would become -1. The "site" variable was simply the mires the samples were collected from. "Time" and "site" was modelled with or without interaction, with only one of the variables or none of them, as shown in table 2. Model 5 does not include the variables "site" or "time, but simply includes the random intercepts.

Table 2. Overview of model variations used in model selection with different combinations of variables "Site" and "Time"

Model		**Variable**	
1	Site	Time	Interaction (*)
2	Site	Time	No interaction (+)
3	Site		
4		Time	
5			+1

A model selection was preformed using the Akaike information criterion (AIC) (Akaike, 1998), a method of evaluating a set of models to get the simplest model that best fit the data while avoiding overparameterization (Bozdogan, 1987). My terms for choosing a model was to choose the model with the lowest AIC score unless a model with the fewer variables were within a ΔAIC threshold of 2. However, for all three plant groups in the transect analysis, the models with the lowest AIC were chosen, as none had similar AIC levels with simpler model structure. Still, for *Sphagnum,* model 4 was picked as this was the simplest model in addition to having the lowest AIC score, but model 2 was within the Δ2 threshold with a difference of 1.47. The models of *Eriophorum* and Ericaceous plants had no AIC scores at similar levels, so the models with the lowest AIC values, respectively model 1 and model 2, were chosen. All AIC values are presented in table A2.1 in the appendix and a full list of chosen models will be presented in table 3.

2.4.1.2 Generalized mixed models for the intensive monitoring method: species lines

For the models which use data from the species lines, all *Sphagnum* species as well as all Ericaceous plants species were sorted into a group each. *Eriophorum vaginatum* was kept as one entity. I removed all species lines from reference transects A5, M4 and K5 for the same reason as in the transect analysis. The number of hits that the species had per species-line were counted. When categorized unto a larger plant group (*Sphagnum* and Ericaceous plants), several species can end up on the same group at the same point. It is worth noting that since only the presence of each species, and not the number of individuals, the count will only be an indicator of the abundance of the group and not a true measure.

A negative binomial distribution was best fit for this count data. The package MASS with the function glmer.nb was used for this purpose (Venables & Ripley, 2002). A nested random effect structure was used to account for dependence between species-lines and their respective transects. Like the models for the transect analysis, 5 models were created for each of the three plant groups, using combinations of the variables "Site" and "Time" shown in table 2. The same ΔAIC threshold was used in this model selection. However, none of the models had similar level of support (table A2.1). Hence, the models with the lowest AIC values were chosen for all *Sphagnum* ssp., *Eriophorum vaginatum*, and Ericaceous plants, respectively model 1, model 1 and model 3 (table 3).

2.4.1.3 Generalized mixed models for the extensive monitoring method

Similar to GLMMs for the transect analysis, the proportions of relevant plant groups (*Sphagnum*, graminoid and Ericaceous plants) from 8 extensively monitored sites were modelled using the package and function glmmTMB with beta distribution (Brooks et al., 2017), with proportions squeezed between 0.01 and 0.99. Transects were added as random intercepts.

Also for this sampling method, five models were created for each of the three plant groups with variations of the variables from table 2 and selected based on their AIC values with a ΔAIC threshold of 2. While *Sphagnum* model 1 had similar levels of support, model 4 was chosen as this was the simplest model and ultimately had a ΔAIC of 1.2 that was lower than model 1 (table A2.1). For graminoids, the model with lowest AIC was chosen, which was model 2. Model 3 was the model for Ericaceous plants with the lowest AIC levels, but model 1 (Δ1.0) and model 5 (Δ0.94) had similar levels of support. Hence, model 5 was chosen as the best and simplest model for the data (table 3).

Table 3. Overview of explanatory variables included in the generalized mixed models for each plant group for the three different types of data collection and whether or not there is an interaction between these variables. "Transect" is models that use data from the transect analysis, "species-line" is models based on data from the species line, while "extensive" is models that use the extensive dataset.

Method	Species group	Variables		Interaction
Transect	*Sphagnum*	Sites		-
Transect	*Eriophorum*	Sites	Time	yes
Transect	Ericaceous plants	Sites	Time	no
Species line	*Sphagnum*	Sites	Time	yes
Species line	*Eriophorum*	Sites	Time	yes
Species line	Ericaceous plants	Sites		-
Extensive	*Sphagnum*	Sites		-
Extensive	Graminoid	Sites	Time	no
Extensive	Ericaceous plants			-

2.4.2 Species composition

For all analyses of the species composition, data from the species lines of the intensive method was used as this contains detailed registers of species.

2.4.2.1 Species composition along mire margin- mire expanse gradient

Each species was given a group according to their placement within the mire margin-mire expanse gradient by Fremstad (1997). The species that were not already categorized by Fremstad (1997) were given equivalent groups using their placement in the EcoSyst Framework

(NiN) [Natur I Norge] (Halvorsen et al., 2020), which is a system that categorizes nature in Norway based on different gradients, like mire expanse characteristics. Fremstad (1997) have 5 species groups that explains how common the species are along a gradient from mire margin to mire expanse (table 4). The NiN-system have a similar gradient to this (mire expanse character), where each species is given a value 0-6 of how common they are along in the mire expanse or the mire margin. I used these values to categorize the species missing in the Fremstad et al. system. These categories were visualized as boxplots per site and were examined visually.

Table 4. Gradient groups based on the common occurrence of mire species in the mire expanse or mire margin, based in illustration by Fremstad (1997)*. Some species are common in both groups and are put in gradient group 3. Some species does not occur in more than one of the locations and are put in group 1 or 5.*

Gradient group	**Mire expanse**	**Mire margin**
1	common	absent
2	common	less common
3	common	common
4	less common	common
5	absent	common

2.4.2.2 NMDS ordination plot

Non-metric multidimensional scaling (NMDS) was used to visualize the change of the species composition within the transects during the study period. The data was sorted to show the number of each species per transect for each year. NMDS was performed with the metaNMDS function with the package vegan (Oksanen et al., 2020), using the default of 20 iterations and 2 dimensions as well as Bray-Curtis distances between the species composition of each transect. This gave NMDS coordinates for 44 transects.

2.4.3 Comparing frequency of plant groups at same transects across sampling methods

For study sites visited during field season 2021, the frequency of relevant plant groups was calculated using data from the extensive dataset and intensive´s transect analysis. For the intensive's transect analysis, *Eriophorum,* sedges and grasses were combined into one category, graminoid, to make it more comparable to the extensive method. Frequencies was calculated by dividing the number of hits per point for each transect. For transects that had been monitored with the intensive method this was 100 points, and for extensive transects this was 60 points.

3. RESULTS

3.1 Restoration status and monitoring overview

60% of peatland restoration projects completed by 2020 in Norway were monitored by either the extensive or the intensive method (table 5). The number of projects varied greatly in each county (0-23), and there was an unequal ratio of monitored restoration projects per county, ranging from 0% to 100% of projects being monitored, as illustrated in figure 4. Counties with fewer restoration projects (≤4) generally had a lower rate of monitoring (≤33%) than counties with more restoration projects. The locations of the intensive method were distributed between Trøndelag and Viken. The county with the most restoration projects was Viken with 23 locations, 52% of these being monitored. Innlandet with its 21 locations was one of the counties with the highest rate of monitored projects (87%). Vestfold and Telemark was the county with the highest rate of monitoring of restoration projects, as all its 7 locations is monitored.

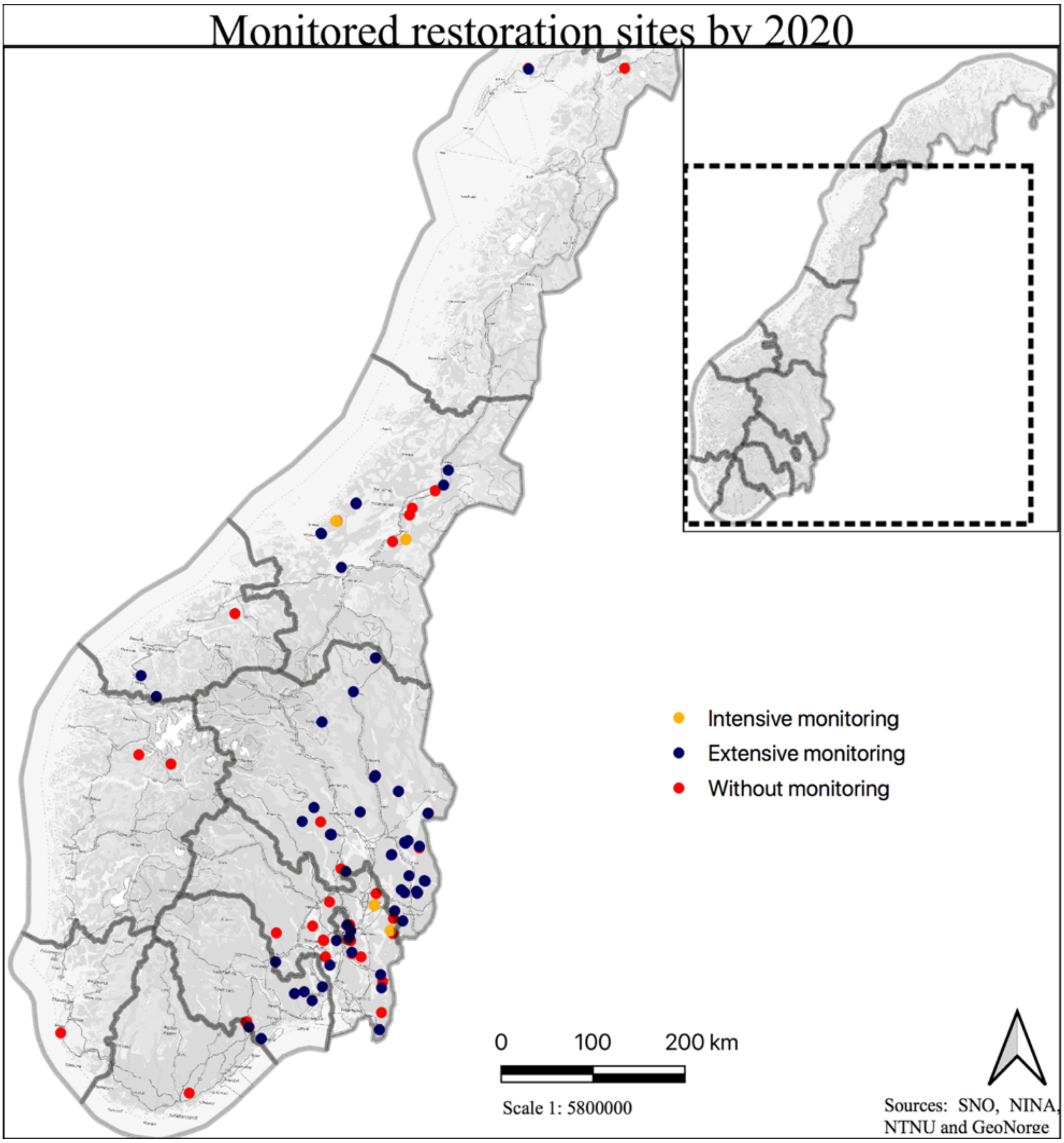

Figure 4. Overview of all restored sites restored by 2020 and their distribution in Norway's counties at that time. Some of the sites are monitored by either the intensive monitoring method (yellow) or the extensive monitoring method (blue). No projects were executed in Finnmark and is therefore excluded from the map.

The total area of restored mires in Norway is $0.23 km^2$, which is a proportion of 0.05 of the total areas of these mires. When multiplied with emission factors by Joosten *et al.* (2015), the restored mire area amounts to a reduction in CO_2 emissions between 43.5 to 292.5 tonne per year. Innlandet had most area affected by restoration ($0.13 km^2$), which is presented in table 5. Agder was the county with least restored area ($0.0012 km^2$) and no monitoring of its one restoration site. Rogaland had also only one restoration project, with no monitoring. Finnmark had no projects. All nature types which overlapped with the peatland restoration sites had representation by the monitoring programme. Detailed description of the restored mire, like what type of mire it is, for example if it is ombrotrophic and/or a raised bog, can be found for approximately half of the monitored mires, which is presented in appendix 4 table A4.1. This is mainly the same mires that have been protected by the protection plan for mires, but also some that belong to protection plan for forest. However, most of the mires that are protected through a protection plan for forest generally does not have this description of the mires within the protected area.

Table 5. Overview of counties with restoration projects, the mire area of the mires which are restored, area affected by restoration (derived by adding a 10 m buffer around the area of blocked ditches and the proportion total mire area which is restored). Also, the table includes number of restoration projects in each county, the number of extensively and intensively monitored sites and the proportion of projects which have monitoring (extensive + intensive) in each county. Counties with no projects are excluded.

County	**Mire area(km^2)**	**Restored (km^2)**	**Proportion area**	**Restoration projects**	**Extensive**	**Intensive**	**Monitored projects**
Innlandet	26.093	0.129	0.05	21	18	0	86 %
Rogaland	0.116	0.004	0.03	1	0	0	0 %
Vestland	0.536	0.024	0.04	3	1	0	33 %
Nordland	3.541	0.172	0.05	4	3	0	75 %
Møre og Romsdal	3.341	0.181	0.05	4	1	0	25 %
Oslo	0.388	0.199	0.51	5	3	0	60 %
Trøndelag	2.897	0.621	0.21	9	3	2	56 %
Viken	8.654	0.930	0.11	23	10	2	52 %
Vestfold og Telemark	0.818	0.191	0.23	7	7	0	100 %
Agder	0.022	0.001	0.06	1	0	0	0 %
Total	49.406	0.242	0.05	78	46	4	59%

3.2 Data Analysis

3.2.1 Change of Sphagnum, Eriophorum(/graminoid) and Ericaceous plants in restored sites for all sampling methods

The following segments includes results from generalized mixed models for the transect analysis and the species lines from the intensive method as well as for the extensive method. The models selected for each method and plant group has been presented in table 3, and a table with all model outputs with standard errors and confidence intervals are presented in the appendix 3 (table A3.1). I will present the estimates from my models with standard error, and in some cases means which I have transformed from the estimate's logit scale (beta models) or log scale (negative binomial models). These will not be presented with standard errors.

3.2.1.1 Transect analysis

The transect analysis shows a significant increase in frequency of Eriophorum dominance in Aurstadmåsan (0.12±0.04) and Kaldvassmyra (0.08±0.03) after restoration, as well as an overall decrease in frequency of dominance by Ericaceous plants across all study sites which are monitored by this method. No clear trend in *Sphagnum* after restoration was detected by this method and there is great variation between transects within certain sites, such as in Aurstadmåsan and Midtfjellmosen (figure 5). However, the analysis summarizes that *Sphagnum* dominance varied greatly between the sites in the first place, with Hildremsvatnet (-2.58±0.54) having the lowest mean frequency of *S.* dominance of 0.07 per transect at the site to Kaldvassmyra (-0.08±0.50), Midtfjellmosen (0.65 ±0.59) and ultimately Aurstadmåsan (2.14± 0.53) with the mean frequency of *S.* dominance of respectively 0.48, 0.66 and 0.89 in each transect. The frequency of *E.* dominance per transect also varies greatly, with Kaldvassmyra (0.08±0.2) and Hildremsvatnet (-0.26±0.20) having similar frequencies, respectively 0.48 and 0.43, but differing from Aurstadmåsan (-1.06±0.21) and Midtfjellmosen (-1.39± 0.25) with its frequency of *E.* dominance per transect of 0.26 and 0.20. While the Ericaceous plants have an overall significant decrease in frequency of dominance per transect, there is a large variation within certain sites, especially Kaldvassmyra and Midtfjellmosen, evident from figure 5.

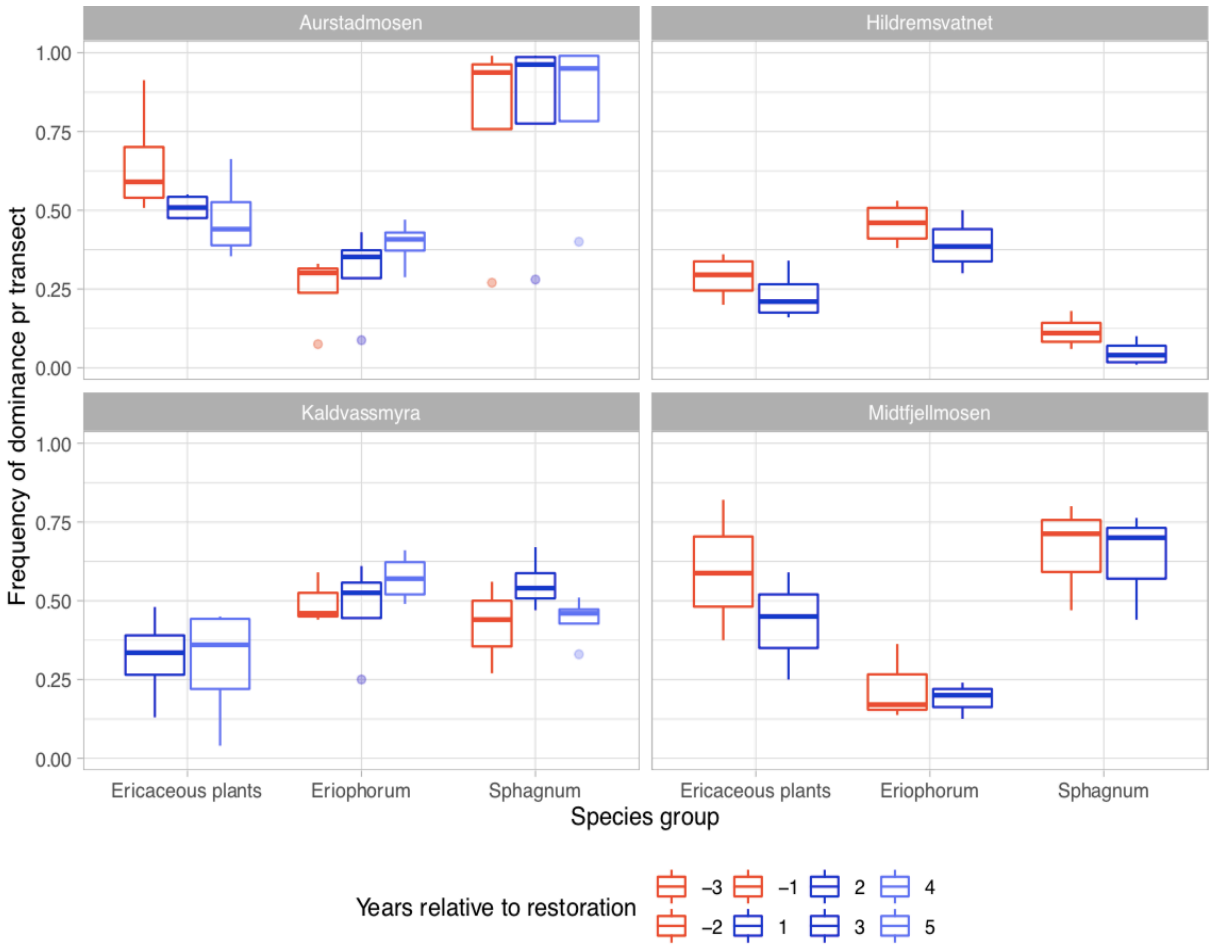

Figure 5. Change in dominance per transect in plant groups Eriophorum*, Ericaceous plants and* Sphagnum *before restoration and 1st (and 2nd) reanalysis for Aurstadmåsan, Hildremsvatnet, Kaldvassmyra and Midtfjellmosen. Time is measured in years relative to restoration; illustrated in red for years before restoration) and shades of blue after restoration). The band is the mean for the location and the whiskers show the variance between the transects.*

3.2.1.2 Species lines

The species lines imply an increase in hits of *Sphagnum* after restoration in Kaldvassmyra (0.14±0.09), Aurstadmåsan (0.06±0.01) and Midtfjellmosen (0.04±0.02). In addition, this sampling method detected an increase in *Eriophorum vaginatum* in one location, Kaldvassmyra (0.08±0.02) While there seem to be an increase in hits after restoration of *E. vaginatum* in Aurstadmåsan, there is much variation between transects to say for certain that this is an effect of time after restoration, as evident from figure 6. The same goes for Ericaceous plants in all locations; while there might be some decrease in number of hits after restoration in Hildremsvatnet and Kaldvassmyra, there is too much variation to tell. Also, the number of hits by Ericaceous plants varied significantly between all sites with a mean number of hits of Ericaceous plants of 8.29, 13.72, 16.76 and 22.26 in Hildremsvatet, Midtfjellmosen, Kaldvassmyra and Aurstadmåsan respectively. As illustrated by figure 6, there is little or no change after restoration for this plant group.

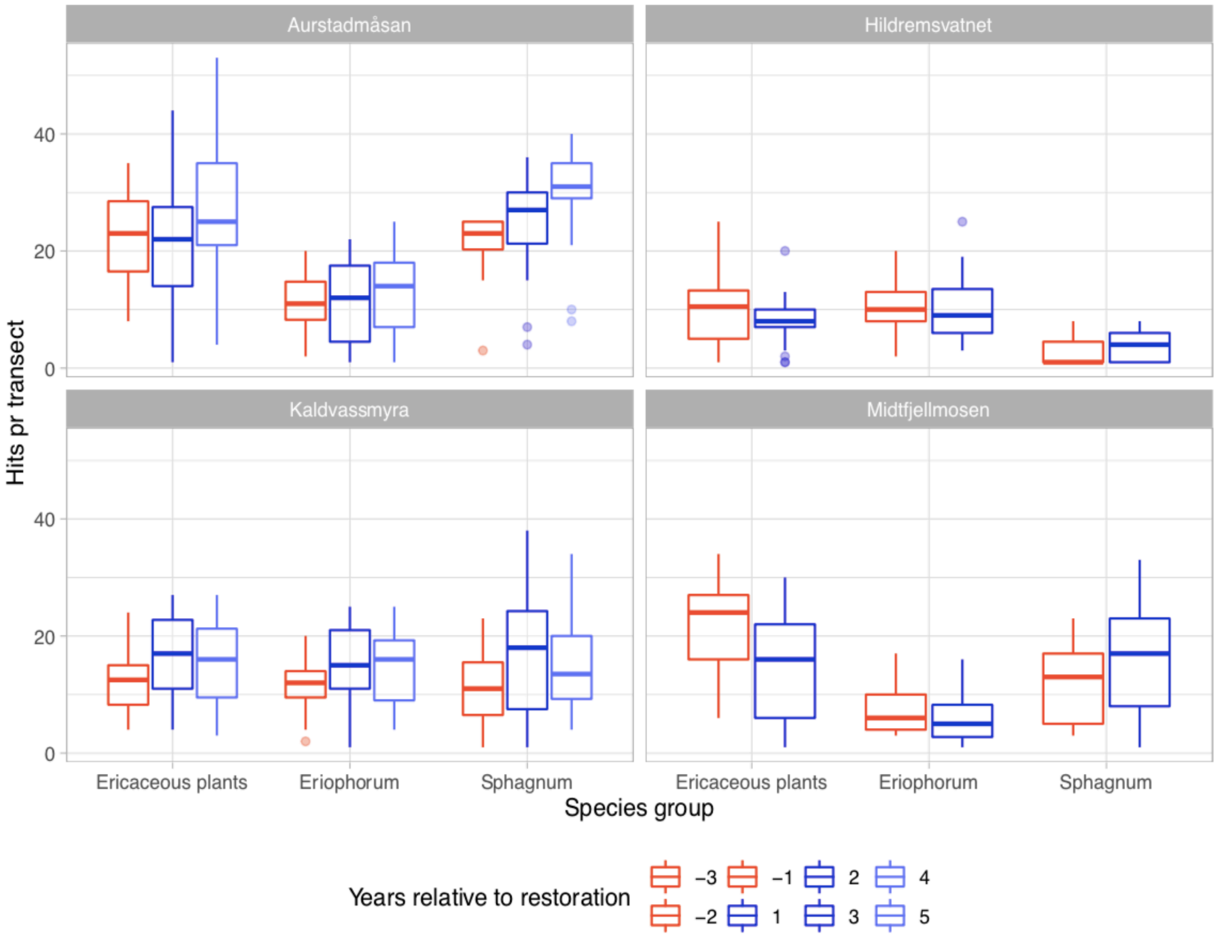

Figure 6. Number of hits by Eriophorum vaginatum*, Ericaceous plants and* Sphagnum *before restoration and 1st (and 2nd) reanalysis for Aurstadmåsan, Hildremsvatnet, Kaldvassmyra and Midtfjellmosen collected in the species lines. Time is measured in years relative to restoration, red for before restoration and shades of blue for after restoration. The band is the mean for the location and the whiskers show the variance between the transects.*

3.2.1.2 Extensive monitoring method

The sampling by the extensive monitoring method is able to reveal a significant increase (0.29±0.08) in the frequency of graminoid hits per transect across sites. However, no change in *Sphagnum* or Ericaceous plants was found. Still, the frequency of *Sphagnum* hits per transect varied greatly between sites, ranging from 0.10 hits of *Sphagnum* per transect in Kringlemyra (-2.18±0.60) to 0.62 hits per transect in Øytjernet (0.47±0.22). For Ericaceous plants, the effect of the different transects was greater than any independent variable, as evident in figure 7; Øytjernet, which is one of the few extensive sites with more than one transects, have as much variation between its transect than the other locations have between themselves.

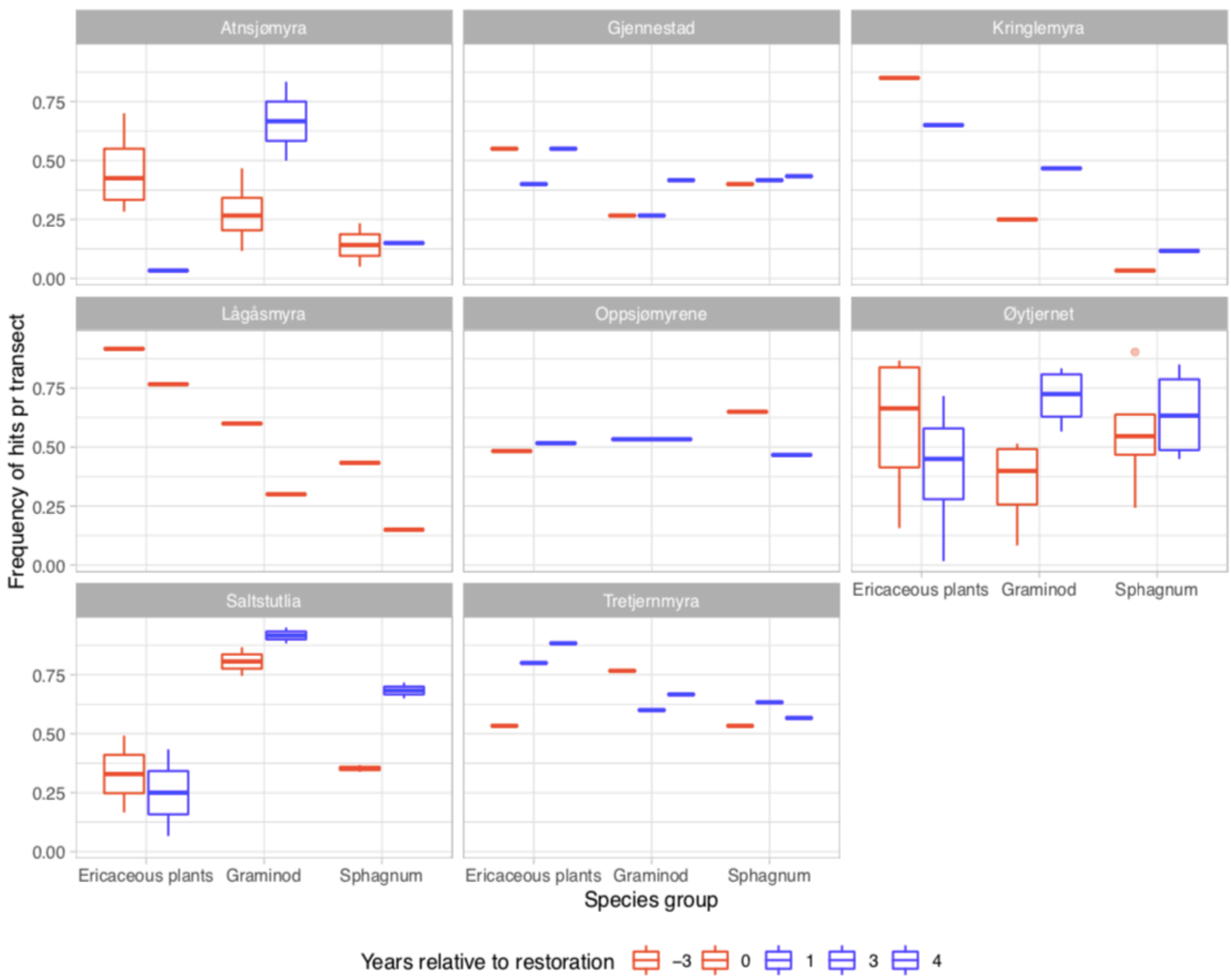

Figure 7. Presence of plant groups Graminoid, Ericaceous plants and Sphagnum before restoration and 1st (and 2nd) reanalysis for extensive sites Atnsjømyra, Gjennestad, Kringlemyra, Lågåsmyra, Oppsjømyrene, Øytjernet, Saltstutlia and Tretjernmyra. Red represents years before restoration and shades of blue years after*. Time is measured in years relative to restoration; negative values are years before restoration, positive is after restoration. The band is the mean for the location and for the locations with more than one transects whiskers show the variance between the transects. *Lågasmyra was restored the same year as its first reanalysis, so year 0 (red) represents the site after restoration.*

3.2.2 Change in species composition

The two methods used to investigate change in species composition, NMDS ordination and change along the mire margin-mire expanse gradient, both showed that there was a change towards wetter mires. Both methods use species data sampled through the species lines.

3.2.2.1 Species composition along mire margin-expanse gradient

The gradient group with the biggest occurrence in all sites was group 3, as illustrated in figure 8. This is the species which can be common both in the mire expanse and the mire margin. For Aurstadmåsan and Kaldvassmyra, there is an increase in this group after restoration, although there is great variation in this group, particularly for Kaldvassmyra. In contrast, the opposite development is true for group 3 in Hildremsvatnet and Midtfjellmosen. In addition, there is a slight increase of group 2 species which is valid for all sites but Hildremsvatnet. These are species that are most common in the mire expanse. Uniquely for Aurstadmåsan, there is a decrease in gradient group 4 in the 2nd reanalysis, which is a group with more typical mire margin plants, as well as an apparent increase in the wettest gradient group, group 1.

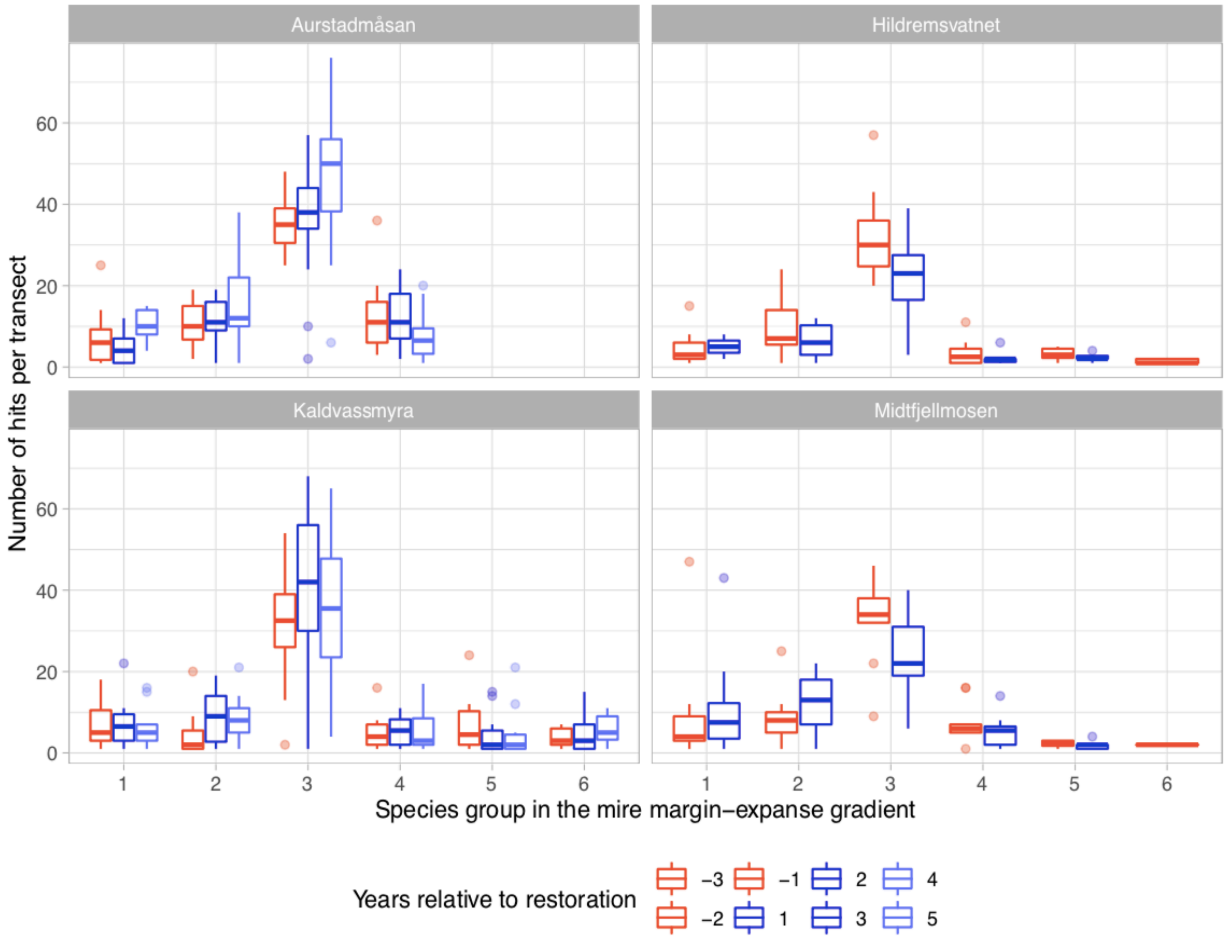

Figure 8. Number of hits by each gradient group (mire margin- mire expanse, Fremstad et al. (1997)) before (red) and after (shades of blue) restoration for Aurstadmåsan, Hilremsvatnet, Kaldvassmyra and Midtfjellmosen based on data from species line.

3.2.2.2 NMDS ordination plot

The NMDS ordination plot, figure 9, show that transects from the same area are similar in composition. Transects in Aurstadmåsan are closely associated with several *Sphagnum* species like the hollow species *S. cuspidatum*, indicating a wet mire (Fremstad, 1997). All transects in this location develop towards the reference transect after restoration, however this trend is not linear. For example, A1, which is the transect in Aurstadmåsan that deviate the most from the reference transect, is closer to the reference in the 1st reanalysis than the 2nd reanalysis. Like the other transects in Aurstadmåsan, the reference transects move downward on the NMDS2 axis. However, the change in this transect is smaller and more linear than the others.

Kaldvassmyra is the site which is most associated with forest species *Vaccinium myrtillis* and *V. vitis-idea*, but this site is also the one with the most spread along the NMDS2 axis. All transect at this site move away from the typical forest plants and towards the reference transect. Some transect at this site are closely associated with *E. vaginatum* after restoration, which is a plant that does well with disturbance and readily establish after restoration (Yan et al., 2008).

In Midtfjellmosen there is a visual change in the transects before and after restoration. There is more change in transects that have been restored, than the reference transects, but in contrast to the other sites with reference transects (Aurstandmåsan and Kaldvassmyra) some restored transects (M2 and M1) are further away from reference transect after restoration. However, M3 move toward the reference transect and is associated with *S. tenellum,* which thrives in relatively wet and hollow like conditions (Fremstad, 1997).

Hildremsvatnet is the site with the biggest change between restored and unrestored transects and move from an *Erica tetralix* associated community to *E. angustifolium* association. The within-year spread between transects increase after restoration. There is no reference transect at this location.

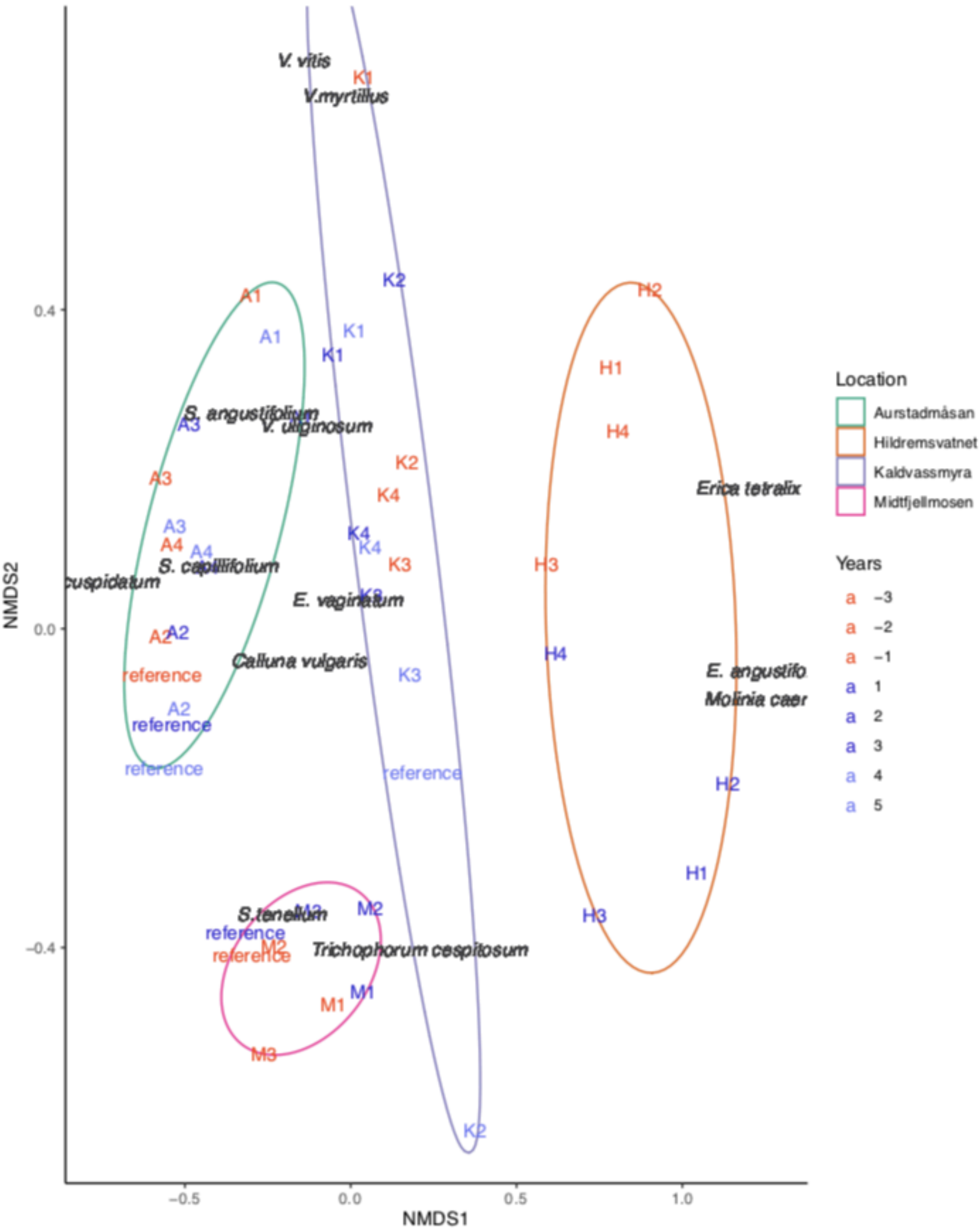

Figure 9. NMDS ordination plot where all transects are given NMDS coordinates based on the species community using Bray-Curtis distances with two dimensions. Same transect from different years are marked with same name coloured in terms of the years relative to restoration (red before restoration, and blue after restoration, with light blue indicating 2nd reanalysis. The transect from same sites are clustered together as their species communities are similar. Hildremsvatnet has no reference site and the reference in Kaldvassmyra was established in 2021. Hence, Midtfjellmosen and Aurstadmåsan is the only sites with reference sites for all years.

3.3 Frequency of plant groups at same transects across sampling methods

The frequency of hits was generally similar based on the two methods which are used to determine frequency, namely the transect analysis for the intensive monitoring method and the extensive method. The group of which there was the greatest deviation was cover of graminoids with Δ0.49 for T1 Δ0.43 for A3 (see appendix 5 table A5.1). However, most deviation was less than Δ0.1 for this group. For *Sphagnum* cover, there was no difference between the methods that exceeded 0.12 (K3), while most had $<\Delta 0.05$. For Ericaceous plants, H4 had the largest difference between methods (0.19).

3. DISCUSSION

4.1 Implication of restoration and monitoring status

The restoration projects were unevenly distributed across the counties, which is both expected and desired, as the distribution of prioritized mires like raised bogs also is uneven. This is in toe with the objectives and plan of The Norwegian Environmental Agency, who specifies that raised bogs are good candidates for restoration (Miljødirektoratet, 2016). This nature type is categorized as threatened (Lyngstad et al., 2018), which makes it especially important for reducing biodiversity loss. In addition, raised bogs typically have deep carbon layers and are considered especially important for greenhouse gas mitigation (Joosten et al., 2015). The overrepresentation of restoration projects in counties that have the most of this mire types, answer to goals set by the Norwegian Environmental Agency to reduce gas emissions. While the restored areas are only 5% of total mire area of the projects, this amounts to a reduction in CO_2 emission by 43.5 to 292.5 tonne per year. Still, the restored area is calculated using only a 10m buffer around the filled mires, which is the strictest of distances used for this as others use up to 30m (IUCN, 2018). The emission factor used for these calculations were chosen as a standard by the Norwegian Environmental Agency, but the reduction in gas emission will vary depending on mire type and degradation level (Joosten et al., 2015).

It is evident from table A4.1 in appendix 4 that the mires which have been restored varies greatly in type, and that there is an information gap in mire description of mires that are not protected by Protection Plan for mires, as approximately half lacked detailed description. Due to the fact that different types of mires react differently to drainage and restoration (Wüst-Galley et al., 2016), every mire restored and monitored should also have detailed records of what type of mire it is. The mire type will affect what the desired outcome of the indicators that are being measured by the sampling methods is. For example, the bottom field of rich fens are dominated by brown mosses (Øien, Moen, et al., 2015) in contrast to raised bogs which are dominated by *Sphagnum* (Moen et al., 2011), and therefore different levels of *Sphagnum* is both expected and desired for these mire types. Hence, mire type should change the criteria for determining if restoration can be deemed successful.

In addition to the detailed description of mires which I found in my GIS-analysis, the intensively monitored sites have reports with detailed description of the sites, as reported in Hagen *et al.* (2015) and Kyrkjeeide *et al.* (2018). The extensive sites lack such a report.

4.2 Impacts of restoration on *Sphagnum*, *Eriophorum* (or graminoid) and Ericaceous plants

The expectation of an increase in *Sphagnum* was not met when using data from the transect analysis and the extensive method as no increase in *Sphagnum* was reported by these sampling methods. However, the models which used data from the species line reports a slight increase in hits of *Sphagnum* per transect in all site but Hildremsvatnet after restoration. While this increase was significant, it is only a few hits of *Sphagnum* per transect. The lack of significant increase in Hildremsvatnet could be explained by the elaborate restoration measures taken at this site due to comprehensive ditching (Kyrkjeeide et al., 2018), and therefore also thorough restoration, resulting in mostly bare peat at the site (Kyrkjeeide et al., 2021). Midtfjellmosen was also considerably affected by ditches before restoration (Hagen et al., 2015). The degradation of Kaldvassmyra and Aurstadmåsan, as well as the restoration measures taken are quite simple in comparison, with only single ditches per site (Kyrkjeeide et al. 2018). In Kaldvassmyra, it is already observed *Sphagnum* establishment in the edges of the restored ditches which was filled with water, indicating rehabilitated hydrology. Nevertheless, increase was found in Midtfjellmosen and not in Hildremsvatnet, but this could be due to the fact that there has been longer time since restoration at Midtfjellmosen.

It is difficult to determine what would be a reasonable time for *Sphagnum* spread and growth after rewetting. One study reports a significant increase in *S.* after just a four-year period (Haapalehto et al., 2011), albeit not to the extent that is equal to a pristine site. Several studies with similar time scales as my study (0-5 years) did not find a significant increase in *S.* after restoration (Howie et al., 2009; Punttila et al., 2016). Still, when reanalysing after a longer period *Sphagnum* increase may yet occur at these sites (Howie et al., 2009). It is more likely to find an increase after 10 years (McCarter & Price, 2013). Therefore, the lack of significant increase detected by the transect sampling and extensive method does not necessarily indicate restoration failure; it may simply be too short time since restoration. Rochefort (2000) found three factors to be paramount for the establishment of *Sphagnum* in their bare study sites in Canada after restoration: reintroduction of moss diaspores, shelter for these (in this study mulch cover was used), as well as rewetting. Hence, simply rewetting the site may not be enough unless there are also existing moss diaspores at the site. Supposedly, more comprehensively restored sites have more bare peat than those with less extensive restoration measures, and time of *Sphagnum* recovery will vary greatly between sites depending on this. However, the extent of the restoration measures is not included as a variable in the models in this study nor is it included in the sampling design, and data of what restoration measures are taken at each site is difficult to acquire as decisions are made in the field. No data of precipitation or temperature was included in the analysis, so all change in vegetation is assumed to be caused by the restoration measures. However, others suggest these factors to have a significant effect on at least some *Sphagnum* species (Rastogi et al., 2020)

While there was little detected change in *Sphagnum,* there was an increase in *Eriophorum vaginatum* in Aurstadmåsan and Kaldvassmyra which was detected by both the transect analysis as well as the species line. The plant group which covers *E. vaginatum* in the extensive dataset is "graminoid". This method reports an increase for all sites. Hence, while slight for the species line, the expectation of restoration having a positive effect on *E. vaginatum* was met and detected by all methods. *E.* is found to be a genus that can reestablish even a short time after restoration (Hancock et al., 2018; Haapalehto et al., 2011; Jauhiainen et al., 2002), which is to be expected as it generally responds well to disturbance (Yan et al., 2008). Jauhiainen et al. (2002) found small changes in *Sphagnum,* but increase in *E.* cover in only 3 years after restoration at its bog site in Finland. Hancock et al. (2018) found a markedly increase in both *E. vaginatum* and *E. angustifolium* during his 10-year study. *E.* is a well-functioning pioneer plant in restored mires, as it tolerates waterlogging and drought and does well under low nutrient conditions (Gore & Urquhart, 1966). As the plant can withstand both a high and low water table (Bragazza & Gerdol, 1996), it should not be an indicator of a wetter mire by itself. Still, *E.* is shown to be important for peat formation (Minayeva et al., 2008), as it reduces nitrogen and phosphorous cycling (Silvan et al., 2004), making a hospitable environment for *Sphagnum* growth and domination. Tuittila et al., (2000) followed several plant species responses to varying *E. vaginatum* levels for 20 years and found that the microclimate of a *E. vaginatum* creates a more humid climate as well as shelter, which promotes other plant species in general. These reports, along with my results of significant *E.* increase and little increase in *Sphagnum*, makes it evident that *E.* is a better indicator of restoration success in such short time intervals after restoration. Even though *E.* does not necessarily indicate a wetter mire by itself, it is likely that short term increase in *E.* will promote *Sphagnum* growth, resulting in an accelerating mire recovery. Note that *E.* is simplified to correspond to graminoid for the extensive method, but this category could potentially contain graminoid species with different implications.

Ericaceous plants were found to decrease through the transect models, but not for the species line or the extensive method. Ericaceous plant species such as *Calluna vulgaris, Vaccinium uligiosum, V. myrtillus* and *V. vitis-idea* is found to thrive in less waterlogged conditions than *Sphagnum* species, *Eriophorum* species as well as other graminoids like *Carex pauciflora* and *C. limosa* (Bragazza & Gerdol, 1996). Hence, a decrease in Ericaceous plants can indicate a higher water level in the restored mires. Along with my results for *Eriophorum* increase, I argue that the samplings methods from the intensive monitoring method were able to indicate that restoration measures possibly have the desired effects on the mires.

4.3 Impacts of restoration on species composition

The data sampled in the species lines from the intensive monitoring show that the species communities differ more between each site than between transects from same site, as evident from the NMDS plot. This is not surprising as the mires differ in degradation level, mire type and geographical region (Hagen et al., 2015; Kyrkjeeide et al., 2018).

For Midtfjellmosen and Aurstadmåsan, the transects crossing restored ditches have a bigger change in species community than reference transects. This is expected as these are the transects that have had the most interference and disturbance during the study period (Grime, 1973; Horn, 1975). Hildremsvatnet stands out as the site with the biggest change in species community after restoration. Yet again, this can be attributed to the extensive restoration at this site which have caused a massive disturbance to the plant community. Most transects move towards the reference transects after restoration, which is the desired state. However, it is evident from the sites that have two data collections after restoration that this trend is not linear nor is it the direction of all transects. These irregularities can be due to variables not measured in this study, such as global warming, precipitation and/or drought. For example, 2018 was a year with little precipitation resulting in drought across the country (Skaland et al., 2019) which likely have influenced the vegetation (Koebsch et al., 2020) in Aurstadmåsan that year, which was the year of the first data collection after restoration.

The species community in the reference transect in Aurstadmåsan change in the same direction as the other transects at that site, albeit less. This impose the question of whether the change is due to the restoration, or other factors not measured here. Alternatively, this change in species composition in the reference transect indicate that the reference transect was impacted by the ditch, causing the restoration measures to have an effect on the reference transect as well as the impacted transects. If that is the case, the area impacted by restoration is greater than first presumed, which were 10 m around the ditches (Miljødirektoratet, 2016). This appears to be the most likely reason, as results from the analysis of *Sphagnum, E. vaginatum* and Ericaceous plants in this site to indicate an overall wetter mire.

The two sites with the longest time since restoration, has had a change in species composition towards species that thrive in wetter conditions. The water level in the mire expanse is generally higher than in the mire margin, and a change towards mire expanse- species indicates improved hydrology. Still, it is important to note that there are other factors than just water levels that decides whether a species thrive in the mire expanse or the mire margin. For example, Bragazza and Gerdol (1996) hypothesizes that even though they occur in both parts of the gradient if conditions are dry enough, *Vaccinium myrtillus* and *V. uligiosum* are much more common in the marginal strip due to its shaded properties. Some of the loss of mire margin species may be due to the removal of trees and general disturbance which occurred at some sites during restoration that would result in less shade for such species. Nevertheless, the combination of these analyses suggests a shift in the species composition towards the wetter references.

4.4 Comparison of the survey methods: similarities, strengths and weaknesses

The extensive method functions as a simplified mix of the transect and species line, as it collects information of what plant groups exist along the transect and in each point. Therefore, it shares similarities with both analyses in the intensive method: Like the species line, it registers all plant groups that hits a stick with an even sampling distance between points (Hagen et al., 2015; Miljødirektoratet, 2016). In contrast, the species lines in the intensive monitoring collects data at the species level for all plant groups except for liverworts. Also, there are four species lines per transect, which enable each species line to function as replicas. As the intensive sites have four transects, this would give 16 replicas for each site, which will have much higher statistical power than the extensive method's one transect (Kraemer & Blasey, 2017). It is evident from the variation between transects at Øytjernet seen in figure 7, that different transects at same sites can have different implications. Hence, multiple transects are needed to be sure of a representative dataset of that site. Also, the extensive method lacks a reference site in contrast to the intensive method.

The level of detail that the species line has, offers opportunities of analysis that the extensive does not; in this study I was able to perform an NMDS ordination on this data as well as examining the species development along the mire margin-mire expanse gradient. The plant groups in the extensive method are too broad to be placed along this gradient. This makes it harder to evaluate restoration success as this would solely be based on the frequency of plant categories which could encompass species with conflicting indications of hydrology.

The species line has potential for other analyses that were not performed here. For example, one could look at the increase in individual species. Different *Sphagnum* species have different implications as they respond differently to changes in the hydrology and nutrient access (Bragazza & Gerdol, 1996). *S. balticum* (Haapalehto et al., 2011), *S. fallax* (Grosvernier et al., 1997), *S. rubellum* (Poulin et al., 2012) thrive in wetter conditions in contrast to species like *S. russowii* and *S. capillifolium* (Bragazza & Gerdol, 1996) and can indicate a bettered hydrology, but it could also warn a change in mineral influx. For example, *S. fallax* indicates a typical minerotrophic influence (Haapalehto et al., 2011), which would not be expected in a bog. There was observed *S. fallax* or *S. angustifolium* close to a ditch in Kaldvassmyra, indicating an influx of minerals from the ditch. This could be linked to the fact that the ditch was placed in what was likely a minerotroph soak separating two plateau raised massifs (Kyrkjeeide et al., 2018). Also, upheaval of soil and changes in drainage patterns due to restoration could lead to a change in nutrient availability, making way for some species within the *S.* genus to establish at a faster rate than others. For example, we observed that *S. angustifolium* had established in many edges of bare peat after restoration.

Still, there are some limitations to the species lines. It is worth noting that while this method gives an indication of the presence of species, there is no data on the cover of said species. Cover, either canopy cover or foliar cover (Godínez-Alvarez et al., 2009), is a more commonly used measure of plant abundance than frequency of hits which is measured here as it avoids the problem of distinguishing individuals, which can be difficult for plants due to differing biomass and ramets (Keddy, 2017). However, this problem is also avoided here, as the method does not count individuals of the same species. When the sampling stick is lowered into the vegetation, all unique species are registered, but if there are several individuals of the same species that hit the stick, this will not be reflected in the dataset. It is important to note that the way I have used the data in my GLMM models does not reflect the true abundance of that species along the species line due to the fact that it is only counted once per point. If true abundance was the desired outcome, cover could be used as an alternative in future monitoring. If the data is to be used to look at increase in specific species, and not just the presence/absence of said species, the number of hits of each species per stick should be counted, as suggested in Goodall (1952). This problem also applies to the extensive method, but these data can be transformed to frequency of plant group per transect. In this way, the extensive method is similar to the transect analysis.

I examined if the transect analysis and the extensive method detected similar frequencies of each plant group at the same transects, which they were. This is in spite of the fact that the methods actually collect different types of frequencies; the intensive transect analysis register the dominating plant group across every 0.5m while the extensive method collect presence/absence for plant groups in a point at every 0.5 m. The extensive method will register several plant groups at the same point while the transect analysis only will register the dominating plant group. It is therefore to some surprise that these methods get the same frequencies for the corresponding plant groups. However, a reason for this might simply be that if a plant group is dominating close to the point, this will increase the probability of registering this plant there, and that the plant groups that I have compared in this study coincidentally happened to dominate at these sites. If I had compared other plant groups, for example lichen or herbs, that did not dominate the vegetation level, the frequencies would probably not be this similar. The intention of this comparison was to find similarities between these methods, as the extensive method is based on the intensive method. For this purpose, to simply examine the frequency of a plant group at the individual transects, both methods are equivalent if the relevant plant groups also are the dominating plant groups.

Still, the transect analysis do have an additional layer of information that the extensive method do not have, namely dominance, and also while not explored in this thesis, the transect analysis collects information of mire structure (hummock to hollow). The measure of mire structure is relevant for mires which typically have this structure, like raised bogs (Moen et al., 2011). The measure of dominance can be a part of indicating good ecological condition in mires, as dominance in *Sphagnum* in terms of primary production in mires is better than dominance by the field layer (grasses) (Nybø & Evju, 2017). However, this information is not directly measured by the transect analysis either, as dominance in the bottom and field layer is separated.

Even though the comparison between the two methods proved similar, it is worth noting that the categories of plant group differs, as seen in field protocols in table A1.1 and A1.2. In contrast to the extensive method, the transect analysis separated between *Eriophorum*, which is previously argued to be an important indicator for restoration success, and gras which does not necessarily belong in most healthy mires. For example, *Nardus stricta* was registered through the species lines in Saltsutlia, which is an untypical graminoid for mires (Fremstad, 1997). Also, while not taken account for in my GLMMs, the transect analysis separates between deciduous Ericaceous plants and evergreen Ericaceous plants in its sampling, which can have different implications of the state of the mire. For example, Fremstad (1997) categorized typical evergreen Ericaceous plants species like *Andromeda polifolia* and *Empetrum nigrum* as a mire-margin- mire expanse gradient category 3 (species that thrive both in the mire margin and the mire expanse), while deciduous Ericaceous plants like *Vaccinium* ssp. prefer the drier mire margin.

Another difference between these two sampling methods is that the categories in the extensive method is yet to be standardized. Through my examination of the data collected from previous years with the extensive method, I found that categories differed between years and the person collecting the data.

In contrast to the transects analysis and the species line, both separate and combined, the extensive method does not take long time to execute. It is also less demanding in terms of field experience. Species lines in particular can be difficult to preform without field experience, as detailed knowledge of species is needed. Separating between *Sphagnum* species can be especially demanding.

4.5 Balancing indicators: comparing with other standards for mire restoration

The monitoring programmes of restored mires in Norway compares to other international monitoring programmes and standards. Society of ecological restoration (SER) proclaims 8 principles that should be followed in ecological restorations (Gann et al., 2019), some of which can be reflected in the Norwegian restoration and monitoring programme. For the most part, these principles are upheld, including ensuring that projects have a cumulative positive value when upheld at large scale, that project are part of a continuum of restoration activities and hopefully that restoration supports recovery of the ecosystem (Gann et al., 2019), which is what the monitoring will measure.

Other key principles which connect with the discussion of this thesis is principle 3 and 5: "Ecological Restoration Practice Is Informed by Native Reference Ecosystems, while Considering Environmental Change" and "Ecosystem Recovery Is Assessed against Clear Goals and Objectives, Using Measurable Indicators" (Gann et al., 2019). Both the extensive and the intensive monitoring programmes use *Sphagnum* levels as well as other plant groups as measurable indicators for restoration success. This is similar to other monitoring programmes, for example Peatland Code UK (IUCN, 2018), which measure the level of *Sphagnum*, *Calluna vulgaris* and bare peat (IUCN, 2022). However, the goals defined by the action plan for wetland restoration, reduced greenhouse gas emissions, increased adaptability to climate change and improved ecological condition (Miljødirektoratet, 2016), are very broad and not directly linked to the indicators actually measured. Bettered ecological condition is the goal that is most closely related to the indicators which are measured as it among other things recognizes that the level of primary production, as well as the services of functionally important species and biophysical structures should be similar to an intact ecosystem of the same nature type (Nybø & Evju, 2017). This is characteristics that can be measured when comparing *Sphagnum* levels to a reference system. However, as the extensive method lacks a reference transect, it would be difficult to measure if the *Sphagnum* levels reach a satisfactory level unless a general standard for *Sphagnum* levels per transect are set. This could be difficult as the extensive sites varies both in geographical location and mire type.

Due to the species line, the intensive method has the opportunity to capture if the biodiversity and species composition deviates from a reference system, which also is one of the characteristics for a good ecological condition (Nybø & Evju, 2017). While the methods, at least the intensive method, arguably are able to detect a bettering ecological condition which is one of the objectives of the restoration plan, the sampling design bears the mark of unspecific targets in the action plan. An issue pointed out by Lindenmayer & Likens (2009), is the uncertainty of how the data that is collected in many monitoring programmes answer to the objectives. Many conservation objectives are difficult to measure directly, for example "healthy ecosystem" or "good ecological condition". Hence, proxies or indicators are used, such as vegetation cover and species composition. These can be good indicators if the desired level of vegetation cover or the expected species composition of the wanted outcome is known: if the goal is to regain good ecological condition, the desired level of *Sphagnum* for that should be known. This will be different for different mire types. For example, *Sphagnum* levels in itself will not be a good enough indicator for fens. According to Tear *et al.* (2005) a good indicator need to meet these criteria: be measurable, precise, consistent and sensible, but they also need to answer to the objectives, which they argue should be impact oriented, measurable, credible and specific. In terms of the criteria for a good indicator, the intensive method is satisfactory, but the extensive method needs standardized plant categories in order to be consistent and precise. As for the objectives, these need to be clearer defined in measurable units to be satisfactory to meet the criteria for good objectives, set by both Tear *et al.* (2005) and SER (Gann et al., 2019). "Equivalent levels of *Sphagnum»* or «Similar species compositions» to a reference would be objectives more in toe with the principles of SER.

A multitude of monitoring programmes within conservation have been criticized for not being rooted in scientific research (Lindenmayer & Likens, 2009; T. H. Tear et al., 2005). This could apply for both the objectives of the conservation programmes (B. Tear et al., 1993), as well as the study design behind the monitoring. A common problem for many monitoring programmes has been pointed out by Lindenmayer & Likens (2009) and Godínez-Alvarez et al. (2009): monitoring programmes are often put to works before a clear study design have been chosen, and data is collected before the statistical analysis have been decided. This is reflected in the monitoring programme in Norway, which was originally designed for raised bogs (Hagen et al., 2015) like Aurstadmåsan, Midtfjellmosen and Kaldvassmyra. These mires only have a few ditches. Also, such mires have similar mire structure (Moen et al., 2011) and similar species composition. When applied to other types of mires, such as Hildremsvatnet which is comprehensively drained, as well as the various different mire types which are monitored by the extensive monitoring, different sampling measures may be necessary.

4.6 Implications for management

Increasing transects for extensive sites would increase the statistical power of this monitoring method without adding much effort, but without a reference site this method has little value if the intent is to measure ecological condition, which clearly states that a good ecological condition shares similarity to an intact system, which is not measured by this method. Also, while the extensive method does detect a change in graminoid, this category is too broad to indicate an improved hydrology with certainty, as species within this category can have different implications. If changes in *Sphagnum* had been detected, this might have some value. However, without knowing the expected level of *Sphagnum*, due to the fact that there is lacking information of the mire types monitored by this method in some sites as evident from my GIS analysis, this seems like an unsatisfactory approach. Instead, I propose to use the transect analysis from the intensive programme as the monitoring for extensive sites, as the categories used in this method are more distinguished and account for the different implications of for example, *E. vaginatum* to grasses and evergreen Ericaceous plants to deciduous Ericaceous plants. Still, this method is efficient enough to work in an extensive monitoring programme. I also suggest removing the mire structure analysis from the transect analysis in mires that is not supposed to have this structure and even in such mires these structures may take decades to evolve. In addition, there need to be more transects and a reference transect or at least a detailed description of the mire type so that one can compare with an intact system similar to the restored sites. As for the intensive method, I suggest counting all hits of the same species when using to point intercept method in the species line or register cover, to get a true abundance of that species. I think the species line have potential to show if the monitoring is successful in itself without the transect analysis, as evident from my result which use this data.

It is essential to monitor restoration projects with researched based measurable indicators and objectives to ensure the success of restoration measures and improve future projects.

REFERENCES

Akaike, H. (1998). Information Theory and an Extension of the Maximum Likelihood Principle. In E. Parzen, K. Tanabe, & G. Kitagawa (Eds.), *Selected Papers of Hirotugu Akaike* (pp. 199–213). Springer New York. https://doi.org/10.1007/978-1-4612-1694-0_15

Almond, R. E. A., Grooten, M., & Petersen, T. (2020). *Living Planet Report 2020 - Bending the curve of biodiversity loss.* World Wildlife Fund.

Andersen, R., Farrell, C., Graf, M., Muller, F., Calvar, E., Frankard, P., Caporn, S., & Anderson, P. (2017). An overview of the progress and challenges of peatland restoration in Western Europe. *Restoration Ecology*, *25*(2), 271–282. https://doi.org/10.1111/rec.12415

Anderson, C. M., Defries, R. S., Litterman, R., Matson, P. A., Nepstad, D. C., Pacala, S., Schlesinger, W. H., Shaw, M. R., Smith, P., Weber, C., & Field, C. B. (2019). Natural climate soultions are not enough.Decarbonizing the economy must remain a critical priority. *Sciencemag*, *363*(6430), 933–934. https://doi.org/10.1126/science.aaw2741

Bonham, C. D. (1989). *Measurements for terrestrial vegetation*. John Wiley and Son.

Bonn, A., Allott, T., Evans, M., Joosten, H., & Stoneman, R. (2016). Peatland restoration and ecosystem services: An introduction. *Peatland Restoration and Ecosystem Services: Science, Policy and Practice*, *November 2017*, 1–16. https://doi.org/10.1017/CBO9781139177788.002

Bossio, D. A., Cook-Patton, S. C., Ellis, P. W., Fargione, J., Sanderman, J., Smith, P., Wood, S., Zomer, R. J., von Unger, M., Emmer, I. M., & Griscom, B. W. (2020). The role of soil carbon in natural climate solutions. *Nature Sustainability*, *3*(5), 391–398. https://doi.org/10.1038/S41893-020-0491-Z

Bozdogan, H. (1987). Model selection and Akaike's Information Criterion (AIC): The general theory and its analytical extensions. *Psychometrika*, *52*(3), 345–370.

Bragazza, L., & Gerdol, R. (1996). Response surfaces of plant species along water-table depth and pH gradients in a poor mire on the southern Alps (Italy). *Annales Botanici Fennici*, *33*(1), 11–20.

Brooks, M. E., Kristensen, K., Benthem, K. J. van, Magnusson, A., Berg, C. W., Nielsen, A., Skaug, H. J., Maechler, M., & Bolker, M. B. (2017). glmmTMB Balances Speed and Flexibility Among Packages for Zero-inflated Generalized Linear Mixed Modeling. *The R Journal*, *9*(2), 378–400.

Bryn, A., Strand, G. H., Angeloff, M., & Rekdal, Y. (2018). Land cover in Norway based on an area frame survey of vegetation types. *Norsk Geografisk Tidsskrift*, *72*(3), 131–145. https://doi.org/10.1080/00291951.2018.1468356/SUPPL_FILE/SGEO_A_1468356_SM0602.DOCX

Byrne, K. A., Chojnicki, B., Christensen, T. R., Drösler, M., Freibauer, A., Friborg, T., Frolking, S., Lindroth, A., Maihammer, J., Malmer, N., Selin, P., Turunen, J., Velentini, R., & Zetterberg, L. (2004). *EU Peatlands: Current Carbon Stocks and Trace Gas Fluxes*. https://www.researchgate.net/publication/254451107_EU_Peatlands_Current_Carbon_Stocks_and_Trace_Gas_Fluxes

CBD. (2021). *First Draft of the Post -2020 Global Biodiversity Framwork*. WG2020. https://www.cbd.int/meetings/WG2020-03

Damgaard, C. F., & Irvine, K. M. (2019). Using the beta distribution to analyse plant cover data. *Journal of Ecology*, *107*(6), 2747–2759. https://doi.org/10.1111/1365-2745.13200

Direktoratet for Naturforvaltning. (2006). *Kartlegging av naturtyper - Verdisetting av biologisk mangfold. DN-håndbok 13 2.utgave 2006 (oppdatert 2007)*. www.dirnat.no.

Erkens, G., Van Der Meulen, M. J., & Middelkoop, H. (2016). Double trouble: subsidence and CO2 respiration due to 1,000 years of Dutch coastal peatlands cultivation. *Hydrogeol J*, *24*, 551–568. https://doi.org/https://doi.org/10.1007/s10040-016-1380-4

Flatberg, K. I. (2002). The Norwegian Sphagna: a field colour guide. *NTNU Vitensk.Mus. Rapp. Bot.*, *Serie 2002*(1), 1–44, 54pl.

Fremstad, E. (1997). *Vegetasjonstyper i Norge*.

Gann, G. D., McDonald, T., Walder, B., Aronson, J., Nelson, C. R., Jonson, J., Hallett, J. G., Eisenberg, C., Guariguata, M. R., Liu, J., Hua, F., Echeverría, C., Gonzales, E., Shaw, N., Decleer, K., & Dixon, K. W. (2019). International principles and standards for the practice of ecological restoration. Second edition. *Restoration Ecology*, *27*(S1), S1–S46. https://doi.org/10.1111/REC.13035/SUPPINFO

Godínez-Alvarez, H., Herrick, J. E., Mattocks, M., Toledo, D., & Van Zee, J. (2009). Comparison of three vegetation monitoring methods: Their relative utility for ecological assessment and monitoring. *Ecological Indicators*, *9*(5), 1001–1008. https://doi.org/10.1016/j.ecolind.2008.11.011

Gore, A. J. P., & Urquhart, C. (1966). The Effects of Waterlogging on the Growth of Molinia Caerulea and Eriophorum Vaginatum. *British Ecological Society*, *54*(3), 617–633.

Grime, J. P. (1973). Control of species density in herbaceous vegetation. *Journal of Environmental Management*, *1(2)*(151–167). https://agris.fao.org/agris-search/search.do?recordID=US201302219925

Griscom, B. W., Adams, J., Ellis, P. W., Houghton, R. A., Lomax, G., Miteva, D. A., Schlesinger, W. H., Shoch, D., Siikamäki, J. V., Smith, P., Woodbury, P., Zganjar, C., Blackman, A., Campari, J., Conant, R. T., Delgado, C., Elias, P., Gopalakrishna, T., Hamsik, M. R., … Fargione, J. (2017). Natural climate solutions. *Proceedings of the National Academy of Sciences of the United States of America*, *114*(44), 11645–11650. https://doi.org/10.1073/PNAS.1710465114/SUPPL_FILE/PNAS.1710465114.SAPP.PDF

Grosvernier, P., Matthey, Y., & Buttler, A. (1997). Growth Potential of Three Sphagnum Species in Relation to Water Table Level and Peat Properties with Implications for Their Restoration in Cut- Over Bogs. *Source: Journal of Applied Ecology*, *34*(2), 471–483.

Günther, A., Barthelmes, A., Huth, V., Joosten, H., Jurasinski, G., Koebsch, F., & Couwenberg, J. (2020). Prompt rewetting of drained peatlands reduces climate warming despite methane emissions. *Nature Communications 2020 11:1*, *11*(1), 1–5. https://doi.org/10.1038/s41467-020-15499-z

Hagen, D., Aarrestad, P. A., Kyrkjeeide, M. O., Myklebost, H. E., Hofgaard, A., & Kvaløy, P. (2015). Etablering av overvåkingsmetodikk for vegetasjon og grunnlagsanalyse før restaureringstiltak på Kaldvassmyra, Aurstadmåsan og Midtfjellmosen. *NINA Rapport*, *1212*, 1–43.

Halvorsen, R., Skarpaas, O., Bryn, A., Bratli, H., Erikstad, L., Simensen, T., Lieungh, E., & Zarnetske, P. (2020). Towards a systematics of ecodiversity: The EcoSyst framework. *Global Ecology and Biogeography*, *29*(11), 1887–1906.

Hancock, M. H., Klein, D., Andersen, R., & Cowie, N. R. (2018). Vegetation response to restoration management of a blanket bog damaged by drainage and afforestation. *Applied Vegetation Science*, *21*(2), 167–178. https://doi.org/10.1111/AVSC.12367

Harris, L. I., Richardson, K., Bona, K. A., Davidson, S. J., Finkelstein, S. A., Garneau, M., McLaughlin, J., Nwaishi, F., Olefeldt, D., Packalen, M., Roulet, N. T., Southee, F. M., Strack, M., Webster, K. L., Wilkinson, S. L., & Ray, J. C. (2022). The essential carbon service provided by northern peatlands. *Frontiers in Ecology and the Environment*, *20*(4), 222–230. https://doi.org/https://doi.org/10.1002/fee.2437

Hartig, F. (2022). *DHARMa: Residual Diagnostics for Hierarchical (Multi-Level / Mixed) Regression Models.* (version 0.4.5). Article version 0.4.5. https://cran.r-

project.org/package=DHARMa
Hedberg, P., Kotowski, W., Saetre, P., Mälson, K., Rydin, H., & Sundberg, S. (2012). Vegetation recovery after multiple-site experimental fen restorations. *Biological Conservation*, *147*(1), 60–67. https://doi.org/10.1016/j.biocon.2012.01.039
Hedberg, P., Saetre, P., Sundberg, S., Rydin, H., & Kotowski, W. (2013). A functional functional trait approach approach to fen to restoration fen restoration analysis analysis. *Applied Vegetation Science*, *16*(4), 658–666.
Horn, H. S. (1975). Markovian properties of forest succession. In M. L. Cody, J. M. Diamond, & Eds. (Eds.), *Ecology and Evolution of Communities* (pp. 196–211). https://cir.nii.ac.jp/crid/1573387451028513280
Howie, S. A., Whitfield, P. H., Hebda, R. J., Munson, T. G., Dakin, R. A., & Jeglum, J. K. (2009). Water table and vegetation response to ditch blocking: restoration of a raised bog in southwestern British Columbia. *Canadian Water Resources Journal*, *24*(4), 381–392. https://doi.org/10.4296/cwrj3404381
Haapalehto, T. O., Vasander, H., Jauhiainen, S., Tahvanainen, T., & Kotiaho, J. S. (2011). The Effects of Peatland Restoration on Water-Table Depth, Elemental Concentrations, and Vegetation: 10 Years of Changes. *Restoration Ecology*, *19*(5), 587–598. https://doi.org/10.1111/J.1526-100X.2010.00704.X
IPCC. (2018). Summary for Policymakers. In:Global Warming of 1.5°C An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to t. In *32*.
IUCN. (2018). *UK Peatland Strategy 2018-2040*.
IUCN. (2022). *Peatland Code-Field Protocol*. www.iucn-uk-peatlandprogramme.org/peatland-code/introduction-peatland-code/projects.
Jauhiainen, S., Laiho, R., & Vasander, H. (2002). Ecohydrological and vegetational changes in a restored bog and fen. *Annales Botanici Fennici*, *39*(3), 185–199.
Jonasson, S. (1988). Evaluation of the Point Intercept Method for the Estimation of Plant Biomass. *Oikos*, *52*(1), 101–106. https://doi.org/10.2307/3565988
Joosten, H., Barthelmes, A., Couwenberg, J., Hassel, K., Moen, A., Tegetmeyer, C., & Lyngstad, A. (2015). *Metoder for å beregne endring i klimagassutslipp ved restaurering av myr*. NTNU Vitenskapsmuseet.
Joosten, H., Tanneberger, F., & Moen, A. (2017). *Mires and peatlands of Europe -Status, distrubution and conservation* (H. Joosten, F. Tanneberger, & A. Moen (eds.); 1st ed.). E. Schweizerbart'sche Verlagsbuchhandlung.
Kartverket. (2022). *Administrative enheter*. Kartverket.No. https://wfs.geonorge.no/skwms1/wfs.administrative_enheter?&service=WFS&acceptversions=2.0.0&request=GetCapabilities
Keddy, P. A. (2017). *Plant Ecology: Origins, Processes, Consequences* (2nd ed.). Cambridge University Press. https://doi.org/10.1017/9781316321270
Koebsch, F., Gottschalk, P., Beyer, F., Wille, C., Jurasinski, G., & Sachs, T. (2020). The impact of occasional drought periods on vegetation spread and greenhouse gas exchange in rewetted fens. *Philosophical Transactions Royal Society B*, *375*. https://doi.org/10.1098/rstb.2019.0685
Kozlov, S. A., Lundin, L., & Avetov, N. A. (2016). *Revegetation dynamics after 15 years of rewetting in two extracted peatlands in Sweden*. *18*(5), 1–17. https://doi.org/10.19189/MaP.2015.OMB.204
Kraemer, H. C., & Blasey, C. (2017). How Many Subjects?: Statistical Power Analysis in Research. In *How Many Subjects?: Statistical Power Analysis in Research*. SAGE Publications, Ltd. https://doi.org/10.4135/9781483398761

Kyrkjeeide, M. O., Lunde, L. M. F., Lyngstad, A., & Molværsmyr, S. (2021). Restaurering av myr. Overvåkning av tiltak i 2021. *NINA Rapport*, *2051*, 1–37.
Kyrkjeeide, M. O., Lyngstad, A., Hamre, Ø., & Jokerud, M. (2018). Overvåking av restaureringstiltak i myr Aurstadmåsan, Kaldvassmyra og Hildremsvatnet. *NINA Rapport*, *1576*, 1–49.
Landry, J., & Rochefort, L. (2012). The drainage of peatlands: impacts and rewetting techniques. *Laval Univeristy*, 1–62. http://www.gret-perg.ulaval.ca/uploads/tx_centrerecherche/Drainage_guide_Web.pdf
Leifeld, J., Wüst-Galley, C., & Page, S. (2019). Intact and managed peatland soils as a source and sink of GHGs from 1850 to 2100. *Nature Climate Change*, *9*(12), 945–947. https://doi.org/10.1038/S41558-019-0615-5
Lindenmayer, D. B., & Likens, G. E. (2009). Adaptive monitoring: a new paradigm for long-term research and monitoring. *Trends in Ecology and Evolution*, *24*(9). https://doi.org/10.1016/j.tree.2009.03.005
Lundin, L., Nilsson, T., Jordan, S., Lode, E., & Strömgren, M. (2017). Impacts of rewetting on peat, hydrology and water chemical composition over 15 years in two finished peat extraction areas in Sweden. *Wetlands Ecology and Management*, *25*(4), 405–419. https://doi.org/10.1007/s11273-016-9524-9
Lyngstad, A., Brandrud, E., Moen, A., & Øien, D.-I. (2018). Norsk rødliste for naturtyper 2018 – Våtmark. –. In *NTNU Vitenskapsmuseet naturhistorisk notat* (Vol. 2018, Issue 15).
McCarter, C. P. R., & Price, J. S. (2013). The hydrology of the Bois-des-Bel bog peatland restoration: 10 years post-restoration. *Ecological Engineering*, *55*, 73–81. https://doi.org/10.1016/j.ecoleng.2013.02.003
Miljødirektoratet. (2016). *Plan for restaurering av våtmark i Norge (2016-2020)*.
Miljødirektoratet. (2020). *Plan for restaurering av våtmark i Norge (2021-2025)*.
Miljødirektoratet. (2022). *Miljøstatus kart 3.0*.
Miljødirektoratet, Kløve P., Kværner, J., B., & Stålnacke. (2015). *Forslag til hydrologisk overvåking av restaurert myr i Norge*. 24.
Minayeva, T., Bragg, O., Cherednichenko, O., Couwenberg, J., van Duinen, G.-J., Giesen, W., Grootjans, A., Grundling, P., Nikolaev, V., & van der Schaaf, S. (2008). Peatlands and Biodiversity. *Assessment on Peatlands, Biodiversity and Climate Change*, *January*, 60–98.
Moen, A. (1973). *Landsplan for myrreservater i Norge*. *27*(3), 174–193. https://doi.org/10.1080/00291957308551956
Moen, A. (1998). Nasjonalatlas for Norge. Vegetasjon. In *Statens kartverk*.
Moen, A., Lyngstad, A., & Øien, D.-I. (2011). Faglig grunnlag til handlingsplan for høgmyr i innlandet (typisk høgmyr). *NTNU Vitensk.Mus. Rapp. Bot.*, *serie 2011*(3), 1–60.
Mälson, K., Backéus, I., & Rydin, H. (2008). Long-term effects of drainage and initial effects of hydrological restoration on rich fen vegetation. *Applied Vegetation Science*, *11*(1), 99–106. https://doi.org/10.3170/2007-7-18329
Nellemann, C., & Corcoran, E. (2010). *Dead planet, living planet. Biodiversity and ecosystem restoration for sustainable development : a rapid response assessment.* Birkeland trykkeri.
Nybø, S., & Evju, M. (2017). *Fagsystem for fastsetting av god økologisk tilstand*. https://www.regjeringen.no/contentassets/7c4be071791f439b83fa035c03cdfc82/fagsystem-for-fastsetting-av-god-okologisk-tilstand_2017.pdf
Oksanen, J., Blanche, F. G., Friendly, M., Kindt, R., Legendre, P., McGlinn, D., Minchin, P. R., O'Hara, R. B., Simpson, G. L., Solymos, P., Stevens, M. H. H., Szoecs, E., & Wagner, H. (2020). vegan: Community Ecology Package. *R Package Version 2.5-7*.

Page, S. E., & Baird, A. J. (2016). Peatlands and Global Change: Response and Resilience. *Annual Review of Environment and Resources*, *41*, 35–57. https://doi.org/10.1146/annurev-environ-110615-085520
Parish, R., Sirin, F., Charman, A., Joosten, D., Minayeva, H., Silvius, T., & Stringer, M. (2008). Assessment on Peatlands, Biodiversity and Climate Change: Main Report. In *Assessment on Peatlands, Biodiversity and Climate Change: Main Report. Global Environment Centre, Kuala Lumpur and Wetlands International*. Global Environment Centre, Kuala Lumpur & Wetlands International, Wageningen. www.peat-portal.net
Paustian, K., Lehmann, J., Ogle, S., Reay, D., Robertson, G. P., & Smith, P. (2016). Climate-smart soils. *Nature*, *532*, 49–57. https://doi.org/10.1038/nature17174
Poulin, M., Andersen, R., & Rochefort, L. (2012). A New Approach for Tracking Vegetation Change after Restoration: A Case Study with Peatlands. *Restoration Ecology*, *21*(3), 363–371. https://doi.org/10.1111/J.1526-100X.2012.00889.X
Punttila, P., Autio, O., Kotiaho, J. S., Kotze, D. J., Loukola, O. J., Noreika, N., Vuori, A., & Vepsäläinen, K. (2016). The effects of drainage and restoration of pine mires on habitat structure, vegetation and ants. *Silva Fennica*, *50*(2). https://doi.org/10.14214/SF.1462
Raeymaekers, G., Sundseth, K., & Gazenbeek, A. (2000). *Conserving mires in the European Union: actions financed by LIFE-nature*. European Commision.
Rastogi, A., Antala, M., Gąbka, M., Rosadziński, S., Stróżecki, M., Brestic, M., & Juszczak, R. (2020). Impact of warming and reduced precipitation on morphology and chlorophyll concentration in peat mosses (Sphagnum angustifolium and S. fallax). *Scientific Reports*, *10*(8592), 1–9. https://doi.org/10.1038/s41598-020-65032-x
Rochefort, L. (2000). *Sphagnum – a keystone genus in habitat restoration. The Bryologist 103: 503–508. The Bryolo*(103), 503–508.
Rusch, G. M., Bartlett, J., Kyrkjeeide, M. O., Lein, U., Nordén, J., Sandvik, H., & Stokland, H. (2022). A joint climate and nature cure: A transformative change perspective. *Ambio*, *51*(1459–1473). https://doi.org/10.1007/s13280
Scholes, R., Montanarella, L., Brainich, A., Barger, N., Ben, ten B., Cantele, M., Erasmus, B., Fisher, J., Gardner, T., Holland, T. G., & Others. (2018). *Summary for policymakers of the assessment report on land degradation and restoration of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. www.ipbes.net
Shantz, M. A., & Price, J. S. (2006). Hydrological changes following restoration of the Bois-des-Bel Peatland, Quebec, 1999-2002. *Journal of Hydrology*, *2006*, 543–553. https://doi.org/10.1016/j.jhydrol.2006.06.002
Silvan, N., Tuittila, E. S., Vasander, H., & Laine, J. (2004). Eriophorum vaginatum plays a major role in nutrient immobilisation in boreal peatlands. *Annales Botanici Fennici*, *41*(3), 189–199.
Skaland, R. G., Colleuille, H., Solveig, A., Andersen, H., Mamen, J., Grinde, L., Therese, H., Tajet, T., Lundstad, E., Sidselrud, L. F., & Tunheim, K. (2019). *Tørkesommeren 2018*. 1–79.
Society for Ecological Restoration International. (2004). *The SER International Primer on Ecological Restoration*. www.ser.org
Solstad, H., & Bratli, H. (2010). Myrflagre Epipactis palustris. In *faktaark nr. 157 artsdatabanken*. www.artsdatabanken.no
Sundberg, S. (2012). Quick Target Vegetation Recovery after Restorative Shrub Removal and Mowing in a Calcareous Fen. *Restoration Ecology*, *20*(3), 331–338. https://doi.org/10.1111/j.1526-100X.2011.00782.x
Tear, B., Scott, T., Hayward, J., & Griffith, P. (1993). Status and prospects for success of the Endangered Species Act: A look at recovery plans. *Science*, *262*, 976–977.
Tear, T. H., Kareiva, P., Angermeier, P. L., Comer, P., Czech, B., Kautz, R., Landon, L.,

Mehlman, D., Murphy, K., Ruckelshaus, M., Scott, J. M., & Wilhere, G. (2005). How much is enough? The recurrent problem of setting measurable objectives in conservation. *BioScience*, *55*(10), 835–849. https://doi.org/10.1641/0006-3568(2005)055[0835:HMIETR]2.0.CO;2

Tuittila, E.-S., Rita, H., Vasander, H., & Laine, J. (2000). Vegetation patterns around Eriophorum vaginatum L. tussocks in a cut-away peatland in southern Finland . *Canadian Journal of Botany*, *78*(1), 47–58. https://doi.org/10.1139/b99-159

Tuittila, E.-S., Vasander, H., & Laine, J. (2009). Impact of rewetting on vegetation of a cut-away peatland. *Applied Vegetation Science*, *3*, 205–212. https://doi.org/10.2307/1478999

van Diggelen, R., Middleton, B., Bakker, J., Grootjans, A., & Wassen, M. (2006). Fens and floodplains of the temperate zone: Present status, threats, conservation and restoration. *Applied Vegetation Science*, *9*(2), 157–162. https://doi.org/10.1111/j.1654-109x.2006.tb00664.x

Vasander, H., Tuittila, E. S., Lode, E., Lundin, L., Ilomets, M., Sallantaus, T., Heikkilä, R., Pitkänen, M. L., & Laine, J. (2003). Status and restoration of peatlands in northern Europe. *Wetlands Ecology and Management*, *11*(1–2), 51–63. https://doi.org/10.1023/A:1022061622602

Venables, W. N., & Ripley, B. D. (2002). *Modern Applied Statistics with S.* (Fourth). Springer.

Wickham, H. (2016). *ggplot2: Elegant graphics for Data Analysis*. Springer-Verlag. https://ggplot2.tidyverse.org

Wüst-Galley, C., Mössinger, E., & Leifeld, J. (2016). Loss of the soil carbon storage function of drained forested peatlands. *Mires and Peat*, *18*. https://doi.org/10.19189/MAP.2015.OMB.189

Yan, W., Artz, R. R. E., & Johnson, D. (2008). Species-specific effects of plants colonising cutover peatlands on patterns of carbon source utilisation by soil microorganisms. *Soil Biology and Biochemistry*, *40*(2), 544–549. https://doi.org/10.1016/J.SOILBIO.2007.09.001

Øien, D.-I., Lyngstad, A., & Moen, A. (2015). *Rikmyr i Norge. Kunnskapsstatus og innspill til faggrunnlag*.

Øien, D.-I., Moen, A., & Lyngstad, A. (2015). Rikmyr i Norge. Kunnskapsstatus og innspill til faggrunnlag. *NTNU Vitenskapsmuseet Naturhistorisk Rapport*, *2015*(1), 1–122. https://www.ntnu.no/documents/10476/1262347829/2015-1+Rikmyr+i+Norge.pdf/dc7e3c37-a90f-4c25-9ebb-39b30836b997

APPENDICES

Table A1.1. Plant groups used in data sampling for the transect part of the intensive monitoring method. In addition to these groups, dominating structures were registered in tree layer and bush layer, as well as mire structure (hummock- wet hollow) was registered.

Layer	**Plant group**	**Explanation**
Field layer	*Carex*	All *Carex* sp.
Field layer	Sedge	All sedges but *Carex* sp. and *Eriophorum* sp.
Field layer	Eriophorum	All Eriophorum species
Field layer	Gras	All other graminoids
Field layer	Evergreen Ericaceous plants	Ericaceous species like *Empetrum, Calluna vulgaris*
Field layer	Deciduous Ericaceous plants	Ericaceous species like *Vaccinum*
Field layer	Herb	All herbs
Bottom layer	Lichen	Alle lichens
Bottom layer	Moss	All mosses but *Sphagnum*
Bottom layer	*Sphagnum*	Peatmoss (*Sphagnum)*
Bottom layer	Litter	Dead organic material

Table A1.2. Examples of plant groups used in data sampling for the extensive monitoring method. These groups were used as a standard for the field season in 2021, but variations of these groups have been used in previous years depending on the person collecting as well as the presence of the groups at the site.

Plant group	**Explanation**
Sphagnum	Peatmoss (*Sphagnum)*
Lichen	Alle lichens
Moss	All mosses but *Sphagnum*
Herb	All herbs
Graminoid	All grasslike plants
Ericaceous plants	All heatherlike species
Bush	small woody growth
Tree	tall woody growth

Table A2.1. The AIC model selection table gives an overview of AIC values across all sampling methods and the relevant plant group. Models corresponds to models described in table 2. The model name that is bold is the model that was chosen based on the lowest AIC value unless a model with fewer variables were within a ΔAIC threshold of 2.

Sampling	Plant group	Models	AIC	Sampling	Plant group	Models	AIC	Sampling	Plant group	Models	AIC
Transect	Sphagnum	Model 1	-60.24	Species line	Sphagnum	**Model 1**	945.9	Extensive	Sphagnum	Model 1	-6.056
Transect	Sphagnum	Model 2	-60.75	Species line	Sphagnum	Model 2	951.1	Extensive	Sphagnum	Model 2	-11.59
Transect	Sphagnum	Model 3	-45.96	Species line	Sphagnum	Model 3	975.8	Extensive	Sphagnum	Model 3	-1.381
Transect	Sphagnum	**Model 4**	-62.72	Species line	Sphagnum	Model 4	994.3	Extensive	Sphagnum	**Model 4**	-12.83
Transect	Sphagnum	Model 5	-47.93	Species line	Sphagnum	Model 5	1020	Extensive	Sphagnum	Model 5	-1.925
Transect	Eriophorum	**Model 1**	-60.31	Species line	Eriophorum	**Model 1**	1134	Extensive	Graminoid	Model 1	NA
Transect	Eriophorum	Model 2	-56.10	Species line	Eriophorum	Model 2	1139	Extensive	Graminoid	**Model 2**	-12.09
Transect	Eriophorum	Model 3	-47.70	Species line	Eriophorum	Model 3	1147	Extensive	Graminoid	Model 3	-3.821
Transect	Eriophorum	Model 4	-54.34	Species line	Eriophorum	Model 4	1142	Extensive	Graminoid	Model 4	-2.557
Transect	Eriophorum	Model 5	-45.70	Species line	Eriophorum	Model 5	1152	Extensive	Graminoid	Model 5	-0.734
Transect	Ericaceous plants	Model 1	-33.28	Species line	Ericaceous plants	Model 1	1207	Extensive	Ericaceous plants	Model 1	11.62
Transect	Ericaceous plants	**Model 2**	-38.66	Species line	Ericaceous plants	Model 2	1223	Extensive	Ericaceous plants	Model 2	4.831
Transect	Ericaceous plants	Model 3	-33.87	Species line	Ericaceous plants	Model 3	1223	Extensive	Ericaceous plants	Model 3	3.797
Transect	Ericaceous plants	Model 4	-28.43	Species line	Ericaceous plants	**Model 4**	1205	Extensive	Ericaceous plants	Model 4	6.612
Transect	Ericaceous plants	Model 5	-23.74	Species line	Ericaceous plants	Model 5	1220	Extensive	Ericaceous plants	**Model 5**	4.746

*Table A3. 1 Model outputs with estimates, standard variables, confidence intervals (Cilow and Cihigh) and mean for the relevant explanatory variables. For transect models and extensive models, estimates are given in logit form, and mean is transformed back to proportion. For species line model, estimates are given in log form and this is exalted by the Eurlers constant. *significant increase time in contrast to the estimate of the site.*

Method	**Species group**	**Site**	**Estimate**	**Std. Error**	**Cilow**	**Cihigh**	**mean**	**Interaction**	**Estimate**	**Std. Error**	**Cilow**	**Cihigh**	**mean**	
			Site variable						**Time variable**					
Transect	Sphagnum	Aurstadmåsan	2,14	0,53	1,10	3,17	0,89	not included	-	-	-	-	-	-
Transect	Sphagnum	Hildremsvatnet	-2,58	0,54	-3,64	-1,52	0,07	not included	-	-	-	-	-	-
Transect	Sphagnum	Kaldvassmyra	-0,08	0,50	-1,06	0,90	0,48	not included	-	-	-	-	-	-
Transect	Sphagnum	Midtfjellmosen	0,65	0,59	-0,50	1,79	0,66	not included	-	-	-	-	-	-
Transect	Eriophorum vaginatum	Aurstadmåsan	-1,06	0,21	-1,48	-0,65	0,26	interaction	0,12	0,03	0,05	0,18	0,53	*
Transect	Eriophorum vaginatum	Hildremsvatnet	-0,26	0,20	-0,66	0,14	0,43	interaction	-0,09	0,06	-0,21	0,03	0,48	
Transect	Eriophorum vaginatum	Kaldvassmyra	-0,08	0,20	-0,47	0,32	0,48	interaction	0,08	0,03	0,01	0,15	0,52	*
Transect	Eriophorum vaginatum	Midtfjellmosen	-1,39	0,25	-1,87	-0,90	0,20	interaction	-0,03	0,04	-0,12	0,05	0,49	
Transect	Ericaceous plants	Aurstadmåsan	0,45	0,28	-0,10	1,00	0,61	no interaction	-0,12	0,03	-0,17	-0,06	0,28	*
Transect	Ericaceous plants	Hildremsvatnet	-1,02	0,29	-1,59	-0,45	0,27	no interaction	-0,12	0,03	-0,17	-0,06	0,28	*
Transect	Ericaceous plants	Kaldvassmyra	-0,60	0,30	-1,19	-0,02	0,35	no interaction	-0,12	0,03	-0,17	-0,06	0,28	*
Transect	Ericaceous plants	Midtfjellmosen	0,06	0,33	-0,58	0,70	0,51	no interaction	-0,12	0,03	-0,17	-0,06	0,28	*
Species-line	Sphagnum	Aurstadmåsan	3,04	0,13	2,79	3,31	20,86	interaction	0,06	0,01	0,03	0,08	1,06	*
Species-line	Sphagnum	Hildremsvatnet	1,04	0,20	0,56	1,48	2,83	interaction	0,10	0,14	-0,20	0,41	1,11	
Species-line	Sphagnum	Kaldvassmyra	2,33	0,11	2,10	2,55	10,30	interaction	0,14	0,09	0,19	0,19	1,15	*
Species-line	Sphagnum	Midtfjellmosen	2,48	0,15	2,14	2,81	11,96	interaction	0,04	0,02	0,00	0,07	1,04	*
Species-line	Eriophorum vaginatum	Aurstadmåsan	2,28	0,11	2,05	2,51	9,85	interaction	0,03	0,02	0,00	0,06	1,03	‘
Species-line	Eriophorum vaginatum	Hildremsvatnet	2,25	0,09	2,07	2,43	9,51	interaction	-0,02	0,06	-0,13	0,10	0,98	
Species-line	Eriophorum vaginatum	Kaldvassmyra	2,39	0,09	2,21	2,56	10,48	interaction	0,08	0,02	0,03	0,13	1,08	*

Species-line	Eriophorum vaginatum	Midtfjellmosen	1,82	0,15	1,52	2,11	6,17	interaction	-0,04	0,03	-0,09	0,01	0,96	no
Species-line	Ericaceous plants	Aurstadmåsan	3,10	0,10	2,89	3,32	22,24	not included	-	-	-	-	-	-
Species-line	Ericaceous plants	Hildremsvatnet	2,25	0,11	1,90	2,36	8,49	not included	-	-	-	-	-	-
Species-line	Ericaceous plants	Kaldvassmyra	2,62	0,09	2,41	2,81	13,71	not included	-	-	-	-	-	-
Species-line	Ericaceous plants	Midtfjellmosen	2,82	0,14	2,53	3,10	16,76	not included	-	-	-	-	-	-
Extensive	Sphagnum	Atnsjømyrene	-1,66	0,44	-2,53	-0,80	0,16	not included	-	-	-	-	-	-
Extensive	Sphagnum	Gjennestad	-0,30	0,35	-1,00	0,39	0,42	not included	-	-	-	-	-	-
Extensive	Sphagnum	Kringlemyra	-2,18	0,60	-3,35	-1,00	0,10	not included	-	-	-	-	-	-
Extensive	Sphagnum	Lågåsmyra	-0,89	0,46	-1,80	0,02	0,29	not included	-	-	-	-	-	-
Extensive	Sphagnum	Oppsjømyrene	-1,66	0,44	-2,53	-0,80	0,16	not included	-	-	-	-	-	-
Extensive	Sphagnum	Øytjernet	0,47	0,22	0,04	0,90	0,62	not included	-	-	-	-	-	-
Extensive	Sphagnum	Saltstutlia	0,07	0,30	-0,52	0,67	0,52	not included	-	-	-	-	-	-
Extensive	Sphagnum	Tretjernmyra	0,28	0,35	-0,41	0,98	0,57	not included	-	-	-	-	-	-
Extensive	graminoid	Atnsjømyrene	-0,75	0,27	-1,29	-0,22	0,32	no interaction	0,29	0,08	0,14	0,44	0,57	*
Extensive	graminoid	Gjennestad	-1,09	0,39	-1,86	-0,32	0,25	no interaction	0,29	0,08	0,14	0,44	0,57	*
Extensive	graminoid	Kringlemyra	-0,98	0,47	-1,89	-0,06	0,27	no interaction	0,29	0,08	0,14	0,44	0,57	*
Extensive	graminoid	Lågåsmyra	0,18	0,50	-0,80	1,17	0,55	no interaction	0,29	0,08	0,14	0,44	0,57	*
Extensive	graminoid	Oppsjømyrene	-1,03	0,68	-2,37	0,31	0,26	no interaction	0,29	0,08	0,14	0,44	0,57	*
Extensive	graminoid	Øytjernet	-0,36	0,24	-0,83	0,11	0,41	no interaction	0,29	0,08	0,14	0,44	0,57	*
Extensive	graminoid	Saltstutlia	1,24	0,39	0,47	0,14	0,47	no interaction	0,29	0,08	0,14	0,44	0,57	*
Extensive	graminoid	Tretjernmyra	0,11	0,44	-0,75	0,96	0,53	no interaction	0,29	0,08	0,14	0,44	0,57	*
Extensive	Ericaceous plants													

Table A4.1. Protection status and description of mire types (as described in Joosten, Tanneberger and Moen (2017)) of restored mires in Norway by 2020

Location	Protection plan	Description
Abborttjern-Oppsjøen	Mire Protection Plan	Ombrotroph, Minerotroph
Adalstjern		
Aspåsmyran	Wetland Protection Plan	Plane bog, flat fen, sloping mire, string mire. Rich fen, poor fen
Atnsjømyrene	Mire Protection Plan	Poor fen; flat fen
Aurstadmåsan	Mire Protection Plan	Concentric raised bog
Bakkusmyra		
Bjørkestul		
Brattås	Forest Protection Plan	Poor fen, mire forest
Endelausmyrene	Wetland Protection Plan	Poor fen; flat fen, string mire
Finnemarka	Forest Protection Plan	Rich fen
Finnsåsmarka	Forest Protection Plan	Rich fen
Fjella	Forest Protection Plan	Concentric raised bog, sloping mire, rich fen, Intermediary fen, ombrotroph
Fjøsmåsan-Eriksvannsmåsan		
Flåmyra	Mire Protection Plan	Rich fen (flat fen), string mire, ombrotroph
Fuglemosehøgda	Forest Protection Plan	
Gaupesteinmarka	Forest Protection Plan	
Gimsøymyrene	Mire Protection Plan	Eccentric raised bog, ombrotroph, poor fen, intermediary fen
Gjennestadmyra		
Gjerlandsøyane	Mire Protection Plan	Flat fen, minerotroph (poor and intermediary calcium rich)
Grunnfjorden	Wetland Protection Plan	Atlantic raised bog
Grunnvatnet	Wetland Protection Plan	
Gråkletten	Forest Protection Plan	
Gulltjernmosen	Mire Protection Plan	Ombrotroph, poor fen, flat fen
Haralundmosen	Forest Protection Plan	Poor fen
Hildremsvatnet	Forest Protection Plan	
Høydalmoan	Forest Protection Plan	
Johannesmyra		
Kaldvassmyra	Wetland Protection Plan	
Kjerringmyr		
Kringlemyr	Mire Protection Plan	Eccentric raised bog, Ombrotroph, poor fen, intermediary fen
Krokmyr		
Kvitmyra	Mire Protection Plan	Eccentric raised bog
Kynndalsmyrene	Mire Protection Plan	Eccentric raised bog, Ombrotroph, flat fen, intermediary fen, rich fen
Langvassbrenna	Forest Protection Plan	
Lanngardsmyra		
Lågåsmyr	Mire Protection Plan	Flat fen, Ombrotroph
Midtfjellmosen	Forest Protection Plan	Raised bog, Ombrotroph, other
Måsan-Oppsjøen	Mire Protection Plan	Ombrotroph, Minerotroph
Netflomyra		

Numyra		
Nygardsmyrene	Forest Protection Plan	
Nøklemyr		
Okstadmyra	Mire Protection Plan	Eccentric raised bog
Olavsmyra		
Oppsjømyrene	Mire Protection Plan	Ombrotroph, poor mire, rich mire and rich mire
Orremyr-Drangedal		
Prestebakkefjella	Forest Protection Plan	Flat fen, sloping mire, hay fen
Regnåsen og Hisåsen	Forest Protection Plan	
Rusaset		
Rønnåsmyra	Mire Protection Plan	Eccentric raised bog
Sakkhusmåsan	Mire Protection Plan	Eccentric raised bog
Saltstutlia	Forest Protection Plan	
Sandungåsen	Forest Protection Plan	
Setertjern		
Sjømannsheia	Forest Protection Plan	
Skasberget	Forest Protection Plan	Ombrotroph
Slattumsrøa	Forest Protection Plan	
Slåttbråtåmyra	Forest Protection Plan	Poor fen; flat fen
Stimannsberget	Forest Protection Plan	
Storfelten	Forest Protection Plan	Flat fen, Ombrotroph
Storfloen	Mire Protection Plan	Rich fen, sloping mire
Stormyra	Mire Protection Plan	Concentric raised bog, eccentric raised bog
Stråmyra	Mire Protection Plan	Ombrotroph, flat fen
Sætremyrane	Mire Protection Plan	Raised bog, flat fen, sloping mire, plane bog, poor fen, Intermediary fen, spring
Tanarkjølen	Mire Protection Plan	Eccentric ombrotroph, flat mire, string mire and sloping mire; poor fen, intermediary/rich fen?
Tomåsan		
Tretjernmyra	Mire Protection Plan	Concentric raised bog
Tveitvann	Forest Protection Plan	
Tøråsen	Forest Protection Plan	Rich fen
Vangestadmyra	Mire Protection Plan	Eccentric raised bog
Veggermyra	Mire Protection Plan	Ombrotroph
Vigre	Mire Protection Plan	Rich fen
Vindflomyrene	Mire Protection Plan	String mire; poor mire, intermediary mire, rich mire
Vølan		
Yngsdalen	Mire Protection Plan	Sloping mire, flat fen, hay fen; poor fen, rich fen, spring
Øgårdsmåsan		
Øytjernet	Forest Protection Plan	
Åholmen	Wetland Protection Plan	
Åmsmyra	Mire Protection Plan	Plateau raised bog, flat mire

Table A5.1. Frequency of plant groups at same transects across sampling methods the difference between transects

Plant group cover	Location		Extensive method	Intensive method	Δ
Sphagnum	Kaldvassmyra	K3	0,58	0,46	0,12
Sphagnum	Aurstadmåsan	A1	0,41	0,50	0,09
Sphagnum	Aurstadmåsan	A3	0,97	1,00	0,03
Sphagnum	Hildremsvatnet	H4	0,07	0,06	0,01
Sphagnum	Regnåsen	R1	0,51	0,54	0,03
Sphagnum	Hisåsen Regnåsen	HR1	0,56	0,48	0,08
Sphagnum	Tretjernmyra	T1	0,57	0,57	0,00
Sphagnum	Lågåsmyra	L1	0,15	0,22	0,07
Sphagnum	Kringlemyra	Kr1	0,12	0,12	0,00
Sphagnum	Gjennestadmyra	G1	0,43	0,48	0,05
Sphagnum	Måsan (Oppsjømyrene)	O1	0,47	0,53	0,06
Sphagnum	Atnsjømyrene	At1	0,00	0,02	0,02
Sphagnum	Saltsutlia	S1	0,72	0,67	0,05
Sphagnum	Øytjernet	OY1	0,45	0,40	0,05
Graminoid	Kaldvassmyra	K3	0,53	0,65	0,12
Graminoid	Aurstadmåsan	A1	0,43	0,23	0,20
Graminoid	Aurstadmåsan	A3	0,40	0,83	0,43
Graminoid	Hildremsvatnet	H4	0,37	0,34	0,03
Graminoid	Regnåsen	R1	0,37	0,33	0,04
Graminoid	Hisåsen Regnåsen	HR1	0,53	0,64	0,11
Graminoid	Tretjernmyra	T1	0,67	0,18	0,49
Graminoid	Lågåsmyra	L1	0,30	0,50	0,20
Graminoid	Kringlemyra	Kr1	0,47	0,30	0,17
Graminoid	Gjennestadmyra	G1	0,42	0,22	0,20
Graminoid	Måsan (Oppsjømyrene)	O1	0,53	0,48	0,05
Graminoid	Atnsjømyrene	At1	0,83	0,95	0,12
Graminoid	Saltsutlia	S1	0,88	0,62	0,26
Graminoid	Øytjernet	OY1	0,83	0,73	0,10
Heather	Kaldvassmyra	K3	0,22	0,28	0,06
Heather	Aurstadmåsan	A1	0,58	0,53	0,05
Heather	Aurstadmåsan	A3	0,68	0,71	0,03
Heather	Hildremsvatnet	H4	0,15	0,34	0,19
Heather	Regnåsen	R1	0,50	0,58	0,08
Heather	Hisåsen Regnåsen	HR1	0,47	0,31	0,16
Heather	Tretjernmyra	T1	0,88	0,75	0,13
Heather	Lågåsmyra	L1	0,77	0,68	0,09
Heather	Kringlemyra	Kr1	0,65	0,70	0,05
Heather	Gjennestadmyra	G1	0,55	0,53	0,02
Heather	Måsan (Oppsjømyrene)	O1	0,52	0,35	0,17
Heather	Atnsjømyrene	At1	0,00	0,00	0,00
Heather	Saltsutlia	S1	0,43	0,38	0,05
Heather	Øytjernet	OY1	0,02	0,18	0,16

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