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Feasibility in using historical data to perceive changes in peatlands

Changes in peatland's structure and vegetation over the past 91 years

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Examensarbete avancerad nivå
Naturgeografi och kvartärgeologi, 30 hp

Master's thesis
Physical Geography and Quaternary Geology, 30 HECs

NKA 31
2010

Förord

Denna uppsats utgör Amanda James examensarbete i Naturgeografi och kvartärgeologi på avancerad nivå vid Institutionen för naturgeografi och kvartärgeologi, Stockholms universitet. Examensarbetet omfattar 30 högskolepoäng (ca 20 veckors heltidsstudier).

Handledare har varit Stefan Wastegård, Institutionen för naturgeografi och kvartärgeologi, Stockholms universitet, externa handledare har varit Kristian Schoning och Gustav Sohlenius, Sveriges Geologiska Undersökning. Examinator för examensarbetet har varit Jan Risberg, Institutionen för naturgeografi och kvartärgeologi, Stockholms universitet.

Författaren är ensam ansvarig för uppsatsens innehåll.

Stockholm, den 29 november 2010

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ABSTRACT

Energy shortages in the early 20th century sparked an intensive survey of peatlands from southern to middle Sweden. In this study a survey of peatlands northeast of Uppsala was conducted that aimed to determine the feasibility of using diaries from the surveys in the early 20th century to assess possible changes in peat structure and vegetation over the last 90 years. Despite differences in the assessments of both determination of peat and vegetation, comparisons of the two surveys indicated a general change to drier and more nutrient-rich conditions in surveyed peatlands. Furthermore, peatland thickness had reduced during the past 90 years most likely because of changes in hydrology caused by wetland drainage. Although the method here was unable to compare coring sites within peatlands at both time periods it did give indications of general changes of peatlands over time. Results suggest that studies of the peatlands in Sweden can be linked to surveys from the early 20th century and provide further information in understanding recent changes in peatlands.

Cover picture: *Polytrichum* moss invasion in a typical *Sphagnum* dominated bog (Photo by A. James 2010)

SAMMANFATTNING

Under första världskriget startades en intensiv undersökning av torvmarker i södra och mellersta Sverige. Syftet var att ha en energiresurs som reserv ifall importen av stenkol skulle begränsas under kriget. I den här studien återbesöktes några av de undersökta torvmarkerna längs en linje nordöst om Uppsala för att studera förändringar i torvmarkerna sedan 1919. Syftet var att se om de dagböcker som användes i fältundersökningen i början av 1900-talet var till nytta för att upptäcka förändringar i torvmarkernas struktur och vegetationssammansättning. Även om olika bedömningar gjordes i de två undersökningarna tyder en jämförelse mellan studierna att torvmarkerna idag har generellt torrare och näringsrikare förhållanden. Studien visar även att torvmarkerna har avtagit i tjocklek sedan 1900-talets början vilket förmodligen är ett resultat av förändrade vattenförhållanden från dikning. Trots problem i att återfinna exakta undersökningsplatser kan man se en generell förändring i torvmarkerna. Informationen som finns i dagböckerna från 1900-talets början bidrar till ökad kunskap om förändringar under kortare tid.

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1. INTRODUCTION

1.1 Background

Peatlands are a central element of the Swedish landscape with 15 % of the country's area covered by peat (Fredén, 2002). Peatlands are important from an environmental science perspective as they contribute to an archive of historical environmental changes (e.g. Blackford, 2000), and because they serve as a habitat for a great number of species in Sweden, they are also important in retaining biodiversity (Miljömålsrådet, 2009). Furthermore, peat plays a role in e.g. hydrological cycling, is important from both cultural and archaeological perspectives (Charman, 2002), and is a valuable natural resource (Regeringskansliet, 2009) due to its high energy content.

During the past century, areas of mainly undisturbed and less affected wetlands in Sweden and other industrialized nations have been in dramatic decline due to farming, forestry and peat extraction (Rydin & Jeglum, 2006). Large areas of wetlands are drained for both agriculture and forestry with the greatest areas of drainage for forestry (in total) occurring in Finland (59 000 km^2), Russia (38 000 km^2) and Sweden (14 100 km^2) compared to 4000 km^2 in USA (Paavilainen & Päivänen, 1995). Draining permanently alters the physical characteristics of a peatland by drying out the surface layer, which causes compaction and increases the aerobic decay of the peatland (Charman, 2002). These peatlands are drained on the surface, which provides enough oxygen for natural decomposition, and hence causes the peatlands to shrink (Charman, 2002). Studies have shown that some peat bogs in southern Sweden have decreased by at least 150 mm over the last 35 years, presumably because of changes in climate or hydrology (Franzén, 2006).

1.2 Physiology of peatlands

Peatlands are made up of two layers (diplotelmic), an upper layer (acrotelm) and a lower layer (catotelm) (Ivanov, 1981; Ingram & Bragg, 1983). The acrotelm is the active layer that occurs above the highest level of the water table, where the water table oscillates. This layer is aerated, in other words oxygen is available (Figure 1). Acrotelm thickness varies among different types of peatlands and plays a large role in peat accumulation rate. Peatlands with a thicker acrotelm are more favourable for trees as the acrotelm provides favourable conditions for root growth. Peat within the acrotelm layer is exposed to conditions favorable for decomposition for longer periods than peat within the catotelm, hence the degree of peat decomposition in the acrotelm is greater (Williams, 2003). *Sphagnum* peat usually has a higher degree of decomposition within the acrotelm. Drier acrotelms provide more aerobic conditions that favour a higher rate of decomposition in the layer (Belyea & Clymo, 2001).

Below the acrotelm lies the catotelm, an inactive layer with more humified, darker peat (Figure 1). Water flow in the catotelm is slow, and therefore water exchange with the underlying substrate, which causes the catotelm to be constantly saturated (Rydin & Jeglum, 2006). In stagnant water, oxygen transport is reduced and microorganisms rapidly consume the small amount available, hence oxygen availability within the catotelm is limited (Rydin & Jeglum, 2006). As a result, the degree of decomposition in this layer is reduced and the presence of anaerobic microorganisms is high. Williams (2003) suggests that in some peatlands peat within the catotelm layer may serve as a reservoir of relatively non-decomposed peat with a potential for carbon mineralization.

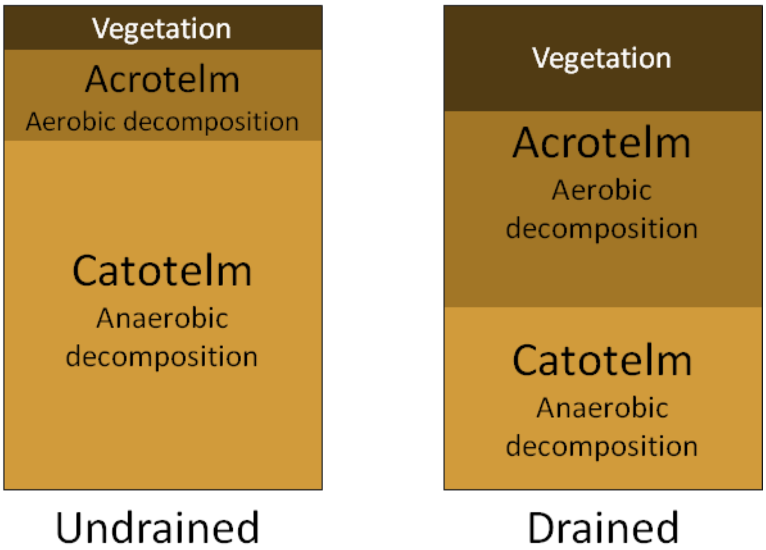


Figure 1. Location of acrotelm and catotelm in an undrained (left) and a drained (right) peatland. Vegetation is usually denser on drained peatlands as the acrotelm layer is aerobic and therefore provides more nutrients for plants (Modified by James, 2010 after Charman, 2002).

1.2.1 Vegetation

Peatlands are either ombrotrophic or minerotrophic (Sjörs, 1967; Stenbeck, 1985). Ombrotrophic peatlands (bogs) receive their water from precipitation directly on the surface and available nutrients are therefore small (Sjörs, 1967; Stenbeck, 1985). The most common bryophytes on bogs are the *Sphagnum* species. They are wetland specialists and are dominant on the poor, low-pH side of the peatland range (Rydin & Jeglum, 2006). Bogs dominated by *Sphagnum* species have a low Graminoid (grasses, sedges, cotton grasses, rushes) diversity whereas *Equisetum* (horsetails) species frequently dominate. Other types of bogs can have a higher Graminoid diversity, however, the diversity of shrubs and trees tends to increase with higher pH and available nutrients. Typical shrubs on wooded bogs are *Andromeda polifolia*, *Calluna vulgaris*, *Chamaedaphne calycuta*, *Erica tetralic*, *Vaccinium spp*, *Rhododendron tomentosum*, *Vaccinium uliginosum* and *Betula nana*.

Minerotrophic peatlands (fens) receive their water from two sources: precipitation and groundwater. Groundwater is constantly moving and contains nutrients, hence the available nutrients in the fens are higher compared to bogs (Sjörs, 1967; Stenbeck, 1985). The most common bryophytes in fens are Bryales (Brown moss, not a taxonomic entity), *Sphagnum* species only occur on nutrient-poor fens (Rydin & Jeglum, 2006). Fens are characterized by Graminoids and richer fens hold a considerable number of herbaceous species. Two common herbs on rich fens are the widespread *Menyanthes trifoliata* and *Rubus chamaemorus*. Rich fens are also usually characterized by orchids. Dominant tree species on fens and bogs are *Betula pendula*, *Picea abies*, *Pinus sylvestris* and *Alnus glutinosa*.

Conditions in peatlands are often acidic and nutrient-poor as cations from mineral soil decrease with time. The organic matter in peat has a high cation exchange capacity and tends to take up cations in exchange for hydrogen ions (Rydin & Jeglum 2006). Therefore, the accumulation of chemicals are often bound to the peat and very little is free in solution. This affects the pH and the availability of plant nutrients (primarily the availability of nitrogen). In general, nutrient and pH levels increase from bog to fen, hence the richness in plant species on peatlands increases from bog to fen (Rydin & Jeglum 2006).

Drainage increases the depth of the aerobic zone (Figure 1), which increases the amount of available nutrients and enhances the pH-value in the peatland. With changed conditions, new species invade the peatland. This leads to further dehydration of the peatland because invasion of plant species increases the evapotranspiration (evaporation and transpiration from plant to atmosphere). Drainage also increases the presence of large plants (e.g. trees) because the oxygen available to their roots increases.

1.2.2 Peat degradation

Degree of peat humification is a colourimetric method that provides information on the dryness or wetness of peatlands. This method can be employed in the field using visible stratigraphic record, the so called von Post scheme (Table 1), by observing the colour and texture of the peat stratigraphy (von Post & Granlund, 1926). Furthermore, peat humification can be measured in laboratory-based colorimetric assays that have been shown to be applicable to all peat types and more sensitive than the visible stratigraphic record (Blackford and Chambers, 1993). Humification data indicates the time elapsed between the death of plant matter and their remains reaching the anaerobic catotelm (Blackford, 2000).

Peat decomposition occurs mostly above the water table, with little or no decomposition once peat enters the deeper, saturated, anaerobic zone (Williams, 2003). Peat decomposition is also temperature dependent and the rate of decomposition differs between bogs and fens due to differences in substrate quality (Dioumaeva *et al*., 2003). Bogs and fens have different proportions of organic matter components, such as roots, which cause a difference in their sensitivity to temperature (Dioumeava *et al*., 2003).

Table 1. The von Post system of humification, H1-10 (von Post & Granlund, 1926).

Degree of humification, von Post					
			Lost material when squeezing between fingers		
	Plant structure	**Decomposed**	Peat mass	Water	**Character after squeezing**
H1	Clear	None	None	Clear	Clear structure
H2	Clear	Almost none	None	Clear, yellow	Clear structure
H3	Clear	Weakly	None	Turbid, brownish	Clear structure
H4	Clear	Very weakly	Insignificant	Turbid	Porridge like, but clear
H5	Moderately clear	Strongly	Some	Very turbid	Porridge-like, but clear
H6	Moderately unclear	Strongly	One third	Very turbid	Porridge-like, moderately clear
H7	Recognizable	Strongly	One half	Viscous	Porridge-like, moderately clear
H8	Unclear	Very strongly	Two thirds	Viscous	Roots, fibers, bark
H9	Almost none	Almost complete	Almost everything	Almost none	Some roots, fibers, bark
H10	None	Completely	Everything	None	None

Lighter-coloured *Sphagnum*-rich layers represent wetter and/or cooler conditions, whereas darker-coloured *Sphagnum*-rich layers represent drier conditions (Blackford, 2000). The degree of humification in a particular peat layer provides information as to the water conditions during the time of decomposition. The von Post scheme is a scale from 1 to 10 where 10 represents highly humidified organic matter that is completely decomposed (von Post, 1926) (Table 1). This method can be criticized for being too general and imprecise as it is a subjective measure dependant on the surveyor's eye. For example, it is difficult to determine whether a sample of peat is an "H4" or an "H5" and the grade of decomposition recorded for the same sample can vary greatly depending on the person. Errors would therefore be systematic, in other words, one survey may underestimate the degree of humification whereas another may overestimate the degree of humification.

1.3 Drainage during the past 90 years

During the past 90 years a number of drainage techniques have been implemented and the number of peatlands being drained has varied (Figure 2). From early 1900 to 1940 ditching of peatlands was common and done by hand (Eliasson, 2008). In the 1950s draining became more intense but with a more modern technique whereby dynamite was used to blast the ditches clear. In the 1960s techniques evolved to using excavators for forest ditching. This technique continued in lesser amounts but the intention of ditching was to protect the groundwater level from rising after the forest had been clear-cut. This technique was questioned in the late 1980s for being a threat to the environment as the leaching of nitrogen increased with draining. Drainage of peatlands has also decreased because of the threats to species richness within swamp forests habitats (Eliasson, 2008). In the present day it is difficult to attain permission for ditching a wetland due to the threats described above.

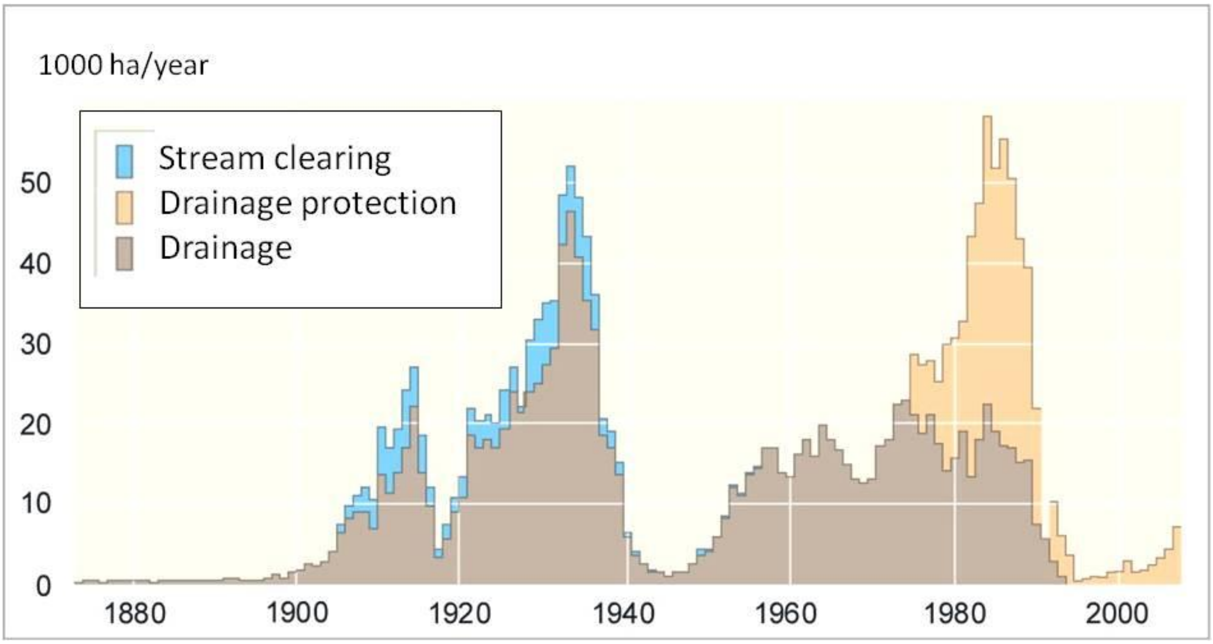


Figure 2. Forest ditching in Sweden with drainage, stream clearing and drainage protection 1870-1999. Brown colour represent drainage; blue colour represent stream clearing and orange colour represent drainage protection. (Bernes & Lundgren 2009).

1.4 Peatlands as carbon sinks

Peatlands are present in numerous regions of the world (covering about 3.5 % of the land mass) with the largest areas occurring in the Northern Hemisphere (World Energy Council, 2007). Peatlands are one of the largest (25 %) terrestrial carbon reservoirs holding between 120 and 460 Pg (1 Pg = 1 billion tons or 1000 x million tons) of all the accumulated terrestrial carbon since the Last Glacial Maximum (Smith *et al*., 2004; Weller, 2004). To provide a relative comparison, the quantity of carbon released by world combustion of fossil fuels is 8.7 Pg C/yr (Global Carbon Budget, 2008). Franzén (1994) suggests that peatlands play a central role in forcing climate change, particularly in the cooling down phase during the transition from interglacial to glacial conditions. As peatlands expand, the atmospheric CO_2 and the CH_4 levels decrease, causing a decreased greenhouse effect and subsequent global cooling effect (Charman, 2002), hence peatlands are an important carbon sink and their degradation through oxidization causes the carbon bound in peat to be released to the atmosphere as CO_2 and CH_4 (Kasimir-Klemedtsson *et al*., 1997). An increase in atmospheric CO_2 and CH_4 will have a significant impact on global warming (Le Treut *et al*., 2007; Naturvårdsverket, 2007; Kander, 2002). A warmer climate is predicted at high latitudes (Sweden included) that will lead to an increase in soil dryness (Manabe & Wetherald, 1986).

The carbon cycle in peatlands is schematically presented in Figure 3. Part of the carbon in peatlands photosynthesized by plants is returned to the atmosphere as CO_2. The remaining carbon is transformed into plant structures and finally deposited as dead plant matter. In the acrotelm approximately 80-95 % of the litter is decomposed by aerobic bacteria and released as CO_2 before it is sunk by the gradually rising water table (Clymo, 1984; Bartsch and Moore, 1985). In water saturated anaerobic parts of the peat, the decomposition processes are very slow (from less than 1% to a few percent [Clymo, 1984]) and C is released to the atmosphere primarily as CH_4.

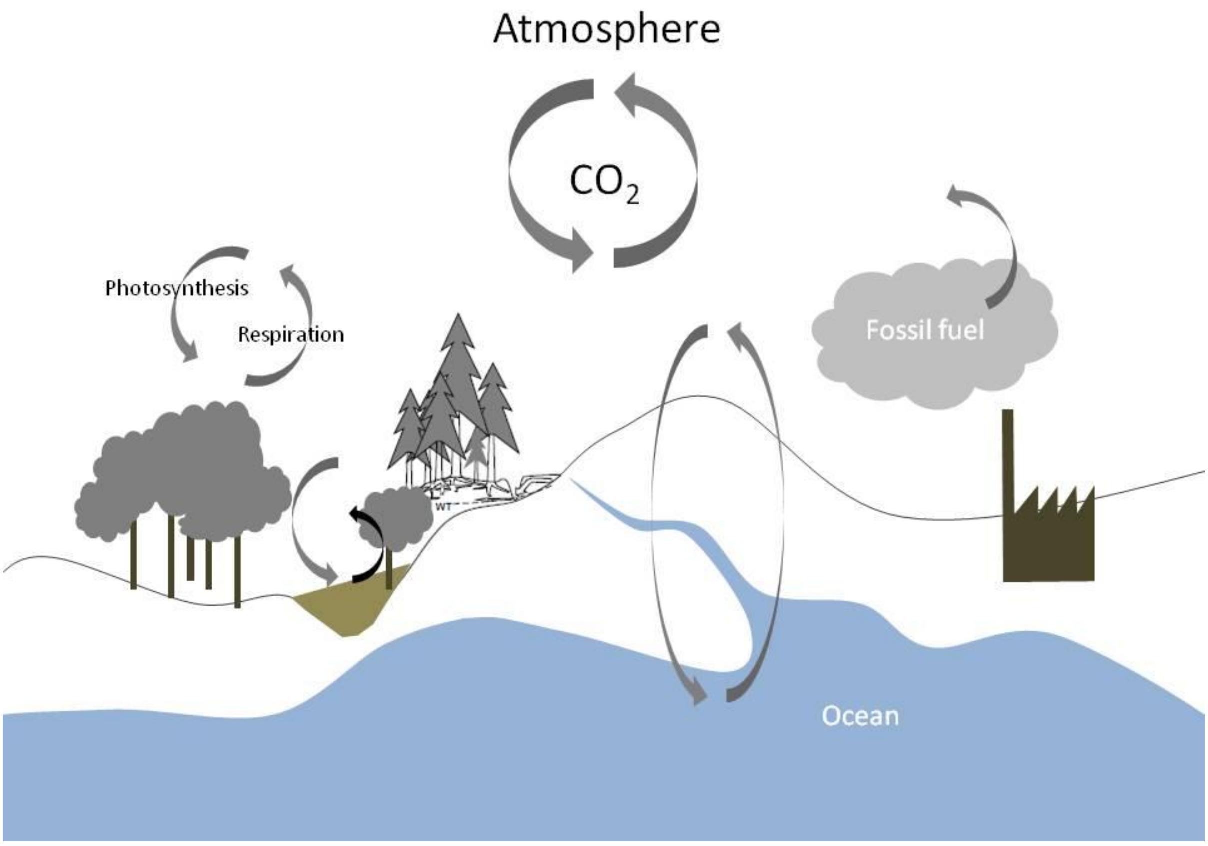


Figure 3. Diagram of the global carbon cycle. Carbon dioxide is released from vegetation through respiration and absorbed from the atmosphere through photosynthesis. Carbon dioxide is also released during burning of fossil fuels. Wetlands are one of the largest terrestrial carbon reservoirs, however carbon is released when wetlands are drained. Oceans and the atmosphere also exchange carbon dioxide. Dissolved carbon dioxide in the ocean is used by marine plants/algae in photosynthesis (Modified by James, 2010 after Earth observatory/Nasa).

1.5 The Swedish peat survey in the early 20th century

During World War One, Sweden's import industry of bituminous coal was threatened and the Committee of Peat (1916) realized the need for a domestic energy source to replace the bituminous coal. Surveys were to be conducted on peatlands in Götaland and Svealand, except for Dalarna (Figure 4). Surveys would measure not only the energy content in peat but all aspects of the total peatland including the size, peat types and condition. This would be useful as a basis for identifying suitable energy peatlands and determining the amount of available energy peat. Systematic surveys of peat resources carried out by the Geological Survey of Sweden (SGU), and initiated in response to an increasing demand for energy resources during the early 20th century, contributed to an increased and detailed knowledge of the distribution and properties of peat (von Post & Granlund 1926).

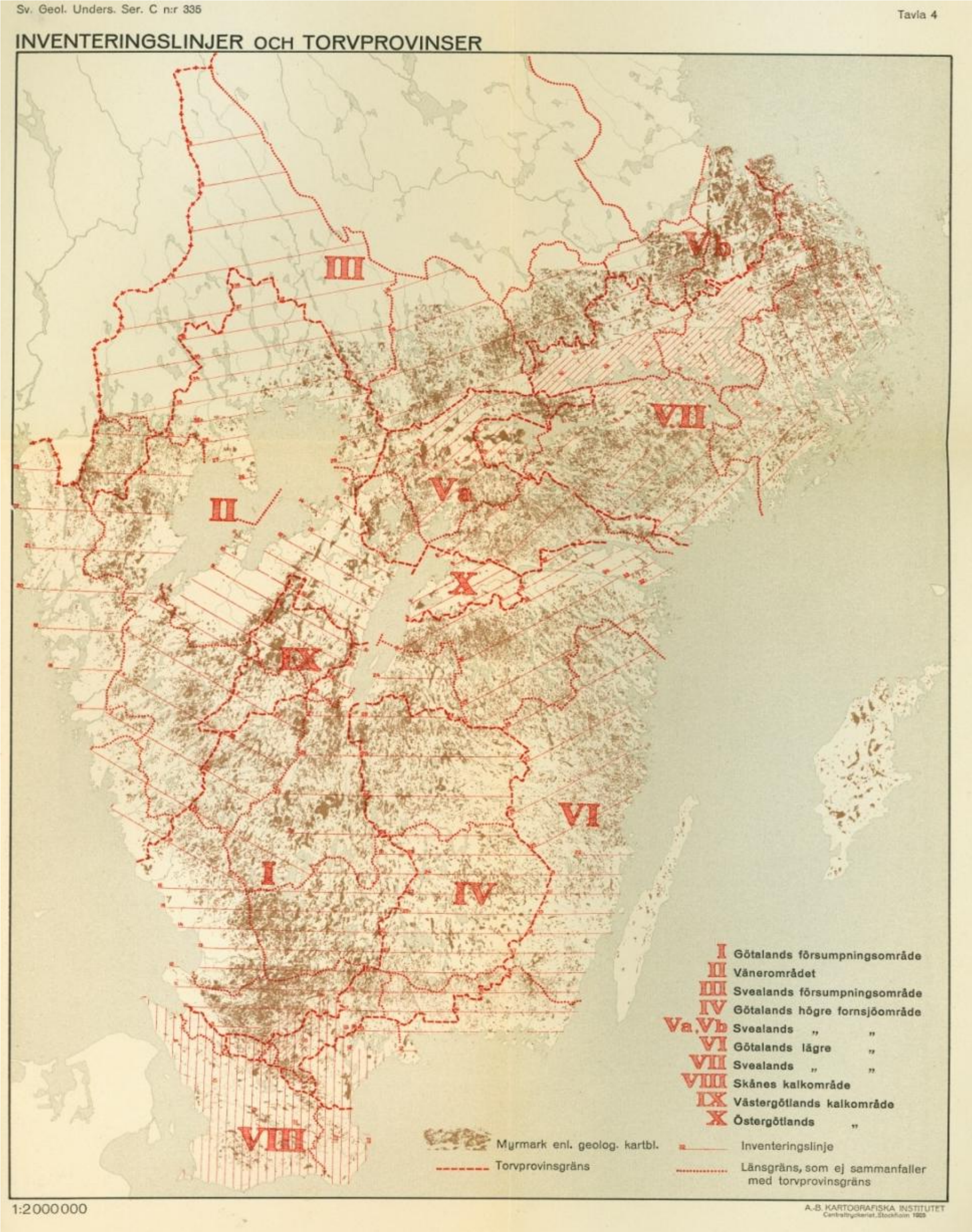


Figure 4. Map of middle and southern Sweden from 1926 with the lines that were surveyed in the early 20th century (von Post & Granlund, 1926).

The unpublished peat stratigraphic and chronological data for additional sites investigated in connection with the regional mappings are stored in the archive of the Geological Survey of Sweden (SGU).

1.6 Purpose and questions

This study aims to determine the feasibility of using data from SGU's peat archive to examine changes in peatlands (vegetation and peat structure) from the beginning of the 20th century to the present. Furthermore, the study also aimed to evaluate the possibility to quantify the amount of peat that had oxidized since the surveys in the early 20th century.

Questions to be answered:

- Can data from the surveys made in the early 20th century be used to perceive changes in peatlands?
- Have the investigated peatlands changed since the early 20th century?
- Has the vegetation changed since the early 20th century?
- Can data from the archive of the Geological Survey of Sweden contribute to understanding the amount of organic matter that has been oxidized in drained-out peatlands since the beginning of the 20th century?

2. METHODS

2.1 Investigated area

Investigated peatlands were situated along a line approximately 40 km long between Uppsala (start of line 59°56´N, 17°51´E) and Hallstavik (end of line 60°0.3´N, 18°26´E) (Figure 5). This line was chosen because the diaries from the survey in early 20th century had good descriptions of peat structure as well as the vegetation. Bedrock in the area is dominated by acid to intermediate intrusive rock (e.g. granite and granodiorite) with segments of basic rocks (e.g. gabbro and basalt). During the late Weichselian ice moved in a NNE direction in this area and left the area about 11 000 years ago (Lundqvist, 2002). General Quaternary deposits in the area are large bouldered till, which were deposited during the ice movement together with sandy till. When the ice retreated from the area, glacial clay was deposited on top of the till. Varved glacial clay in the Uppsala area contains limestone that was transported by the ice from an area located in the Gulf of Bothnia (Strömberg, 1992). After the ice melted postglacial clay was deposited on top of the glacial clay. The investigated peatlands are located between 15 and 27 m a.s.l. During early stages of the Littorina Sea the area was covered by water and the land rose from the Littorina Sea about 2500 to 3500 years ago (SGU). Mean annual rainfall in the area is 700 mm and the mean annual temperature is 5°C (1961-1990, Swedish Meteorological and Hydrological Institute, SMHI).

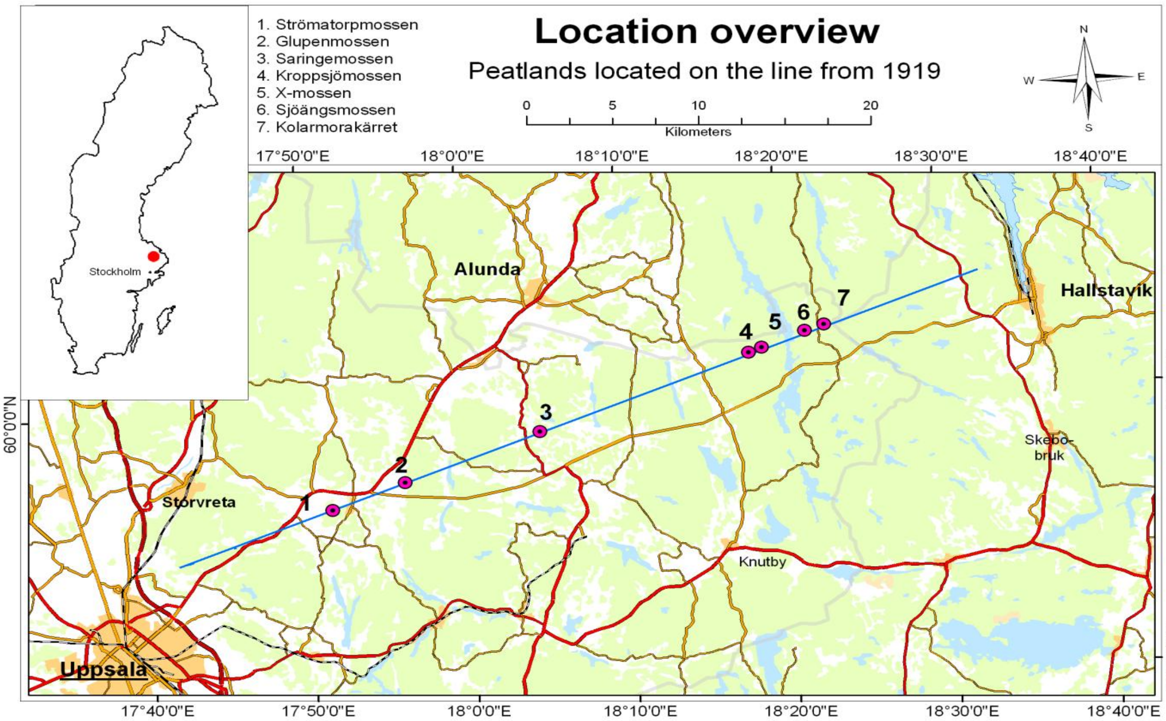


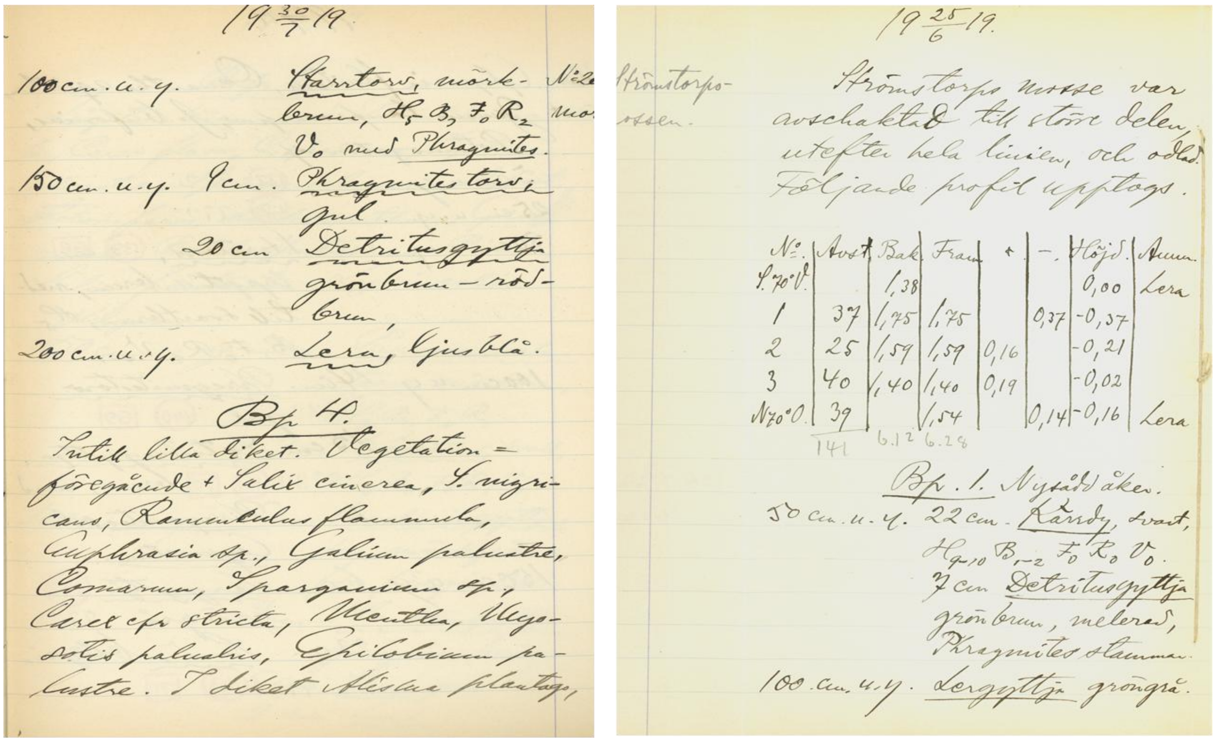
Figure 5. Investigated area located North East of Uppsala, between Uppsala and Hallstavik. An approximately 40 km long line from the survey in 1919 with the seven peatlands that were revisited in 2010 plotted.

2.2 Digitizing and Archive work

The first part of this study was to determine a good survey line (a line with descriptions detailed enough to allow the peatlands and drilling sites to be revisited) where peat investigations were performed in the early 20th century. In the archives of SGU, field-diaries are kept in the peat investigation archive. A suitable line of approximately 40 kilometers, in the direction of N 70° E was selected with a start point just north of Old Uppsala. This line was investigated by Martin Ekström during the summer of 1919, and consists of 140 drillings from 26 peatlands.

To locate the investigated peatlands, the geological maps used in 1919 (SGU Aa 27, Aa 31, Aa 104, Aa 111) were rectified into a geographic information system (GIS) (Esri 9.3) and the line from the field map was superimposed onto the GIS map.

In the diaries each peatland is described with the distance from the edge of the peatland to the first drilling point and the distances between each drilling (Figure 6). With approximate locations provided by the surveyors it was possible to rediscover the areas on the modern maps of Quaternary deposits. There were some disagreements between the surveyor's measurements and the modern coordinates as distances were determined by pacing out the distance on foot. For each drilling the layers with humification grade, wetness, and wood content were recorded.



19 30/7 19

100 cm. u. y. Starrtorv, mörkbrun, H5 B3 F0 R2 V0 med Phragmites.

150 cm. u. y. 9 cm. Phragmites torv, gul.

20 cm Detritusgyttja grönbrun – rödbrun,

200 cm. u. y. Lera, gråblå.

Bp. 4.

Intill lilla diket. Vegetation = föregående + Salix cinerea, S. nigricans, Ranunculus flammula, Euphrasia sp., Galium palustre, Comarum, Sparganium sp., Carex cfr stricta, Mentha, Myosotis palustris, Epilobium palustre. I diket Alisma plantago,

19 25/6 19.

Strömstorps-mossen.

Strömstorps mosse var avschaktad till större delen, utefter hela linien, och odlad. Följande profil upptogs.

Nº	Avst	Bak	Fram	+	−	Höjd	Anm.
S.70°V.		1,38				0,00	Lera
1	37	1,75	1,75		0,37	-0,37	
2	25	1,59	1,59	0,16		-0,21	
3	40	1,40	1,40	0,19		-0,02	
N70°O.	39		1,54		0,14	-0,16	Lera
	141	6.12	6.28				

Bp. 1. Nysådd åker.

50 cm. u. y. 22 cm. Kärrdy, svart, H9-10 B1-2 F0 R0 V0.

7 cm Detritusgyttja grönbrun, melerad, Phragmites flammor.

100 cm. u. y. Lergyttja grongrå.

Figure 6. Two pages of a diary from the survey by Martin Ekström in 1919. Here the surveyor describes the vegetation and peat stratigraphy at one site (left) and distance of each site visualized as a table (right).

All the coring sites were digitized into GIS with the assistance of the diaries. Determining the sites of some of the drilling sites was difficult due to vague descriptions in the diaries. Hence, there could be some inconsistency in the sites.

Comparison of the modern map of Quaternary deposits with the 26 peatlands surveyed during 1919 made it possible to ascertain that only 14 of these peatlands still contained peat.

2.3 Field study

Field-work on selected peatlands was performed in mid-August 2010. 14 peatlands were initially chosen from the dataset, however the number reduced to seven as the other seven were too difficult to reach due to boulder-rich till, or the roads to access the peatlands were barred.

By digitizing the information from the 1919 survey coordinates of each coring site were available. Coordinates were helpful to locate the correct peatland but to find a specific coring site was best done in the field using the descriptions of the surroundings from the diaries. As the total width of the peatland was known as well as the direction and specific vegetation an approximate location could be found.

Upon locating the peatland and approximately standing on the line with a compass direction according to the diaries, the search for the coring sites began. From the edge of the peatland to the first coring site to the next and so on, a measurement by foot according to the diaries was made. At each coring site a GPS coordinate was taken in order to be able to revisit the line in the future. A protocol of the layers collected with a Russian peat corer was made. For each layer, the depth (cm), type of peat, humification grade (1-10, von Post scheme) and wetness (1-4) was recorded. The surrounding vegetation and specific topography was also recorded (within an area of c. 5 x 5 m). No detailed inventory of the vegetation was conducted.

In order to determine changes in the observed vegetation between 1919 and 2010 plant species were divided into categories by vegetation type; cryptogams (ferns, horsetails and lycopods), trees, bushes, grasses, *carex*, water plants, low herbs and high herbs. Furthermore, vegetation was also divided into categories by specific requirements: nutrient-poor and humid, nutrient-rich and humid, and nutrient-rich and dry according to Mossberg and Stenberg (2003). For lists of species and to which category they belong refer to Appendix 1.

2.5 Colorimetric analysis

A colorimetric analysis was conducted in order to determine the humification in a sample of peat and compare it with the grades recorded by eye using the von Post scale. For this analysis a core dominated by *sphagnum* peat collected from a peatland in field was used.

The colorimetric analysis method followed Borgmark (2005), which is a modified method from Blackford and Chambers (1993). For the analysis 17 peat samples of 1-2 cm^3 were taken from the core at random intervals. Each of the samples was then freeze-dried for 43 h before being homogenized. 50.0 ± 0.3 mg of each sample was then placed into separate 50 ml sample tubes. 1000 ml of 8% NaOH solution was prepared and then 25 ml was added to each sample tube. The time of initial mixing was noted (t=0). Tubes were placed without caps in a 95°C water bath for 1 h. 25 ml of distilled water was then added to each sample tube. The samples were mixed with a vortex for 10 sec each and then centrifuged for 10 min at 4000 rpm. Samples were filtered and 25 ml of the filtered solution and 25 ml of distilled water was then placed into a 50 ml volumetric flask. 30 min before measurement the spectrophotometer was turned on and set to 540 nm and turned on to absorbance (Abs). Distilled water was taken up in the flow cell to reset the spectrophotometer at 0.000 Abs. Each sample was analyzed in absorbance scale 4 h after t=0. Each sample was measured three times and between the samples the spectrophotometer was reset to Abs=0.000.

To compare the two measurement techniques all the data were standardized separately to provide a comparable scale for each category. Standardization was performed using the formula: STANDARDIZE = x (measured data) * (average)* Standard deviation (SD).

3. RESULTS

Considerable variation in both peat structure and vegetation was observed in the seven peatlands investigated in 2010 compared to the datasets made in 1919 (Figure 8a-d, 10a-c, 12, 13). Four of these were disturbed peatlands (drained, planted etc.) and three were undisturbed peatlands in 2010 (Table 2). Whether the disturbed peatlands were already disturbed in 1919 was unknown for a number of peatlands as only some of the historical datasets provided this information. However, comparison of the descriptions of peat structure and vegetation from 1919 with those from 2010 suggest some impact on the disturbed peatlands during the past 90 years. This is exemplified in Table 2, which provides a good overview of the type of land use that occurred in both 1919 and 2010.

Table 2. General description of land use for each coring site in 1919 and 2010.

Peatland	Coring site	1919	2010	Disturbed	Disturbed
1.Strömatorpmossen	1	Field	Tree plantation	Yes	Yes
	2	Field	Tree plantation	Yes	Yes
	3	Equisetum bog	Ditched fen	Unknown	Yes
2. Glupenmossen	1	Lagg fen	Lagg fen	No	No
	2	Pine bog	Pine bog	No	No
	3	Pine bog	Pine bog	No	No
3. Saringemossen	1	Field	Abandoned field	Yes	Yes
	2	Alnus carr	Forest fen	Unknown	Yes
	3	Carex bog	Forest fen	Unknown	Yes
	4	Eriophorum bog	Forest fen	Unknown	Yes
4. Kroppsjömossen	1	Bog	Bog	No	No
	2	Pine bog	Pine bog	No	No
	3	Bog	Pine bog	No	No
	4	Pine bog	Bog	No	No
	5	Alnus carr	Alnus carr	No	No
5. X-mossen	1	Forest bog	Clear-cut forest	Unknown	Yes
6. Sjöängsmossen	1	Pine bog	Pine bog	No	No
	2	Pine bog	Pine bog	No	No
	3	Pine bog	Pine bog	No	No
	4	Pine bog	Pine bog	No	No
	5	Pine bog	Pine bog	No	No
7. Kolarmorakärret	1	Alnus carr	Alnus carr	Yes	Yes
	2	Alnus carr	Tree plantation	Yes	Yes
	3	Alnus carr	Tree plantation	Yes	Yes
	4	Alnus carr	Tree plantation	Yes	Yes

3.1 Changes in peat layers

Peat layer thickness in 2010 had decreased in 18 out of 25 coring sites and had increased in seven coring sites when compared to 1919 cores (Figure 7). Based on the mean depths of the peat layers (mean of corings) within each peatland from 1919 and 2010, five peatlands had distinct reductions in the peat layer (on average a 31 cm reduction in the peat layer) whereas others showed increases in the peat layer (on average a 10 cm increase). Kroppsjömossen and Sjöängsmossen were undisturbed peatlands and showed the highest growth with averages of 17.4 cm and 3.8 cm growth respectively. Strömatorpmossen, Saringemossen, X-mossen and Kolarmorakärret were disturbed peatlands and had an overall loss of on average 7.3 cm, 85.2 cm, 20 cm and 28 cm respectively. For tables with profiles from each coring see Appendix 2 and 3.

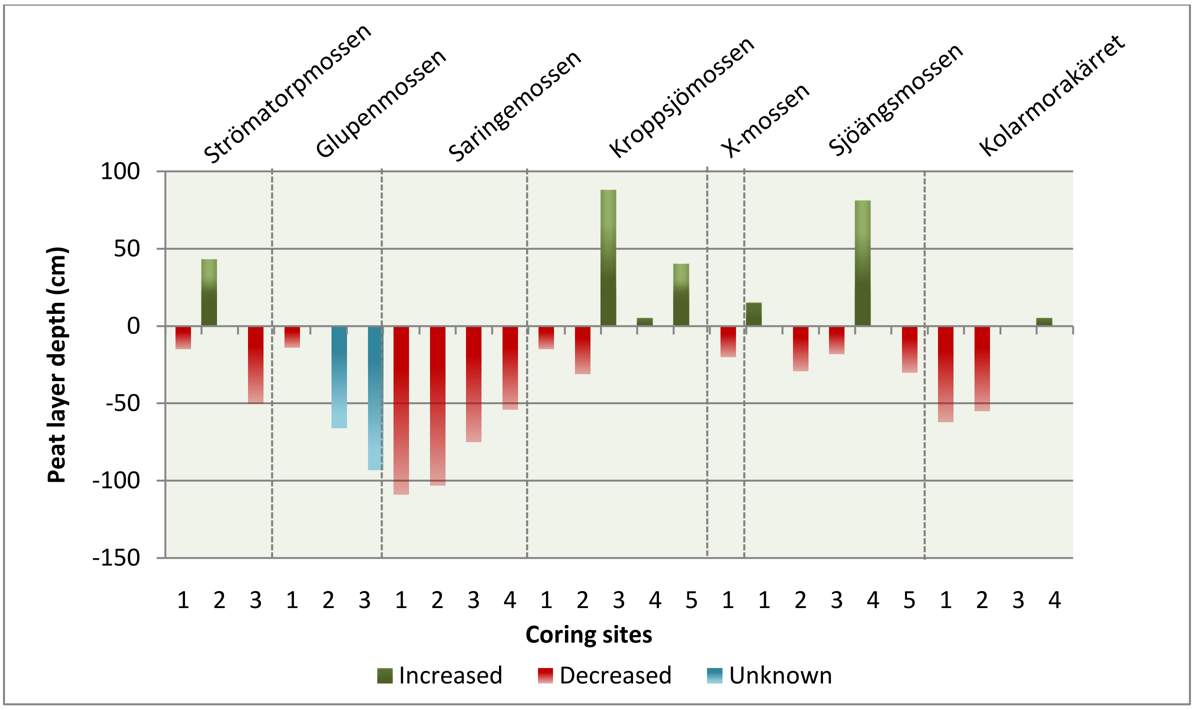


Figure 7. Diagramatic presentation of the change in peat layers for each coring site from 1919 to 2010. Blue bars represent Glupenmossen coring sites 2 and 3 where the peat layer depth was unable to be measured in 2010 due to an inability to push the corer throught the peat layer.

Two of the disturbed peatlands, Strömatorpmossen and Kolarmorakärret, had some sites where the peat layer had increased (Fig 8a and 8d), while the other two, Saringemossen and X-mossen, had a reduced peat layer thickness at all sites (Figure 8b and 8c). At Kolarmorakärret it was clear that the peat level had reduced as a few trees (approximate age 50 years) had roots above the ground (Figure 9) which occurs when the surface sinks after the tree has germinated.

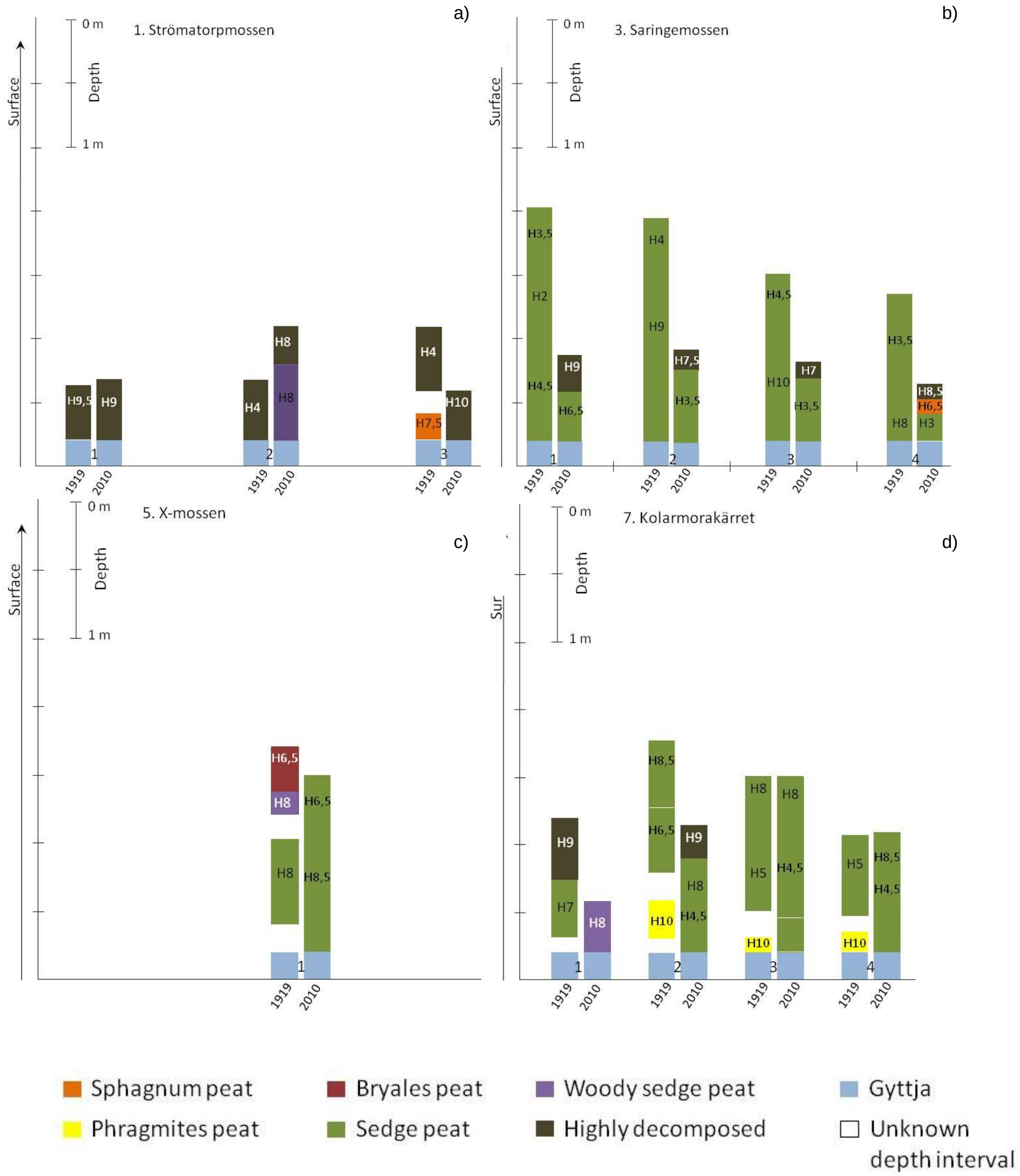


Figure 8a, b, c and d. Stratigraphic profile from four disturbed peatlands, (a) Strömatorpmossen, (b) Saringemossen, (c) X-mossen and (d) Kolarmorakärret. Numbers between each set of bars represent the drilling site within each peatland and each bar represents the stratigraphic profile from either 1919 or 2010 (denoted below the bar). The bottom layer (light blue) represents the gyttja layer (unspecified gyttja) and on top of that, each layer of peat up to the surface is presented. Numbers in each layer represent the grade of humification (H). The unknown (white) boxes are there because information about that depth was missing in the diaries from 1919. A Swedish translation of peat types can be found in Appendix 4.

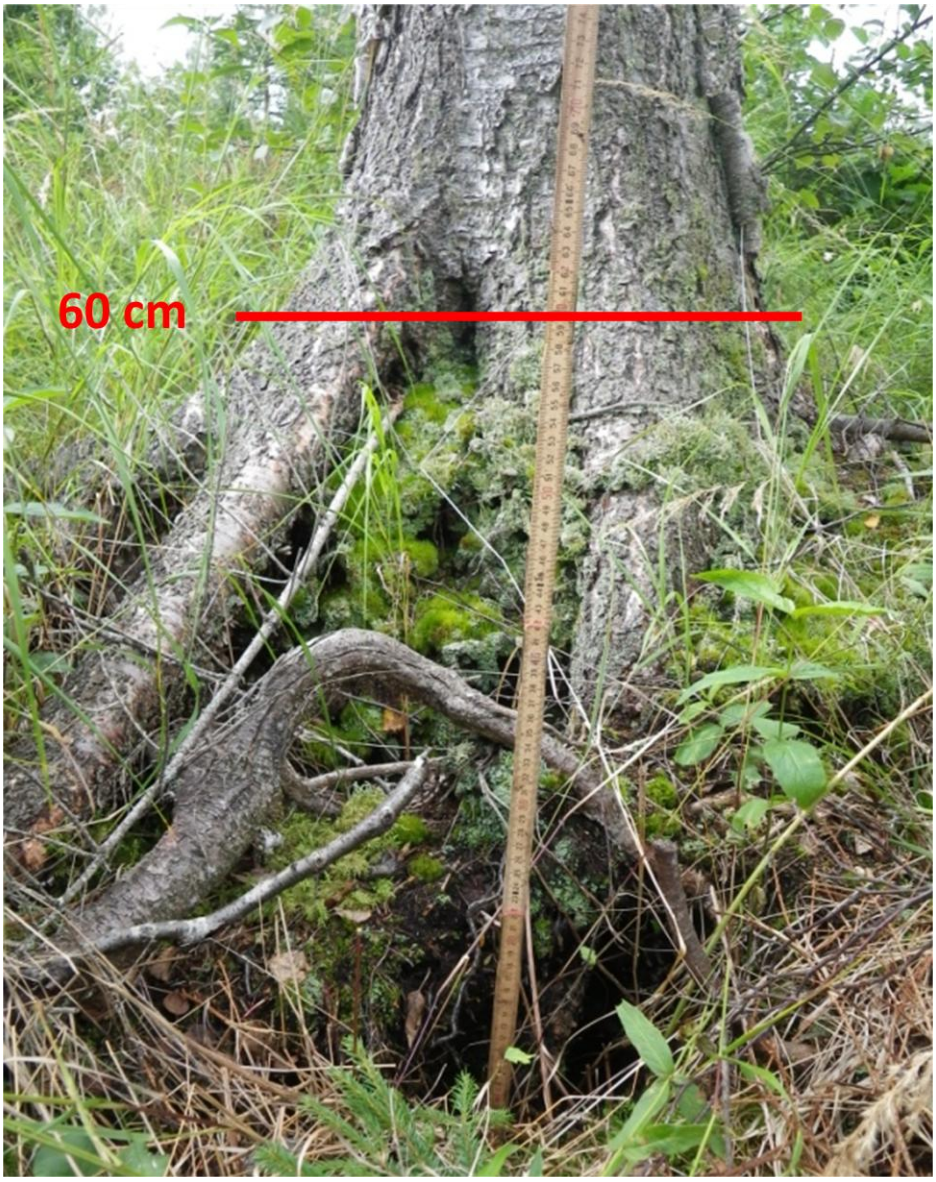


Figure 9. An approximately 50 year old birch*, Betula pendula*, from Kolarmorakärret, with roots 50-60 cm above ground indicating a decreased thickness of the peat layer over the past 50 years. (Photo: Amanda James 2010).

Coring in the undisturbed peatland, Glupenmossen was difficult (unable to push the core through the peat), hence the depth of the peat layer was unknown (Figure 10a). In the undisturbed peatland, Kroppsjömossen, sites 3 and 5 had increased peat thickness whilst the other sites had decreased (Figure 10b). In this peatland the peat types in each layer from 2010 varied considerably from the peat type described in 1919 (Figure 10b). Similar trends were observed for the undisturbed peatland, Sjöängsmossen, where coring sites 1 and 4 had increased and the rest had decreased (Figure 10c). Peat types in the layers from 1919 were dominated by woody sedge peat whereas 2010 corings showed peat layers dominated by sedge peat.

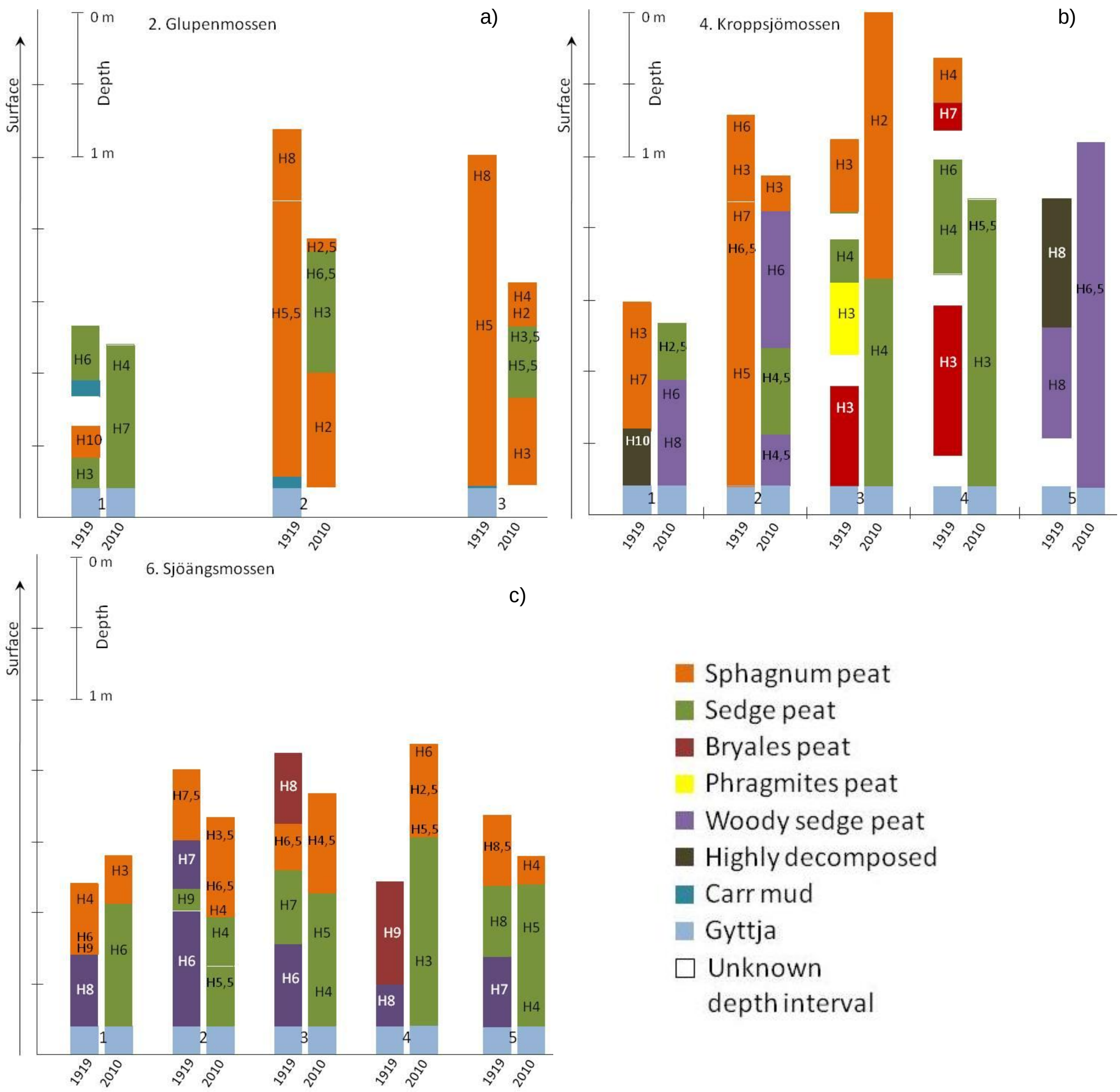


Figure 10a, b, c. Stratigraphic profile from three undisturbed peatlands, (a) Glupenmossen, (b) Kroppsjömossen and (c) Sjöängsmossen. Numbers between each set of bars represent the drilling site within each peatland and each bar represents the stratigraphic profile from either 1919 or 2010 (denoted below the bar). For Glupenmossen 2010 coring sites 2 and 3 have unknown depth intervals (white in the bottom). The bottom layer (light blue) represents the gyttja layer (unspecified gyttja) and on top of that, each layer of peat up to the surface is presented. Numbers in each layer represent the grade of humification (H). The unknown boxes are there because information about that depth was missing from the diaries from 1919. A Swedish translation of peat types can be found in Appendix 4.

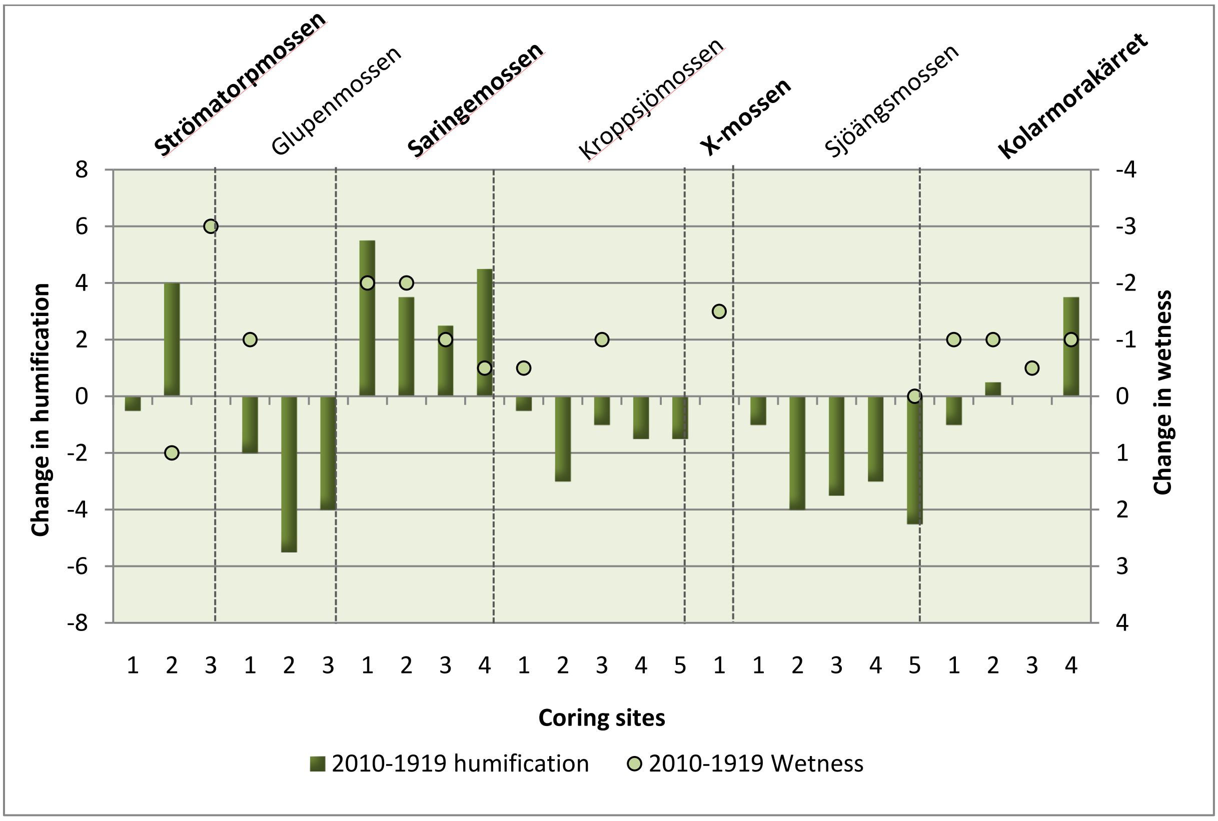


Figure 11. Difference in humification and wetness grade between 2010 and 1919 at the surface of all coring sites. Left axis denotes difference in humification grade between 2010 and 1919; represented by bars. Right axis denotes difference in wetness grade between 2010 and 1919; represented by dots. Negative values for humification/wetness grade occur when 2010 values are lower than those from 1919 whereas the opposite is true when 2010 values are higher than 1919 values. Furthermore, there is a relationship between humification and wetness grade whereby peat with high humification will have low wetness and vice versa. Names in bold are disturbed peatlands.

All the peatlands had either a lower degree of wetness in 2010 (except for coring site 2 in Strömatorpmossen) or had not changed at all (Figure 11). At all of Saringemossen´s coring sites, Strömatorpmossen´s coring site 2 and Kolarmorakärret´s coring site 2 the humification value vas higher in 2010. At all other coring sites humification values were lower in 2010 compared to 1919.

3.2 Changes in vegetation

There were substantial differences in the number of species present between 1919 and 2010 (Figure 12). At all coring sites in 2010 new[1] species were observed and at almost all coring sites some species that had occurred in 1919 were absent[1] in 2010 (Figure 12). The number of new species observed across all coring sites (mean ± 1 SD) was 4.8 ± 3.3 species whereas the number of species that had disappeared[1] since 1919 (mean ± 1 SD) was 5.8 ± 6.4 species. The number of species present in both 1919 and 2010 across all coring sites (mean ± 1 SD) was 3.9 ± 2.8 species.

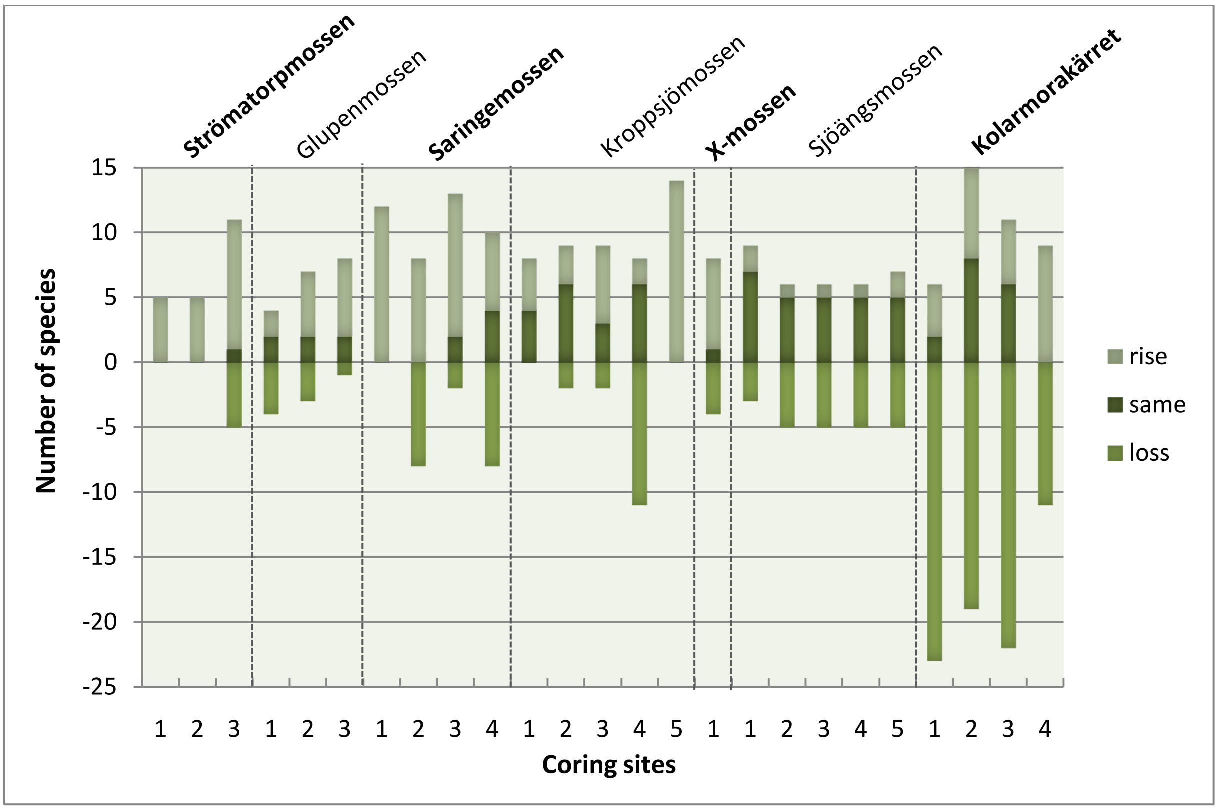


Figure 12. Variation in the number of species of vegetation between 1919 and 2010. Light-green bars represent the number of species observed in 2010 but not in 1919 (rise). Dark-green bars represent number of species observed in both 1919 and 2010 (same). Green bars represent the number of species observed in 1919 but not in 2010 (loss). Names in bold are disturbed peatlands.

When plant species diversity was divided into nutrient and moisture requirements there were some interesting comparisons. Across all peatlands there was 3 ± 0.5 new[1] plant species (mean ± 1 SD) with requirements for nutrient-poor and humid conditions in 2010 whereas 13 ± 1.3 species (mean ± 1 SD) from the same category had disappeared[1] since 1919 (Figure 13). Number of plant species (mean ± 1 SD) with requirements for nutrient-rich and humid conditions were fairly similar with 26 ± 2.5 new[1] species compared to 22 ±4.6 species that had disappeared[1] (Figure 13). With respect to plant species requiring nutrient-rich and dry conditions 35 ± 4.2 new[1] species (mean ± 1 SD) were observed in 2010 compared to almost three times (12 ± 2; mean ± 1 SD) fewer plants species observed for this category in 1919 (Figure 13).

[1]New species are species that were only observed and recorded in 2010 but not in 1919. Disappeared/absent species refers to species that were only observed and recorded in 1919 but not in 2010.

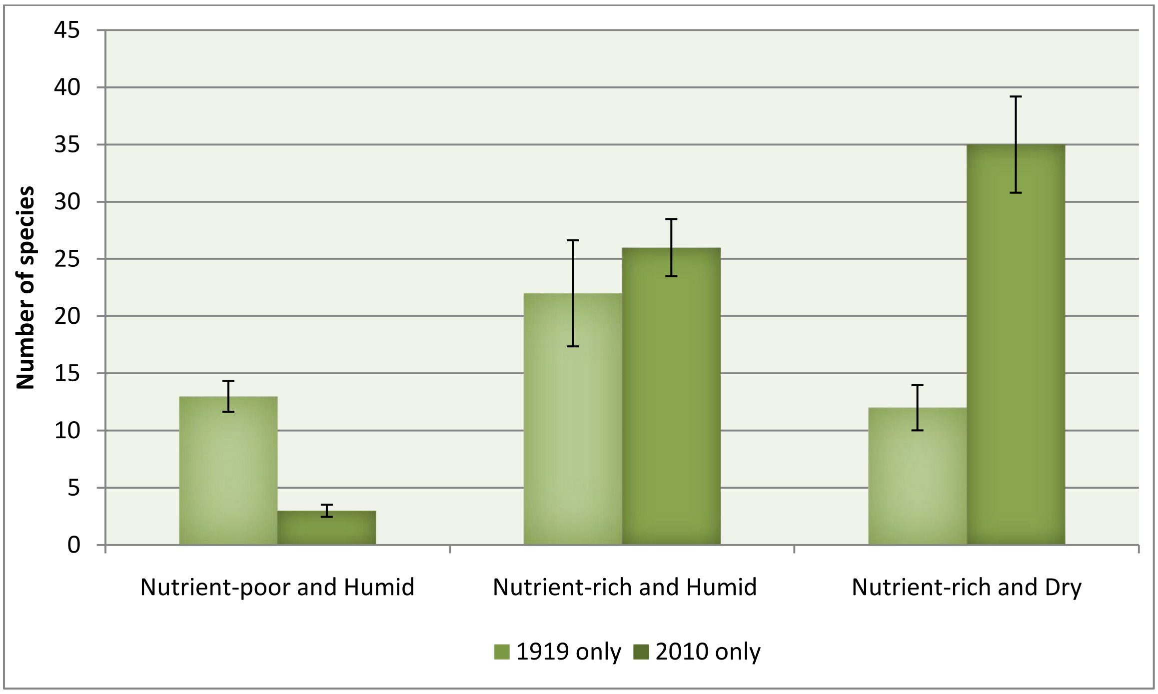


Figure 13. Variation in species only observed in 1919 and only observed in 2010 according to the requirements for nutrient- and moisture conditions the species have. Note: species represented in both 1919 and 2010 are not presented here as they do not show the change.

Three of the four disturbed peatlands (Strömatorpmossen, Saringemossen and X-mossen) had a larger number of species with requirements for nutrient-rich and humid conditions observed in 2010 but not in 1919 compared with those observed in 1919 but not in 2010 (Table 3). Kolarmorakärret was the exception with three times more species observed in 1919 but not in 2010 than observed in 2010 but not in 1919 (Table 3). The disturbed peatland Saringemossen had one new[1] species with requirements for nutrient-poor and humid conditions observed in 2010 compared with 4 species that were only observed in 1919 (Table 3). The other two disturbed peatlands had no new[1] observations of species with requirements for nutrient-poor and humid conditions (Table 3).

Changes in undisturbed peatlands between 1919 and 2010 were not that remarkable (Table 3), although Kroppsjömossen had more species (4 new[1]) with requirements for nutrient-rich and dry conditions in 2010 compared with those which were observed only in 1919 (1 species).

Table 3. Variation in species on each peatland only observed in 1919 and only observed in 2010 according to the requirements for nutrient- and moisture conditions for the species. Names in bold font are disturbed peatlands.

	Nutrient poor and Humid		Nutrient rich and Humid		Nutrient rich and Dry	
Peatland	Only 2010	Only 1919	Only 2010	Only 1919	Only 2010	Only 1919
1.Strömatorpmossen	0	1	7	2	8	1
2. Glupenmossen	0	1	1	0	0	0
3. Saringemossen	1	4	7	4	11	2
4. Kroppsjömossen	1	0	3	3	4	1
5. X-mossen	0	2	3	0	4	1
6. Sjöängsmossen	1	2	1	0	0	1
7. Kolarmorakärret	0	3	4	13	8	6
Total	3	13	26	22	35	12

Dividing vegetation into categories by type of species (trees, bushes, low herbs etc.) provided a better indication of vegetation assemblages in each peatland (Figure 14a-d). In three coring sites from 1919 (Strömatorpmossen 1 & 2, Saringemossen 1) detailed descriptions of the vegetation were missing from the diary as the surveyor wrote “cultivated land” in his description (Figure 14a, b). In Strömatorpmossen´s third coring site the vegetation description from 1919 was available. Comparisons with the data from 2010 suggested a greater number of species were present in the more recent survey, e.g. more grasses, high herbs and bushes (Figure 14a).

In Saringemossen´s coring site 2 the high herbs and grasses had disappeared (Figure 14b). Although there were more trees and cryptogams observed in 2010, the species abundance in that site had decreased. Saringemossen´s third coring site had a higher presence of different species observed but the water plants from 1919 were not observed. In X-mossen there were trees and cryptogams that were observed only in 2010 and there were a higher number of different species observed in 2010 (Figure 14c).

Changes in vegetation were obvious in Kolarmorakärret (Figure 14d) where coring site 1 had 22 different species observed in 1919 compared to only six observed species in 2010. In the second coring site there were also 22 different species in 1919 that had reduced to 14 in 2010. No new species were observed in coring sites 1 and 2. However, in the 3rd coring site there were only 10 species observed in 2010 compared with 23 observations in 1919. This reduction was predominantly caused by losses of high herbs, bushes and all of the cryptogams. Although more grass species were observed. The final coring site in Kolarmorakärret had fewer species of low herbs, water plants and *carex* observed but more trees, grasses and high herbs (Figure 14d).

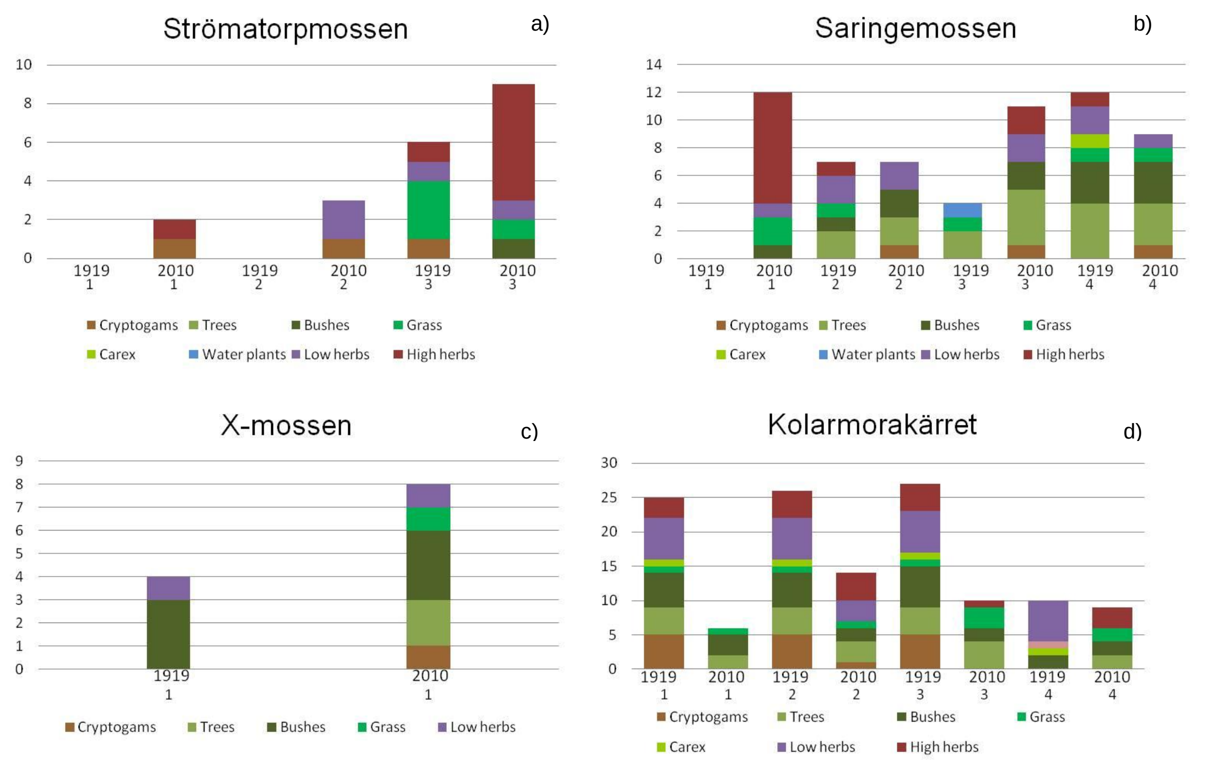


Figure 14a, b, c, d. Variation in species abundance from 1919 and 2010 in four disturbed peatlands, (a) Strömatorpmossen, (b) Saringemossen, (c) X-mossen and (d) Kolarmorakärret. Species are divided into eight categories. Each coloured box represents the number of different species within the catogory for each coring site.

In the undisturbed peatlands the species assemblages (e.g. bushes, trees, low herbs) from 1919 were still represented in 2010 although with a reduced number of species (Figure 15a, b, c). In Sjöängsmossen (Figure 15c) there were fewer species of bushes observed in 2010 than in 1919 but there was a greater number of tree species observed in 2010 compared to 1919. The species diversity (number of different species within each category) had decreased further in the middle of the peatland (coring sites 2-4) compared to the edges of the peatland (Figure 15c)

In all coring sites from Glupenmossen the diversity of tree species observed had increased although the number of observed low herb species had decreased (Figure 15a).

In Kroppsjömossen the number of species had increased in coring sites 1-3 with more bush species observed in 2010 compared to 1919 (Figure 15b). Conversely, the number of species in coring sites 4 and 5 had decreased with fewer species of bushes and no grass species (Figure 15b). Number of observed species from coring site 4 in 1919 had reduced from 15 to only 8 in 2010. This trend was mirrored in coring site 5 which reduced from 16 species in 1919 to 12 in 2010 (Figure 15b).

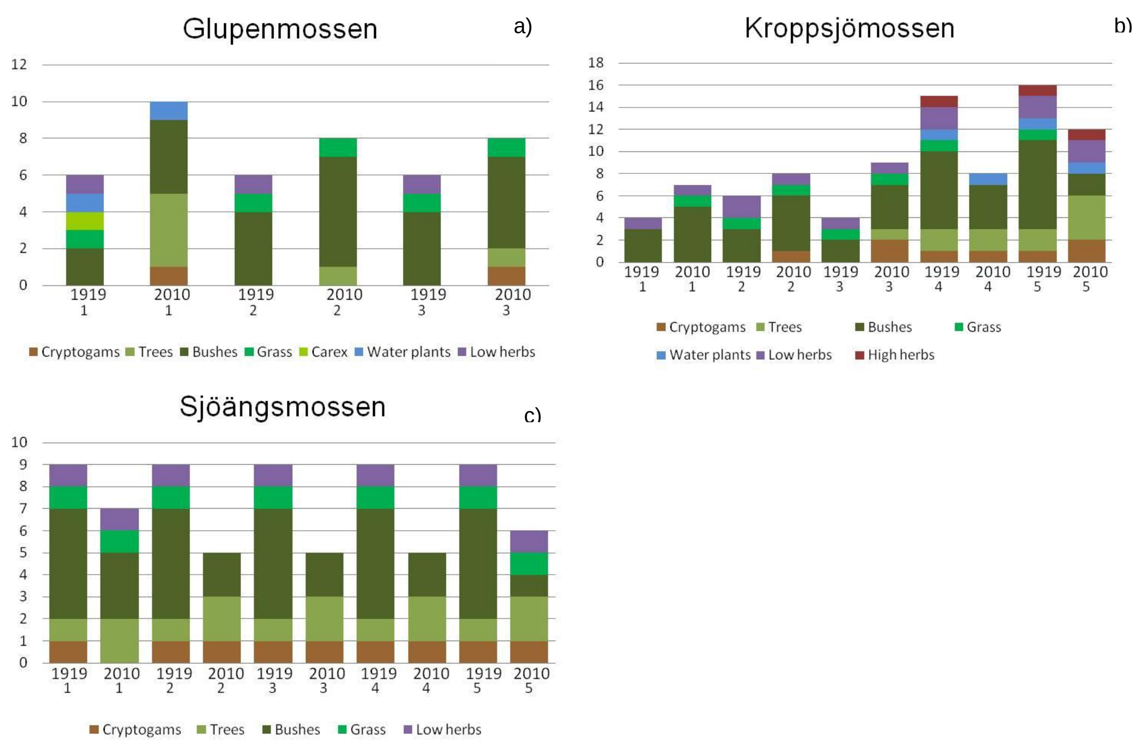


Figure 15a, b, c. Variation in species abundance from 1919 and 2010 in three undisturbed peatlands, (a) Glupenmossen, (b) Kroppsjömossen and (c) Sjöängsmossen. The species are divided into categories of eight and one colour box represents the number of different species within the category for each coring site.

3.5 Colorimetric analysis

Measurement of humification grade by spectrophotometer showed a greater variation compared to that of von Post´s humification scale using visible stratigraphic record (Figure 16). However, both measurement techniques show similar trends, darker/more humified peat with increasing depth.

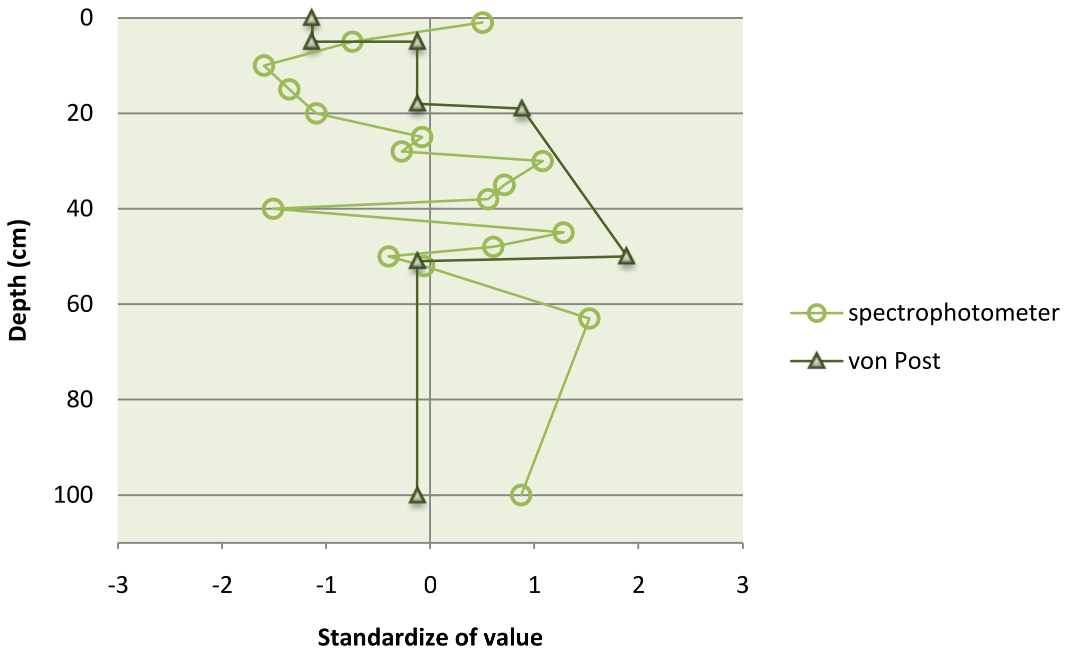


Figure 16. Comparison of measurement techniques for humification grade. Graph represents a comparison of humification grade of a single peat core at different depths measured by a spectrophotometer (light green) and by sight using the von Post humification scale (dark green). Higher values with increasing depth indicates increased humification.

4. DISCUSSION

This study provides strong evidence that a general decrease in peat thickness has occurred in most investigated peatlands over the past 90 years but more importantly it suggests that historical peat data sets are useful to show general changes in peatlands but not at the coring site level. Resolution is low; however, the method does provide information about general changes across peatlands.

4.1 Rediscovering coring sites from 1919

I am confident that the correct peatlands were revisited in the 2010 survey as the maps used in the field in 1919 visualized the exact sites of each peatland. However, they did not visualize the site of each coring because rediscovering each coring site in 2010 was based on descriptions from the historical diaries and site descriptions were quite vague in some instances. Although the likelihood of rediscovering the exact coring sites from 1919 within each peatland in 2010 was unlikely, it was possible to detect some general changes in both vegetation and peat type at the peatland level.

Comparison of land use descriptions from 1919 to those from 2010 also confirmed that the correct peatlands were revisited. Based on land use descriptions in the area it is conceivable that what was observed as a bog in 1919 could be a pine bog in 2010 (Kroppsjömossen site 4), a forest bog in 1919 is a clear-cut forest in 2010 (X-mossen) and a fen from 1919 is an afforestation in 2010 (Kolarmorakärret), as changes like these may occur during 90 years.

4.2 Information about drainage in these peatlands

Information on the draining histories of specific peatlands over the past 90 years was difficult to find. However, the National Wetland Inventory database (VMI) from Swedish University of Agricultural Sciences (SLU) had information about one of the disturbed peatlands from this study, Saringemossen. Saringemossen is described as a fen with a nature value of 4 (scale 0-4 where 0= unknown value, 1=Very high value, 2= High value, 3= Some value and 4=Low value) since it was disturbed by ditching and water regulation. Information about other peatlands in this study was unavailable although according to Eliasson (2008) a large number of peatlands had been drained for various reasons during the past 90 years (Figure 2).

4.3 Changes in peat stratigraphy

Differences in peat type when comparing cores from 1919 with those from 2010 could be explained by the fact that we were unable to rediscover the exact coring site. Peat layer thickness is often highly variable within a peatland (Charman, 2002) hence it might be expected that peat type and structure would be completely different if the exact coring site from 1919 was not rediscovered in 2010, particularly near the edges of the peatland. It is also possible that the assessment of peat types in 1919 differed from those made in 2010. The determination of peat type (which is a subjective measure) and structure was made by visual inspection in the field both in 1919 and in 2010 and it is possible to think that there were differences of opinion in determining the peat type and structure in the two time periods. When it came to determining the humification grade of a sample, this study showed that the variation in colour (determined with spectroscopy) could be much larger than what was observed in field. Although the von Post scale has a reference that is followed, it lies in the viewer's eyes to determine whether the sample is weakly or very weakly decomposed (Table 1). Therefore it would be unadvisable to use only peat humification grade and wetness data as a measure of peatland change over time, particularly when two different people have collected the data 90 years apart.

Some peatlands showed substantial changes in peat type and structure, for example in Saringemossen (Figure 8b) the peat layer had decreased in all the coring sites and in the surface of each site in 2010 there was a layer of highly decomposed peat. However, datasets from 1919 showed that coring sites 2, 3 and 4 had a layer of very highly decomposed sedge peat (8-10) whereas the corings from 2010 showed peat with lower decomposition (3-4) and that distance to the gyttja layer from the surface was much shorter. It might be possible that the surveyor from 1919 recorded the gyttja layer as highly decomposed peat instead of gyttja. However, comparisons of the vegetation in 1919 and 2010 from this peatland confirmed that changes had occurred as the presence of species with requirements for nutrient-rich and dry conditions was much higher in 2010 compared to 1919.

Datasets from 1919 and 2010 showed that both humification and wetness grade in the upper layer was lower in 2010 (except for Saringemossen, see paragraph above), which would be unlikely as the degradation would be expected to continue and therefore show a higher humification. This disparity might be explained by different assessments by the surveyors, i.e. the surveyor from 1919 overestimated the degree of humification and the surveyor from 2010 underestimated the degree of humification.

4.4 Changes in vegetation

Since information about draining of these peatlands during the past 90 years was unavailable for all peatlands except one, it was difficult to tell if the changes from 1919 to 2010 were a result of drainage sometime between the two surveys or if it was a result of continuous dry-out of a peatland after a drainage that was conducted previous to 1919. However, it should be noted that observed vegetation in 1919 and in 2010 indicated that conditions were drier and more nutrient rich in 2010 and therefore confirms that changes have occurred. This type of vegetation indicates that there is available oxygen for roots and that nutrients are being released by the peat for absorption by the plants.

Species with requirements for nutrient-rich and humid conditions were observed in large numbers both 1919 (22 species) and 2010 (26 species). Although all of these species are classified as having the same requirements this particular category covers quite a large range of humid conditions. Therefore it is possible that the 22 species observed only in 1919 had requirements for more humid conditions than the 26 species observed in 2010, but due to a lack of resolution within the category it gives the appearance that the vegetation assemblage has not changed.

Vegetation analyses could also be questioned as the recording methods were different between the two time periods. Times of when the surveys were conducted were also different as the survey in 1919 was conducted during the summer (June to August) whereas the survey in 2010 was conducted during a week in the middle of August. This could therefore show a difference in species abundance as some species grow in June and some only in August. In some instances descriptions of the vegetation from the diaries in 1919 were very detailed with lists of species provided whereas in others the descriptions of vegetation description were vague. Inventories conducted in 2010 were by no means detailed with only the vegetation observed in a small area around each coring site. Therefore small or hidden species might not have been recorded. Although vegetation was for the most part similar within an specific area, species may have changed. Hence, there may have been some uncertainties about the number of species observed between the two time periods particularly if the exact coring site from 1919 was not located in 2010. That being said, nutrient requirements for plant species observed in 2010 were different compared to those from 1919 suggesting that in general the nutrient composition had changed in the peatlands over time. Presumably this is as a result of aerobic conditions in the peat that release nutrients that are then available for plants.

4.5 Carbon sink or release?

No measurements of carbon content were recorded either in 1919 or 2010 so it would be impossible to state that the observed reductions in the peat layers in some of the peatlands has released CO_2 rather than functioning as a carbon sink. However, these peatlands showed a general decrease during the past 90 years and other studies (Franzén, 2006; Kasimir-Klemedtsson, *et al.* 1997; Ilnicki, 2003) show that decreases in peatlands cause CO_2 and methane to be released into the atmosphere. As several wetlands in Sweden have been drained during the past 90 years it would be reasonable to assume that greenhouse gases are being released into the atmosphere from peatlands in Sweden. CO_2 is absorbed by peatlands when new peat develops on the surface and since no peatland in this study showed an increase in peat layer thickness, CO_2 cannot have been absorbed by the peatlands. Moreover, according to Ilnicki (2003) the long-term subsidence of drained agricultural peat soils is often caused by peat oxidation and mineralization. During the past 90 years peat should have developed, however, draining has caused it to shrink more than it has risen. The presence of highly humified peat in the surface indicated that the peat had been decomposing and would therefore contribute to the increase in atmospheric carbon dioxide. It is possible to roughly calculate how much carbon dioxide is being released from the drained peatlands if bulk density and carbon content in the surface is known before and after subsidence (Kasimir-Klemedtsson *et al*., 1997). However, since no such measurements were conducted in this study this type of calculation could not be made.

4.6 Feasibility in using the peat archive of the Geological Survey of Sweden

Applying these methods might give general indications of peatland change over a century and might provide greater understanding of the impacts of land use, climate change, etc., on peatlands. A similar study conducted by Kristian Schoning (SGU, unpublished data) where a line north of this line was revisited and compared with the historical data sets showed results similar to this study. Further studies should include more in depth inventories of vegetation, which may be useful information to incorporate in environmental policy. Several lines are useful and possible to rediscover, however, it is important that time is spent searching for good sites based on how well the sites are described in the historical diaries as well as how detailed the provided information is. It would be advisable to look at several lines and select the best sites in a specific area. Changes in vegetation coupled with observed reductions in peatlands suggest that changes have occurred over the past 90 years. Although understanding the impacts on these peatlands requires further investigation the study suggests that general changes in peatlands can be detected by comparing historical peatland surveys to modern surveys.

5. CONCLUSIONS

Due to uncertainties in finding exact coring sites conducted in the early 20th century and different assessments in the two surveys it is difficult to understand the amount of organic matter that has been oxidized in the drained-out peatlands since the beginning of the 20th century. However, it is possible to use data from the surveys made in the early 20th century to perceive changes in peat layers and vegetation. Over the past 90 years a general decrease in most peatlands has occurred. Changes in observed vegetation confirm that dehydration within the peatland has occurred and peatlands have therefore become more favourable for species that prefer nutrient-rich and dry conditions.

ACKNOWLEDGEMENT

I would like to give my sincerest thanks to my supervisors Stefan Wastegård at the Department of Physical Geography and Quaternary Geology at Stockholm University as well as Kristian Schoning and Gustav Sohlenius at the Geological Survey of Sweden (SGU). Your support and guidance was of great importance to this study.

I would also like to thank Finn Baumgartner for struggling with the editing of the text and the patience and support he showed for my work. Thanks also to the library and archive staff at SGU for their assistance in locating information and maps. Thanks to Eva Jirner Lindström for her helpful supervision in GIS. Also, thank you Anders Borgmark for your thoughts and feedback on peat associated questions.

Finally I would like to apologize to my friends and the rest of my family for neglecting them during these past weeks of work. Thank you for your patience!

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APPENDIX 1

Species observed in field in 1919 and 2010 divided into categories by specific requirements.

Nutrient-poor and humid		Nutrient-rich and dry		Nutrient-rich and humid	
1919	**2010**	**1919**	**2010**	**1919**	**2010**
Andromeda polifolia	*Andromeda polifolia*	*Agrostis sp.*	*Achillea millefolium*	*Alnus glutinosa*	*Alnus glutinosa*
Carex sp.	*Drosera rotundifolia*	*Dryopteris linearis*	*Agrostis sp.*	*Anemone nemorosa*	*Athyrium filix femina*
Drosera rotundifolia	*Equisetum sp.*	*Hylocomium splendens*	*Anthriscus sylvestris*	*Athyrium filix femina*	*Betula pendula*
Empetrum nigrum	*Eriophorum vaginatum*	*Juniperus communis*	*Artemisia vulgaris*	*Betula pendula*	*Cirsium palustre*
Equisetum sp.	*Ledum palustre*	*Melampyrum palustre*	*Dryopteris linearis*	*Carthusiana spinulosa*	*Convallaria majalis*
Eriophorum vaginatum	*Menyanthes trifoliata*	*Poa sp.*	*Fraxinus excelsior*	*Dactylorhiza incarnata*	*Epilobium sp.*
Ledum palustre	*Rubus chamaemorus*	*Polytrichum commune*	*Galeopsis speciosa*	*Deschampsia cespitosa*	*Epipactis palustris*
Menyanthes trifoliata	*Sphagnum spp.*	*Pyrola rotundifolia*	*Galium album*	*Epilobium sp.*	*Filipendula ulmaria*
Rubus chamaemorus	*Vaccinum oxycoccus*	*Rubus idaeus*	*Hieracium sp.*	*Euphrasia stricta*	*Frangula alnus*
Sparganium sp.		*Rubus saxatilis*	*Hylocomium splendens*	*Filipendula ulmaria*	*Geum rivale*
Sphagnum spp.		*Rumex acetosella*	*Juniperus communis*	*Frangula alnus*	*Lycopodium annotinum*
Vaccinum oxycoccus		*Vaccinium myrtillus*	*Melampyrym sylvaticum*	*Galium palustre*	*Lysimachia sp.*
		Vaccinium vitis-idaea	*Melica nutans*	*Lysimachia sp.*	*Galium uliginosum*
			Platanthera bifolia	*Maianthemum bifolium*	*Geum rivale*
			Poa sp.	*Mentha sp.*	*Phragmites australis*
			Polytrichum commune	*Myosotis palustris*	*Picea abies*
			Quercus robur	*Phragmites australis*	*Potentilla erecta*
			Rubus idaeus	*Picea abies*	*Salix ssp.*
			Rubus saxatilis	*Potentilla erecta*	*Solanum dulcamara*
			Tragopogon pratensis	*Potentilla palustre*	*Vaccinium uliginosum*
			Urtica dioica	*Prunella vulgaris*	
			Vaccinium myrtillus	*Salix ssp.*	
			Vaccinium vitis-idaea	*Scutellaria glariculata*	
			Vicia spp.	*Vaccinium uliginosum*	
				Viola palustris	

APPENDIX 2

Peat profiles from 1919 showing the number of the peatland, the specific coring site number, and depth of the deposit, the deposit and humification based on von Post's scale.

Peatland	Coring site no.	Depth (cm) from	Depth (cm) to	Deposit layer	Humification	Wetness
1 Strömatorpmossen	1	10	43	Carr mud	9.5	1.5
	1	43	50	Detritus gyttja		
	1	50	100	Gyttja clay		
	1	100		Clay gyttja		
1 Strömatorpmossen	2	10	47	Carr mud	4	2
	2	47	122	Detritus gyttja		
	2	122		Clay gyttja		
1 Strömatorpmossen	3	20	50	Carr mud		
	3	70	90	*Sphagnum* peat	7.5	2.5
	3	90	100	Gyttja clay		
	3	140		Clay gyttja		
2 Glupenmossen	1	10	38	Sedge peat	6	4
	1	38	50	Carr mud	10	3
	1	70	83	*Sphagnum* peat	10	4
	1	83	100	Tree stump		
	1	100	114	Sedge peat	3	3
	1	114		Clay		
2 Glupenmossen	2	20	50	*Sphagnum* peat	8	3
	2	50	238	*Sphagnum* peat	5.5	4
	2	238	246	Lake mud		
	2	246		Clay		
2 Glupenmossen	3	10	31	*Sphagnum* peat	8	3
	3	31	231	*Sphagnum* peat	5	2.5
	3	231	233	Lake mud		
	3	233		Clay		
3 Saringemossen	1	20	50	Sedge peat	3.5	3
	1	50	100	Sedge peat	2	3
	1	100	179	Sedge peat	4.5	3
	1	179	231	Detritus gyttja		
	1	231	241	Sand		
	1	241		Clay		
3 Saringemossen	2	20	50	Sedge peat	4	3
	2	50	177	Sedge peat	9	5
	2	177	250	Detritus gyttja		
	2	270		Clay		
3 Saringemossen	3	20	50	Sedge peat	4.5	3
	3	50	134	Sedge peat	10	5
	3	134	150	Gyttja clay		
	3	150	200	Clay gyttja		
	3	210	229	Sand		
	3	229		Clay		
3 Saringemossen	4	20	50	*Carex* peat	4	1.5

	4	70	95	*Carex* peat	3	2
	4	95	100	Sedge peat	8	1
	4	120	150	Clay gyttja		
	4	170		Sand/Clay		
4 Kroppsjömossen	1	10	33	*Sphagnum* peat	3	3.5
	1	33	91	*Sphagnum* peat	7	3
	1	91	131	Highly decomposed	10	
	1	131	150	Detritus gyttja		
	1	150	228	Algae gyttja		
	1	228		Clay		
4 Kroppsjömossen	2	10	29	*Sphagnum* peat	6	3
	2	29	50	*Sphagnum* peat	3	3
	2	70	80	*Sphagnum* peat	6	3
	2	80	100	*Sphagnum* peat	7	3
	2	100	150	*Sphagnum* peat	6.5	3
	2	150	250	*Sphagnum* peat	5	4
	2	270	297	Detritus gyttja		
	2	297	300	Algae gyttja		
	2	335		Cobbles		
4 Kroppsjömossen	3	20	50	*Sphagnum* peat	3	4
	3	70	100	*Carex* peat	4	3
	3	120	150	Phragmites peat	3	5
	3	170	242	Bryales peat	3	5
	3	242	250	Detritus gyttja		
	3	270	291	Shell gyttja		
	3	291	342	Algae gyttja		
	3	342		Clay gyttja		
4 Kroppsjömossen	4	10	31	*Sphagnum* peat	4	3
	4	31	50	Bryales peat	7	3
	4	70	100	*Carex* peat	6	4
	4	120	150	*Carex* peat	4	4.5
	4	170	200	Bryales peat	3	5
	4	200	300	Bryales peat	2.5	5
	4	310	347	Detritus gyttja		
	4	347	400	Algae gyttja		
	4	410	428	Sand		
	4	428		Clay		
4 Kroppsjömossen	5	20	89	Highly decomposed	8	3
	5	89	200	Woody sedge peat	8	4
	5	231	247	Detritus gyttja		
	5	247	300	Algae gyttja		
	5	300	350	Clay gyttja		
	5	350		Cobbles		
5 X-mossen	1	10	33	Bryales peat	6.5	3
	1	33	50	Woody sedge peat	8	3
	1	70	150	*Carex* peat	8	2.5
	1	170	189	Algae gyttja		
	1	189	194	Gravel		
	1	194		Clay		
6 Sjöängsmossen	1	20	36	*Sphagnum* peat	4	3

	1	36	43	*Sphagnum* peat	6	3
	1	43	50	*Sphagnum* peat	9	3
	1	70	100	Woody sedge peat	8	3
	1	100		Clay gyttja		
6 Sjöängsmossen	2	20	50	*Sphagnum* peat	7.5	3
	2	70	84	Woody sedge peat	7	3
	2	84	100	*Carex* peat	9	3
	2	120	181	Woody sedge peat	6	4
	2	181	200	Algae gyttja		
	2	220	222	Clay		
	2	222	236	Sand		
	2	236		Clay		
6 Sjöängsmossen	3	20	50	Bryales peat	8	3
	3	50	83	*Sphagnum* peat	6.5	3
	3	83	135	*Carex* peat	7	3
	3	135	193	Woody sedge peat	6	3
	3	193	200	Detritus gyttja		
	3	220		Algae gyttja		
6 Sjöängsmossen	4	20	77	Bryales peat	9	3
	4	77	100	*Carex* peat	8.5	3
	4	120	129	Woody sedge peat	8	3
	4	129		Algae gyttja		
6 Sjöängsmossen	5	20	50	*Sphagnum* peat	8.5	3
	5	70	100	*Carex* peat	8	3
	5	120	150	Woody sedge peat	7	3
	5	170	200	Algae gyttja		
	5	220		Clay		
7 Kolarmorakärret	1	10	46	Highly decomposed	9	3
	1	46	100	*Carex* peat	7	3
	1	110	180	Detritus gyttja		
	1	180	189	Vaucheria gyttja		
	1	189	200	Algae gyttja		
	1	220		Clay		
7 Kolarmorakärret	2	20	50	*Carex* peat	8.5	3
	2	70	100	*Carex* peat	6.5	3
	2	120	150	Phragmites peat		
	2	170	186	Detritus gyttja		
	2	186	187	Vaucheria gyttja		
	2	187	200	Algae gyttja		
	2	220		Clay		
7 Kolarmorakärret	3	20	36	*Carex* peat	8	3
	3	36	100	*Carex* peat	5	3
	3	120	130	Phragmites peat		
	3	130	150	Detritus gyttja		
	3	170		Clay		
7 Kolarmorakärret	4	20	50	*Carex* peat	5	3
	4	70	85	Phragmites peat		
	4	85	100	Detritus gyttja		
	4	120	127	Clay gyttja		
	4	127		Sand		

APPENDIX 3

Peat profiles from 2010 showing the number of the peatland, the specific coring number, and depth of the deposit, the deposit and humification based on von Post's scale.

Peatland	Coring site no.	Depth start	Depth stop	Deposit	Humification	Wetness
1 Strömatorpmossen	1	0	20	Highly decomposed	9	1.5
	1	20	28	Highly decomposed	9	3
	1	28	88	Clay gyttja		
	1	88	90	Clay gyttja		
	1	90		Clay		
1 Strömatorpmossen	2	0	15	Highly decomposed	8	3
	2	15	90	Highly decomposed	8	1
	2	90		Detritus gyttja		
1 Strömatorpmossen	3	0	15	Highly decomposed	10	1
	3	15	30	Highly decomposed	10	1
	3	30	40	Highly decomposed	10	1
	3	40		Clay gyttja		
2 Glupenmossen	1	0	30	Sedge peat	4	3
	1	30	90	Sedge peat	7	3
	1	90	100	Sedge peat	7	3
	1	100	110	Clay, roots		
	1	110		Clay gyttja		
2 Glupenmossen	2	0	10	*Sphagnum* peat	2.5	3
	2	10	23	*Carex*/*Sphagnum* peat	6.5	3
	2	23	33	*Sphagnum*/*Carex* peat	5	3
	2	33	100	*Carex*/*Sphagnum* peat	3	3
	2	100	180	*Sphagnum* peat	2	3
2 Glupenmossen	3	0	10	*Sphagnum* peat	4	3
	3	10	30	*Sphagnum* peat	2	3
	3	30	45	*Carex*/*Sphagnum* peat	3.5	3
	3	45	80	*Carex*/*Sphagnum* peat	5.5	3
	3	80	140	*Sphagnum* peat	3	3
3 Saringemossen	1	0	29	Highly decomposed	9	1
	1	29	70	*Carex*/*Sphagnum* peat	6.5	2.5
	1	70	90	Detritus gyttja		
	1	90		Clay gyttja		
3 Saringemossen	2	0	17	Highly decomposed	7.5	1
	2	17	74	*Carex*/*Sphagnum* peat	3.5	3
	2	74		Detritus gyttja		
3 Saringemossen	3	0	14	Highly decomposed	7	2
	3	14	51	*Carex*/*Sphagnum*	3.5	3

				peat		
	3	51	59	Sedge peat	3	3
	3	59		Detritus gyttja		
3 Saringemossen	4	0	12	Highly decomposed	8.5	1
	4	12	24	*Sphagnum* peat	6.5	1.5
	4	24	41	*Carex*/*Sphagnum* peat	3	3
	4	41	46	Sedge peat	3.5	3
	4	46	80	Detritus gyttja		
	4	80		Clay gyttja		
4 Kroppsjömossen	1	0	40	*Carex*/*Sphagnum* peat	2.5	3
	1	40	70	Woody sedge peat	6	3
	1	70	116	Woody sedge peat	8	3
	1	116	138	Clay gyttja		
	1	138		Clay gyttja		
4 Kroppsjömossen	2	0	25	*Sphagnum* peat	3	3
	2	25	75	Woody sedge peat	5	3
	2	75	80	Woody sedge peat	5	3
	2	80	120	Woody sedge peat	6.5	3
	2	120	180	*Carex* peat	4.5	3
	2	180	219	Woody sedge peat	4.5	3
	2	219	222	Detritus gyttja		
	2	222		Clay gyttja		
4 Kroppsjömossen	3	0	185	*Sphagnum* peat	2	3
	3	185	300	*Carex*/*Sphagnum* peat	4	3
	3	300	330	*Carex* peat	4	3
	3	330	352	Detritus gyttja		
	3	352	373	Shell gyttja		
	3	373		Algae gyttja		
4 Kroppsjömossen	4	0	48	*Sphagnum* peat	2.5	3
	4	48	128	*Carex* peat	5.5	3
	4	128	200	*Carex* peat	4	3
	4	200	305	*Carex* peat	2.5	3
	4	305	335	Detritus gyttja		
	4	335	356	Shell gyttja		
	4	356	380	Algae gyttja		
	4	380		Clay gyttja		
4 Kroppsjömossen	5	0	240	Sedge peat	6.5	3
	5	240	260	Detritus gyttja		
	5	260		Clay gyttja		
5 X-mossen	1	0	40	Sedge peat	6.5	1.5
	1	40	130	Sedge peat	8.5	2.5
	1	130		Clay gyttja		
6 Sjöängsmossen	1	0	34	*Sphagnum* peat	3	3
	1	34	95	*Sphagnum*/*Carex* peat	6	3
	1	95	100	*Sphagnum*/*Carex* peat	6	3

	1	100	115	*Carex* peat	6	3
	1	115		Clay gyttja		
6 Sjöängsmossen	2	0	34	*Sphagnum* peat	3.5	3
	2	34	64	*Sphagnum* peat	6.5	3
	2	64	75	*Sphagnum* peat	4	3
	2	75	110	*Carex*/*Sphagnum* peat	4	3
	2	110	152	Sedge peat	5.5	3
	2	152	171	Detritus gyttja		
	2	171		Clay gyttja		
6 Sjöängsmossen	3	0	70	*Sphagnum* peat	4.5	3
	3	70	130	Sedge peat	5	3
	3	130	140	Tree stump		
	3	140	175	*Carex* peat	4	3
	3	175		Detritus gyttja		
6 Sjöängsmossen	4	0	20	*Sphagnum* peat	6	3
	4	20	56	*Sphagnum* peat	2.5	3
	4	56	68	*Sphagnum* peat	5.5	3
	4	68	95	Sedge peat	3	3
	4	95	210	Sedge peat	3	3
	4	210	220	Detritus gyttja		
	4	220		Clay gyttja		
6 Sjöängsmossen	5	0	20	*Sphagnum* peat	4	3
	5	20	100	*Carex* peat	5	3
	5	100	120	Sedge peat	4	3
	5	120		Tree stump		
7 Kolarmorakärret	1	0	38	Woody sedge peat	8	2
	1	38	57	Gyttja		
	1	57		Clay		
7 Kolarmorakärret	2	0	25	Highly decomposed	9	2
	2	25	77	Sedge peat	5.5	3
	2	77	95	Sedge peat	4.5	3
	2	95	115	Detritus gyttja		
	2	115		Gyttja		
7 Kolarmorakärret	3	0	30	Sedge peat	8	2.5
	3	30	105	*Carex* peat	4.5	3
	3	105	130	Sedge peat	3.5	3
	3	130		Gyttja		
7 Kolarmorakärret	4	0	35	Sedge peat	8.5	2
	4	35	60	Sedge peat	4.5	3
	4	60	90	*Carex* peat	4	3
	4	90		Sedge peat	3	3

APPENDIX 4.

Swedish translation of peat -and sediment types described in this study.

English name	Swedish name
Algae gyttja	Alggyttja
Bryales peat	Brunmosstorv
Carr mud	Kärrdy
Clay	Lera
Clay gyttja	Lergyttja
Cobbles	Sten
Detritus gyttja	Detritusgyttja
Highly decomposed	Torvmylla
Gravel	Grus
Gyttja	Gyttja
Gyttja clay	Gyttjelera
Phragmites peat	Vasstorv
Sand	Sand
Sand/Clay	Sand/Lera
Lake mud	Sjödy
Sedge peat*****	Kärrtorv
Shell gyttja	Skalgyttja
Sphagnum peat	Vitmosstorv
Tree stump	Ved
Vaucheria gyttja	Pappersgyttja
Woody sedge peat	Lövkärrtorv
*** Sedge peat also includes**	
Carex peat	Starrtorv
Carex/*Spaghnum* peat	Starr- Vitmosstorv
Sphagnum/*Carex* peat	Vitmoss- Starrtorv