Comparison of mire characteristic for the south-eastern Sweden and the north-western Poland

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Summary

Four peatlands areas were investigated in this thesis, i.e. Lommaflet and Gatmyren are typical mires for the south-eastern Sweden, while the Linkowo and Sarbinowo mires are characteristic for the north-western Poland. The comparison was carried out on several levels: vascular plant flora, cryptogamic plant flora, plant communities, red-listed species, species and plant communities valuable at the European scale, origin of peat deposit, type of peatland, changes in the mire limits and the watershed area in the last 50 years. Factors related to changes in wetland structure and composition in time and space were identified.

Peatlands classified during the field work fulfilled the following assumptions: the peatlands are of a topogenic type, the area contains from 9.66 to 34.3 ha, the mires were formed during the terrestrialisation process, and the water flushing down from the surrounding terrain is its main source. The investigated mires were formed since the end of the last glacial period.

The glaciation process was completed about 9-13 years ago on the terrain of the studied areas. The Linkowo and Sarbinowo peatlands started to develop about 4 thousand years earlier than the Lommaflyet and Gatmyren ones. The peatlands are situated in the area covered by forests and characterised by high intensity of silvicultural treatments within the watershed area.

During the field work carried out on four mires, 32 species of mosses, 142 vascular plant species and 23 plant communities were investigated. The origin of the Lommeflyet and Gatmyren mires is connected with a shallow water reservoir, while the Linkowo and Sarbinowo ones are developed on a deep lake. The investigated mires are in a period of transition from topogenous into ombrogenous type. The main changes within the mire limits in the last 50 years are as follows: drainage process, increased area of *Vaccinio uliginosi–Pinetum* Kleist 1930 em W. Mat. 1962 plant community and decreased area of open bog habitats. Clear cuts are the main disturbing factor stated during the last 50 years on mire watershed area. Drainage, past fire events, nitrogen deposit, changes on the watershed area are the main factors determined that induced changes in the plant cover on the peatland surface.

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1 Introduction

1.1 Background

Peatlands are important ecosystems at local, regional and global scales due to their considerable impact on the biotic and abiotic environment. They affect both water and greenhouse gas cycling. Wetland restoration is at present an ecological issue of a paramount importance because of the increasing areas with no water supply and growing concentration of CO_2 in the atmosphere. At a global scale, wetlands cover approximately 3.5% of the Earth surface and store from 120 to 400 Gt of carbon (Franzé 2006). Peatlands have accumulated an amount of CO_2 similar to its atmosphere content (Silvola 1979, Malmer 2004). The uncontrolled release of such a substantial quantity of carbon dioxide can accelerate the process of global warming.

Numerous specialised plant and animal species live in wetlands. These species are classified as stenotopic ones. They are capable of tolerating only small environmental changes and therefore many "wetland species" are threatened by local extinction. The concern about these vulnerable ecosystems is expressed by them being often included in regional and national red lists of species. Moreover, numerous wetland habitats are classified within the Natura 2000 network.

The limited knowledge about compound processes that support the stability of peatland areas have led very often to the destruction of these sensitive habitats. Human impact on wetland areas has been intense in the past. Mires have been drained for forestry and agricultural purposes. In Sweden, the peak of land melioration activity occurred in the 1930s and 1980s. Drainage in a large part of the southern Sweden has been forbidden since1992 due to a change in legislation (Rydin 1999). In Poland, high-intensity land melioration in wetland areas occurred in 1950-1970.

Peatlands are very fragile habitats and even today we can observe changes resulting from the past drainage process. Currently, the drainage processes have have been stopped, while public attitudes towards wetland areas have changed. Restoration of the peatland biotope has now become desirable, which is partly connected with the general process of decreasing water supply in the landscape.

The increasing knowledge about ecological processes that support the stability of peatland ecosystems can help to protect and save them for future generations.

1.2 Objective of the study

The purpose of this study was to compare peatlands that are typical for the southeast Sweden and the northwest Poland and to identify factors that are related to changes in wetland structure and composition in time and space. The comparison was carried out on the following levels:

- vascular plant flora;
- cryptogamic plant flora;
- plant communities;
- red-listed species;
- species and plant communities valuable at the European scale;
- origin of peat deposit;
- type of peatland;
- changes in the mire limits and the watershed area in the last 50 years.

Hopefully, the information from the present study may also provide a baseline for investigations on future vegetation changes and possible restoration efforts.

2 Description of the study areas

2.1 General information

The investigation was carried out in four mire areas, i.e. two mires situated in South East Sweden and two situated in the northwest part of Poland.

During the preliminary field work, the peatlands were classified according to:

- type of peatland;
- peatland area;
- origin of peat deposit;
- source of water.

The classifications fulfil the assumptions presented below:

- the peatlands are of a topogenic type;
- the area covers from 9.66 to 34.3 ha.
- the mires were formed during a past terrestrialisation process of water reservoir;
- the water flushing down from the surrounding terrain is the main source of water.

More information on the origins of the peatlands under study as well as on the source of water is presented in the next part of the thesis.

The location of these peatlands is showed on Figure 1, using green rectangles.

The mires have been formed since the end of the last (fourth) glacial period. The glaciation process in the studied areas came to an end about 9-13 years ago. The ice wall retreated slowly. This was interrupted by periods of stagnation and reversion. Ice masses moved gradually back from the south to the northern part of Europe.

The Linkowo and Sarbinowo peatlands, situated in the North-West Poland, started to develop about 4 thousand years earlier than the Lommaflyet and Gatmyren peatlands, situated in the south-eastern part of Sweden. Lommaflyet and Gatmyren are official geographical names. Sarbinowo is a customary name which derives from the name of the nearest village – Sarbinowo. Linkowo is a geographical name of a lake located in the centre of the Linkowo peatland.

The peatlands are situated in the area covered by forests. The Linkowo peatland is surrounded by pine forest stands aged from 40 to 80 years. The Sarbinowo mire lies among pine and oak stands of different age structure. The water drainage basin of the Gatmyren and Lommaflyet mires is overgrown with a structure of coniferous stands of various ages. The Norway spruce monocultures managed by a clear cut system are the prevailing forest type.

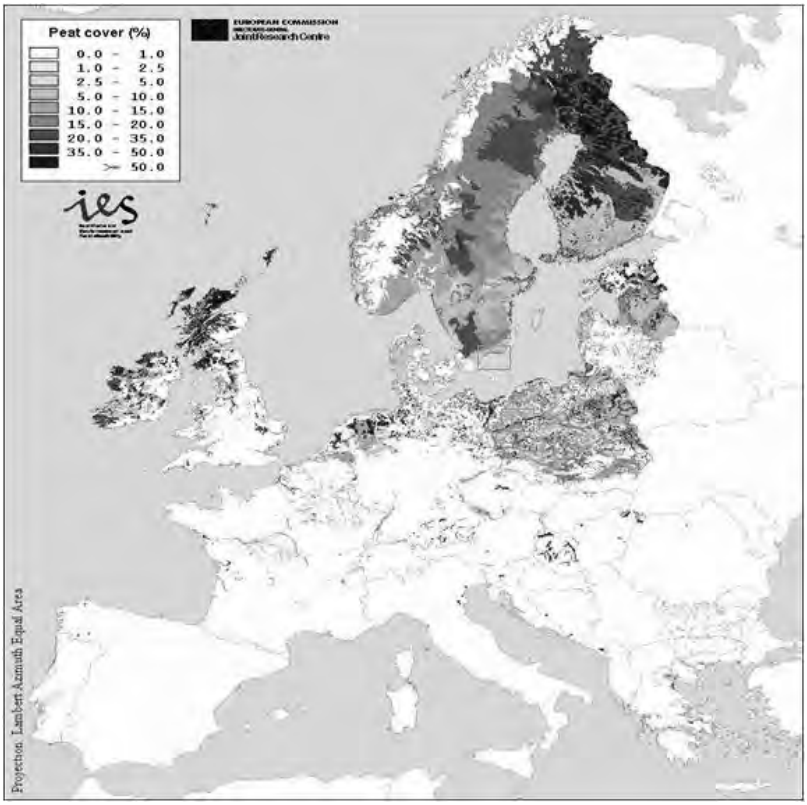

Figure 1. The location of study plots on the map of Europe. The continent is divided into soil mapping units. The unit shows a relative cover (%) of peat and peat-topped soils (Montanarella 2006 from Jones *et al.* 2004).
Not to original scale.

2.2 Geography

Poland

Name of the mire: Linkowo
Location: latitude N 52º 95' 43.0''
longitude E 15º 93' 00.5''
(geographical location for the centre of the study plot)
Peatland area: 20.66 ha
Area of the Linkowo lake: 19.46 ha
Area of the Linkówko lake: 3.00 ha

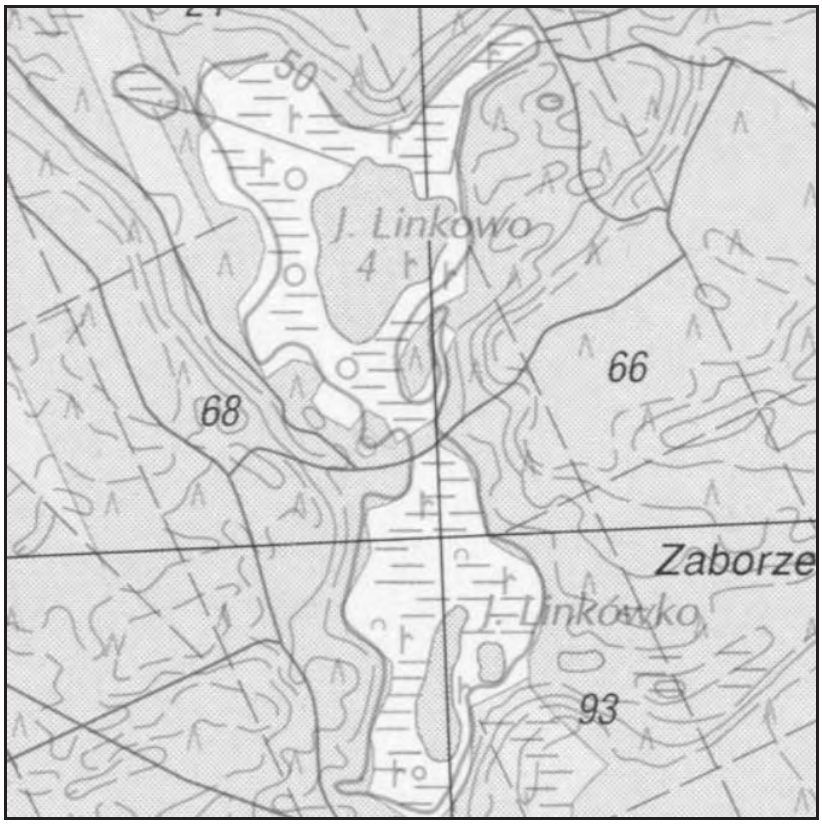

Figure 2. Map of the Linkowo study area (GOGiK 2000). Not to original scale.

Name of the mire: Sarbinowo
Location: latitude N 52º 95’ 24.4’’
longitude E 15º 88’ 30.4’’
(geographical location for the centre of the study plot)
Peatland area: 9.66 ha

Figure 3. Map of the Sarbinowo study area (GOGiK 2000). Not to original scale.

Sweden

Name of the mire: Lommaflyet
Location: latitude N 56º 25’ 02.4’’
longitude E 15º 37’ 93.3’’
(geographical location for the centre of the study plot)
Peatland area: 34.3 ha
Area of the Lommagölen lake: 2 ha

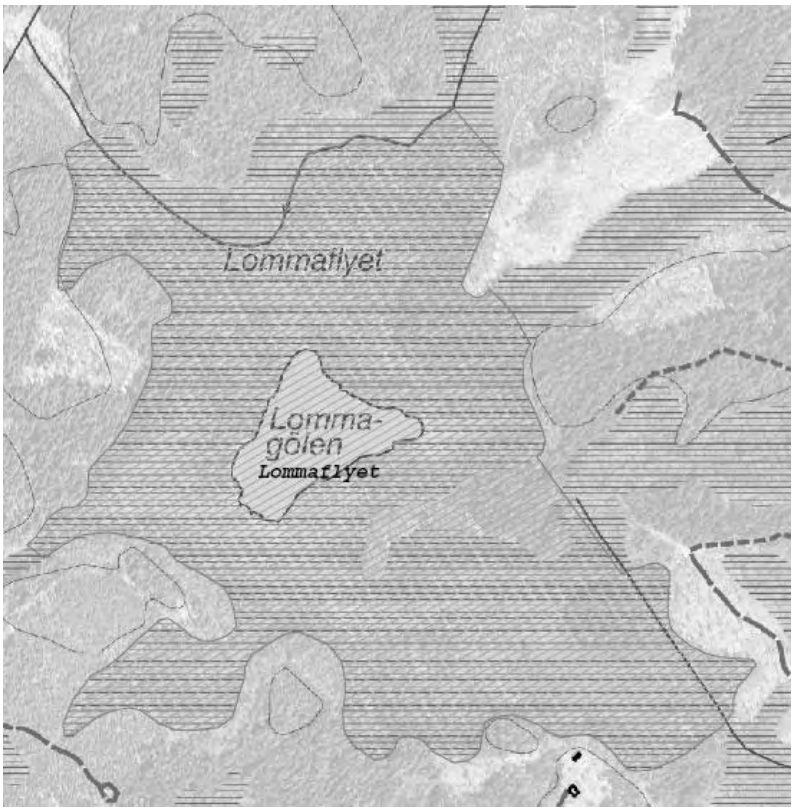

Figure 4. Map of the Lomaflyet study area (Myrskyddsplan för Sverige Objekt i Blekinge län.2007). Not to original scale.

Name of the mire: Gatmyren
Location: latitude N 56º 21’ 97.9’’
longitude E 15º 05’ 75.4’’
(geographical location for the centre of the study plot)
Peatland area**:** 12 ha

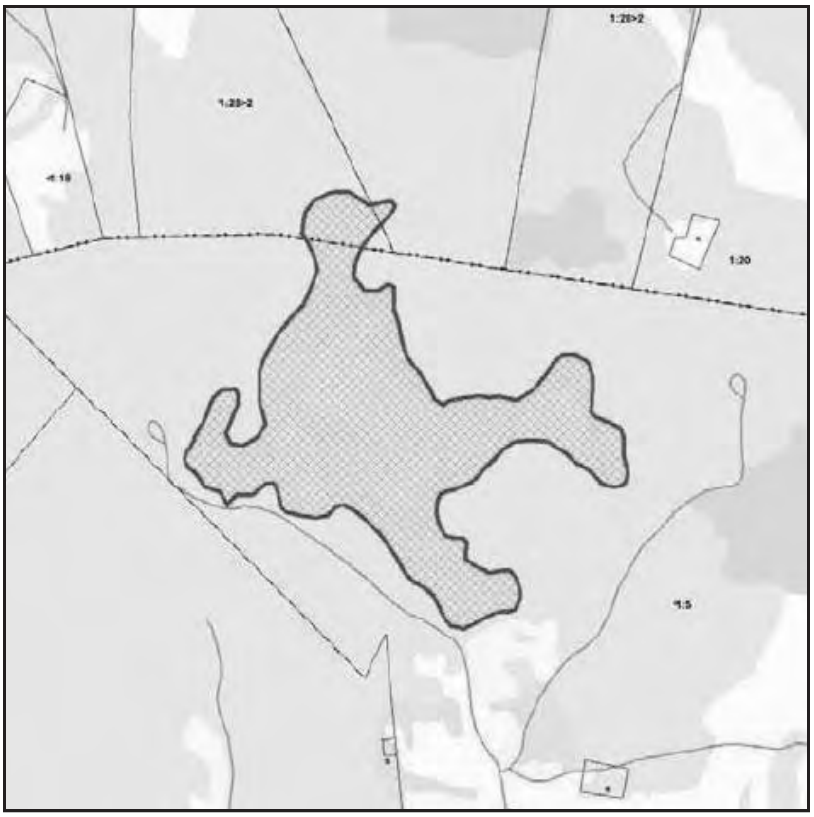

Figure 5. Map of the Gatmyren study area (Myrskyddsplan för Sverige Objekt i Blekinge län.2007). Not to original scale.

2. 3 Position in administrative division

Poland

Province: Lubuskie

Administrative district: Strzelecko-Drezdenecki

Commune: Dobiegniew

Linkowo mire

Sarbinowo mire

Sweden

Region: Blekinge

Commune: Karlskrona

Lommaflyet mire

Commune: Ronneby

Gatmyren mire

2.4 Location in the Natura 2000 network

Poland

The Linkowo and Sarbinowo peatlands are located within the continental biogeographical region. Both study plots are part of a Nature 2000 area known as "Uroczyska Puszczy Drawskiej" (The Drawa Forest Ranges) under the code number PLH320046.

Sweden

Lommaflyet and Gatmyren are located in the boreal biogeographical region.
The Lommaflyet Peatland – under the code number SE0410227.
The Gatmyren Peatland – under the code number SE0410199.

2.5 Climate

The climatic data referring to Swedish study plots come from a meteorological station in Bredåkra (Alexandersson 2001). The station is situated about 30 km southwest from the Lommaflyet peatland and 16 km southeast from the Gatmyren peatland.
The climatic data for the mires in Poland come from a meteorological station in Gorzów Wielopolski (Popiel 2004). The station is situated 50 km southwest from the Linkowo and Sarbinowo peatlands. (*Table 1* and *Table 2*).

Table 1. Comparative temperature chart from meteorological stations in Bredåkra and Gorzów Wielkopolski

Mean temperature [°C]	**Bredåkra 1961-1990**	**Gorzów Wielkopolski 1966-2001**
Annual	6.8	9.9
January	–1.7	–0.1
February	–1.7	1.7
March	0.8	10.4
April	4.8	12.3
May	10.4	15.3
June	14.7	17.3
July	16	16.4
August	15.4	18.1
September	11.7	13.3
October	7.8	9.2
November	3.3	3.5
December	0	0.2

Table 2. Comparative precipitation chart from meteorological stations in Bredåkra and Gorzów Wielkopolski

Mean precipitation data [mm]	**Bredåkra 1961-1990**	**Gorzów Wielkopolski 1966-2001**
Annual	631	539.3
January	54	36
February	35	29.7
March	38	34.2
April	37	37.7
May	42	49.1
June	46	65.9
July	68	67.7
August	56	56.4
September	64	45.2
October	63	36.6
November	72	37.1
December	56	43.7

In the Blekinge region, mean annual precipitation is about 500-600 mm for the measurement period from 1901 to1930 (Axel Sømme 1960). The rate of mean annual temperature and precipitation shows a decrease from inland (higher altitude) to sea shore (lower altitude) (Shi–Yong 2005). Mean annual precipitation in the Drawa Plain physio-geographical region was around 550 mm for the measurement period 1971–2000 (Lorenc 2005).

Table 3. Thickness of snow cover according to meteorological station in Ronneby and Gorzów Wielkopolski

Data for January 1996 to December 2007	**Ronneby**	**Gorzów Wielkopolski**
Mean snow cover thickness	1.3 cm	0.6 cm

The average number of days with snow per year for the meteorological station in Ronneby was 37.7, while that for the station in Gorzów Wielkopolski is 38.6. The snow cover in Southern Sweden is not permanent (Nowak 1975).

Characteristic of vegetation period

Vegetation period is the number of days per year with conditions that enable the growth of plants. This period has a direct effect on development of plant cover.
There are two different types of vegetation period distinguished:

- meteorological – is a part of the year with a stable air temperature which supports plant vegetation, with threshold temperature determined individually by different researchers;
  3ºC was adopted as the threshold value for the data collected in Sweden;
  5ºC was established as the threshold value by meteorologists and used in the thesis for the data from Poland.

  Therefore the number of days determining the vegetation period for both countries is not comparable. Nevertheless, these data were applied in the thesis for a complete climatic analysis.
- agro-meteorological – is connected with phenology of plants.

The meteorological vegetation period is in general more commonly used because temperature data are more easily accessed than the phenologic ones.
In the Blekinge region, the meteorological vegetation period lasts for about 240 days.
The accumulated sunshine is between 1700–1800 hours per year (www.blekinge.se).
For the Drawa Plain area, the meteorological vegetation period is about 220 days (Kotońska 1980), while the accumulated sunshine is 1650–1700 hour per year (Lorenc 2005).
It is important to add that mires are high moisture habitats hence vegetation processes start there with a delay of several weeks in comparison to drier biotopes.

2.6 Geology and geomorphology

Sweden

The Lommaflyet and Gatmyren peatlands are situated in a plain region of the south-eastern Smalland which is rich in forests and lakes. This part of Sweden is characterised by the Stockholm landscape type. This landscape type is characterised by a net of deep narrow valleys as well as by wide depressions. Hills are not covered by post-glacial mineral material. The bottoms of valleys are filled by layers of clay and water reservoirs (Nowak 1975).

Poland

The Linkowo and Sarbinowo peatlands are situated in the Drawa Plain. This region stretches from the north to the south for about 65 km and for about 15 kilometres in the east-west direction. Fluvioglacial sands and gravels build the bed rock of the area. Numerous glacial lakes are also present in the landscape (Kondracki 1998).

The study plots located in the southeast Sweden as well as in the northwest Poland are placed on low-moor peats and transitional bogs formed during the terrestrialisation process of water reservoirs. There is a gyttja layer below peat deposits, being laid down on the bottom of water reservoirs. The detailed geological analyses of respective mire are presented in the next part of the thesis.

3 Methods

3.1 Cartographic materials

Poland

Topographic map has been supplied from AKWNGiG UAM (Cartographic Archive of the Department of Geology and Geography, the Adam Mickiewicz University) in Poznań (Mapa Topograficzna Polski 2000. Scale 1:50 000. N-33-116-B Drezdenko GOGiK; Prepared and issued for printing by PPGK Warszawa 2000). In the thesis, aerial photographs taken over the Linkowo and Sarbinowo peatlands in 1963 and 2002 are used.

Sweden

Aerial photographs included into the thesis have been supplied by Lantmäteriet – National Land Survey of Sweden (www.lantmateriet.se). They were taken in 1956 and 2006 over Lommaflyet, while those taken over Gatmyren are dated on 1957and 2006.

3.2 General method

The field work was carried out in two vegetation seasons, i.e. 2006 and 2007, on four study plots. During the field work the following was prepared:

1) List of flora

- Vascular plants classification and Latin names were based on "Flora Europaea" (Tutin 1964–1980). The vascular plants examined on the study plots were collected and their categories defined according to the Swedish and Polish Red Lists;
- Cryptogamic plants were diagnosed only in respect of mosses. Names and classification were based on "Census catalogue of the Polish mosses" (Ochyra 2003). Species were subordinated to threat category according to the Swedish and Polish Red Lists.

2) List of plant communities

- Plant community classification and nomenclature were based on the "Zespoły roślinne Wielkopolski, ich stan poznania i zagrożenie" (Plant communities of the Wielkopolska; their recognition and threats) (Wojterska 2001) and "Die Wichtigsten Pflanzengesellschaften der Moore NW–Europas" (Dierssen 1982);
- List of NATURA 2000 priority plant communities was combined on the basis of EU Habitats Directive (92/43/EEC).

The lists of plant communities, vascular plants and mosses are presented in the Appendix at the end of thesis.

3) Stratigraphic analysis of peat deposit

- Stratigraphical samples were collected using a Russian borer. Description of different peat layers provided information on their origins and helped to define the character of changes which took place in the past;
- Parameters of the water accumulated in peat surface layers were measured with a MULTILINE P4 pocket multi-meter. Analyses of the measured pH value allowed for determining the present-day changes within the peatlands.

3.2.1 Classifications

The statistical analysis of data collected during the field work enabled a comparison of the peatlands situated in the northwest Poland and the southeast Sweden. The comparison was made with respect to flora, plant communities and peat deposit history.

3.2.1.1 Classification of red-listed vascular plants and mosses

Poland

1) Vascular plants were classified according to appropriate threat symbol based on the "Czerwona lista roślin naczyniowych Polski" (Red list of the vascular plants in Poland) (Zarzycki 2006).

Ex–Extinct and missing: Species, the occurrence of which has not been confirmed in Poland in their known localities and no new localities have been found.

EW–Extinct and missing at natural localities: Species that have survived in cultivation and/or in localities they have been transplanted to.

E–Declining, critically endangered: Species that are considered to be under extremely high risk of extinction and the survival of which is unlikely if casual factors continue to operate; this group includes the species classified as CR – critically endangered.

[E]–Declining, critically endangered: Species that face an extremely high risk of extinction in isolated localities situated outside the main area of their occurrence.

V–Vulnerable: Endangered species that are believed to likely move into decline – a critically endangered category in the near future if causal factors continue to operate.

[V]–Vulnerable: Species that are endangered in isolated localities situated outside the main area of their occurrence.

R–Rare, **potentially endangered**: Species localised within restricted geographic areas or habitats or sparsely scattered over a more extensive range; this group includes species classified as LR (species of lower risk).

2) Moss classification was based on the "Czerwona lista mchów zagrożonych w Polsce" (Red list of threatened mosses in Poland) (Ochyra 1992). This Red List is contained in the "Lista roślin zagrożonych w Polsce" (List of threatened plants in Poland) (Zarzycki 1992)

EX–Extinct and probably extinct: Species that are no longer known to exist in Poland.

E–Endangered: Taxa in danger of extinction and the survival of which is unlikely if casual factors continue to operate.

V–Vulnerable: Taxa being likely to move into endangered category in the near future if casual factors continue to operate.

R–Rare: Taxa with small populations that are not endangered or vulnerable at present but are at risk.

I–Indeterminate: Taxa known to be extinct, endangered, vulnerable or rare but there is insufficient information to say which of the four categories is appropriate.

Sweden

1) Classification of endangered vascular plants and mosses is based on the "Rödlistade arter i Sverige 2005" (Gärdenfors 2005). Taxa were ordered in the following categories:

RE–Regionally Extinct: Species is regionally extinct when there is no reasonable doubt that the last individual potentially capable of reproduction within the country (region) has died or disappeared from the country (region).

CR–Critically Endangered: Species is Critically Endangered when it faces an extremely high risk of extinction in the wilderness in the immediate future, as defined by any of the criteria A to E for that category.

EN–Endangered: Species is endangered when it is not critically endangered but still faces a very high risk of extinction in the wilderness in the near future, as defined by any of the criteria A to E for that category.

VU–Vulnerable: Species is vulnerable when it is not critically endangered or endangered but still faces a high risk of extinction in the wilderness in the medium-term future, as defined by any of the criteria A to D for that category.

NT–Near Threatened: Species is near threatened when it does not satisfy the criteria of any of the categories critically endangered, endangered or vulnerable, but is close to be qualified as vulnerable.

DD–Data Deficient: Species is assigned to data deficient when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status. According to the guidelines adopted in this Red List, no species should however be placed in this category unless there is some indication that it may be threatened or even regionally extinct.

3.2.1.2 Unified red-listed category based on the Swedish and the Polish Red Lists

The combined classification was based on original threat categories from the Polish and the Swedish Red Lists. The unified red-listed categories are necessary for comparative analysis of the studied areas.

Table 4. Unified classification of threat categories based on the Swedish and the Polish Red Lists (Gärdenfors 2005, Ochyra 1992, Zarzycki 2006)

Threat symbol and Category	**Polish Red List of vascular plants (Zarzycki 2006)**	**Polish Red List of mosses (Ochyra 1992)**	**Swedish Red List (Gärdenfors 2005)**
Ex–Extinct	**Ex**–Extinct and missing **EW**–Extinct and missing in natural localities	**Ex**–Extinct and probably extinct	**Re**–Regionally extinct
E–Declining, critically endangered	**E, [E]**–Declining, critically endangered	**E**–Endangered.	**Cr**–Critically Endangered **En**–Endangered
V–Vulnerable	**V, [V]**–Vulnerable	**V**–Vulnerable	**Vu**–Vulnerable
R–Rare	**R**–Rare, potentially endangered	**R**–Rare	**Nt**–Near threatened
I–Indeterminate		**I–**Indeterminate	**DD**–Data deficient

Europe

The threatened and valuable species at the European scale were based on Appendix II of the Habitats Directive 92/43/EEC.
According to the original document of the Habitats Directive, priority plant species that need protection in the form of establishing the Nature 2000 areas are marked with an asterisk (*).

3.2.1.3 Classification of valuable habitats at the European scale

In the thesis, a combined list of valuable plant communities at the European Union scale is presented. The classification is based on the Habitats Directive 92/43/EEC. Habitat codes used in the Habitats Directive are included in the thesis. Priority habitats are marked by an asterisk (*).

3.2.1.4. Peat classification

To describe the stratigraphy of peat deposits, the Polish Standard PN-85-G-02500 has been used (Tołpa 1985). This classification is based on a close relation between a plant community and types of peat produced by particular vegetation. It distinguishes three peat types: low moor peat, transitional peat and raised bog peat. Among the three peat types, 10 genera and 24 species are distinguished. The Latin nomenclature is applied to enable its international use. The nomenclature of peat genera and species is a modified nomenclature of phytosociological classification. Peat genus name is a modified name of the plant association with the "i" letter added at the end of the word. When the name of peat species is the transformed name of plant community, the original ending "etum" is changed into "eti".

Table 5. Peat classification and nomenclature (Tołpa 1985); PN–85–G–02500

Peat type	Peat genus		Peat species	
	Name	Symbol	Name	Symbol
Low – moor peat	*Potamioni*	**1**	NOT STANDARDISED	**–**
	RUSH-PEAT *Limno–Phragmitioni*	**2**	REED PEAT *Phragmiteti*	**PHR**
			BULRUSH PEAT *Scirpo–Typheti*	**SCT**
			HORSETAIL PEAT *Equiseti*	**EQU**
			MANNAGRASS *Glycerieti*	**GLY**
	TALL SEDGE PEAT *Magnocaricioni*	**3**	SEDGE–REED PEAT *Carici–Phragmiteti*	**CAP**
			SEDGE PEAT *Cariceti*	**CAR**
			SAWGRASS PEAT *Cladieti*	**CLA**
	SEDGE–MOSS PEAT *Bryalo–Parvocaricioni*	**4**	MOSS PEAT *Bryaleti*	**BRY**
			MOSS-SEDGE PEAT *Carici–Bryaleti*	**CAB**
			GRASS–SEDGE PEAT *Gramini–Cariceti*	**GRC**
	ALDER PEAT *Alnioni*	**5**	WILLOW PEAT *Saliceti*	**SAL**
			ALDER SWAMP FOREST PEAT *Alneti*	**ALN**
			ALDER–BIRCH PEAT *Alno–Betuleti*	**ALB**
Transition peat	SEDGE–SPHAGNUM PEAT *Minero–Sphagnioni*	**10**	SCHEUCHZERIA PEAT *Sphagno–Scheuchzerieti*	**SPC**
			MOSS–SEDGE PEAT *Sphagno–Cariceti*	**SPC**
	BIRCH TYPE *Betulioni*	**11**	BIRCH WOOD PEAT *Betuleti*	**BET**
Raised bog peat	SPHAGNUM PEAT *Ombro–Sphagnioni*	**20**	HOLLOW SPHAGNUM MOSS PEAT *Cuspidato–Sphagneti*	**CUS**
			HUMMOCK SPHAGNUM MOSS PEAT *Eusphagneti*	**EUS**
			COTTON GRASS–SPHAGNUM PEAT *Eriophoro–Sphagneti*	**ERS**
			PINE–SPHAGNUM PEAT *Pino–Sphagneti*	**PIS**
	HEATHER PEAT *Ericioni*	**21**	HEATH PEAT *Ericaceti*	**ERI**
			DEERGRASS *Trichophoreti*	**TRI**
	PINE PEAT *Ledo–Pinioni*	**22**	PINE PEAT *Pineti*	**PIN**

3.2.1.5 Peatland classification

To define the type of peatland, a classification was used based on the source of water (Dembek 1992). According to this classification, the following mire types are distinguished:

- **fluviogenous:** periodically flooded by water coming from a river or see;
- **soligenous:** fed by underground water running from the surrounding terrain without direct contact with atmospheric gases;
- **topogenous:** fed by water flushing down from the surface of the surrounding area; this mire type develops in the process of water reservoir terrestrialisation;
- **ombrogenous:** mires fed only by precipitation.

3.2.1.6 Division of vascular plant flora into histo-geographical groups

Division of the flora in histo-geographical groups was applied according to Thellung's studies conducted in 1915-1918. The vascular plant species examined at the time of the field work were divided into appropriate categories based on the "Klucz do oznaczania roślin naczyniowych Polski Niżowej" (Identification key for the vascular plants of the Lowland Poland) (Rutkowski, 2004).

There are two important criteria which classify a species:

- origin of species;
- time of arrival and degree of settling.

Table 6. Classification of flora into histo-geographical groups

A. SPONTANEOPHYTES Native species with natural geographical distribution covering the area of study plot
A.1. Non-synanthropic spontaneophytes Native species that occur only in natural and semi-natural plant communities
A.2. Synanthropic spontaneophytes Native species that occur permanently in modified habitats
B. ANTHROPOPHYTES Foreign species with natural geographical distribution not covering the area of study plot
B.1. Metaphytes Foreign species permanently settled in the area of study plot
B.1.2. Kenophytes Species with settlement since the beginning of the 16th century
B.1.2.1. Holoagrophytes Foreign species settled in natural plant communities
B.1.2.2. Hemiagriophytes Foreign species settled in semi-natural plant communities
B.1.2.3. Epoecophytes Foreign species occurring only in synanthrophic plant communities
B.2. Diaphytes Species that occur periodically in the examined areas
B.2.1.Ergasiophygophytes Species spreading out from the area under cultivation
B.2.2. Ephemerophytes Occasionally occurring foreign species with populations not being established

3.2.1.7 Division of vascular plant flora into plant distribution group

The species were classified into phytogeographical units (Meusel 1965, 1978; Rothmaler 199; Hulten 1986). The following phytogeographical units were distinguished:

1. EUROSIBERO–BOREOAMERICAN SUB-KINGDOM
    - Circumboreal region (CB)
    - Eurosiberian region (ES)
    - Central Europe province (E)
    - Subatlantic province (sOZ)
    - Pontus Euxinus province (P)
    - Eastern Asiatic region (OAS)
    - Boreoamerican region (AM)
    - Caucasus region (CAUC)
2. MEDITERRANEN SUB-KINGDOM
    - Mediterranean region (M)

3.2.1.8 Phytosociological classification of moss species

The moss species examined during the field work were analysed according to phytosociological classes. The basis of phytosociological taxonomy is derived from the "Przewodnik do oznaczania zbiorowisk roślinnych Polski" (The guidebook for identification of the plant communities of Poland) (Matuszkiewicz 2002). The occurrence of particular classes is connected with the mire type (source of water). The results from the moss classification presented above have provided information on the actual type of mire as well as that concerning the future changes in plant cover.

The examined peatlands were compared and analysed based on the above classifications. The comparison of historical and current aerial photographs shows changes within the peatlands and their surrounding areas in the last 50 years.

4 Results

4.1 Moss analysis

4.1.1 Statistical analysis

The total number of moss species examined in four study areas was 32 (*Table 7*). During the field work carried out within the Linkowo peatbog, 22 moss species were examined, being 68.75% of the total number of mosses studied in the four mires situated in Poland and Sweden. In the Sarbinowo peatbog, 14 moss species were present, which makes 43.75% of all moss species examined in the four mires. Based on the field work carried out within the Lommaflyet peatbog, 23 moss species were found, constituting 71.87% of the total number of mosses occurring in the examined mires. Only 18 moss species were found in the Gatmyrem peatbog; this is 56.25% of moss species studied in the Swedish and Polish study areas.

Table 7. The number and percentage of moss species examined in the Linkowo, Sarbinowo, Lommaflyet and Gatmyren study areas

		Poland		Sweden		Total
		Linkowo	**Sarbinowo**	**Lommaflyet**	**Gatmyren**	
Species	Number	22	14	23	18	**32**
	%	68.75	43.75	71.87	56.25	**100**

4.1.2 List of threatened moss species

During the field work carried out within the Linkowo, Sarbinowo, Lommaflyet and Gatmyren peatbogs, 2 threatened moss species were found (*Table 8*). The first species, i.e. *Sphagnum fuscum* (Schimp.) H. Klinger, occurs in the Linkowo and Lommaflet peatlands. According to the Polish Red List (Ochyra 1992), this species is classified as vulnerable one but it is not included in the Swedish Red List (Gärdenfors 2005). The second one, i.e. *Sphagnum papillosum* Lindb., was found in the Lommaflyet and Gatmyren locations in Sweden and in the Linkowo and Sarbinowo peatbogs situated in Poland. According to the Polish Red List, this species is classified as vulnerable one, based on the unified categories, but it is not included in the Swedish Red List.

Table 8. The list of threatened moss species examined in the Linkowo, Sarbinowo, Lommaflyet and Gatmyren study areas

Latin name	**Poland (Ochyra 1992)**		**Sweden (Gärdenfors 2005)**		**Unified category**
	Linkowo	**Sarbinowo**	**Lommaflyet**	**Gatmyren**	
Sphagnum fuscum (Schimp.)H. Klinger	V	–	X	–	V
Sphagnum papillosum Lindb.	V	V	X	X	V

Description:

X - present

– - absent

V - vulnerable

4.1.3 Phytosociological classification of moss species

As mentioned in Methods, the classification of moss species was based on the phytosociological taxonomy adopted after Matuszkiewicz (2002).

Poland

Linkowo

Based on the field work carried out within the Linkowo peatbog, 22 moss species were examined and arranged into 6 classes (*Table 9*). The prevailing classes are *Oxycocco-Sphagnetea* Br.-Bl. et R. Tx. 1943 and *Scheuchzerio-Caricetea* (Nordh. 1937) R. Tx. 1937. Each of them consists of 8 moss species. The *Vaccinio-Piceetea* Br.-Bl. 1939 class has 2 species. The smallest number of species is in the *Alnetea glutinosae* Br.-Bl. et R. Tx. 1943 and *Utricularietea intermedio-minoris* classes. Each of these classes has one species only.

Sarbinowo

In the Sarbinowo peatland, 14 moss species were examined included into 5 classes (*Table 9*). The *Oxycocco-Sphagnetea* Br.–Bl et R. Tx. 1943 and *Scheuchzerio-Caricetea* (Nordh. 1937) R.Tx. 1937 classes consist of 5 species each. Two moss species belong to the *Molinio-Arrhenatheretea* R. Tx. 1937 class, while the last one is *Vaccinio-Piceetea* Br.-Bl. 1939 with only a single moss species.

Table 9. The number and percentage of moss species separated into classes examined in the Linkowo, Sarbinowo, Lommaflyet and Gatmyren study areas

			Class						
			Alnetea glutinosae	***Molinio–Arrhenatheretea***	***Oxycocco–Sphagnetea***	***Scheuchzerio–Caricetea***	***Utricularietea intermedio–minoris***	***Vaccinio–Piceetea***	**Total**
Species	**Linkowo**	Number	1	2	8	8	1	2	**22**
		%	4.54	9.09	36.36	36.36	4.54	9.09	**100**
	Sarbinowo	Number	1	2	5	5	–	1	**14**
		%	7.14	14.28	35.71	35.71	–	7.14	**100**
	Lommaflyet	Number	1	1	9	5	–	7	**23**
		%	4.37	4.37	39.13	21.74	–	30.43	**100**
	Gatmyren	Number	–	1	8	4	–	5	**18**
		%	–	5.55	44.44	22.22	–	27.78	**100**

Description:

– - absent

Sweden

Lommaflyet

During the field work carried out within the Lommaflyet peatbog, 23 moss species were recorded (*Table 9*). They are separated into 5 classes, which are ranked according to the increasing number of moss species, as follows: *Alnetea glutinosae* Br.-Bl. et R.Tx. 1943 and *Molinio-Arrhenatheretea* R. Tx. 1937 with the same number of species – 1, then *Scheuchzerio-Caricetea* (Nordh. 1937) R.Tx. 1937 with 5 species, *Vaccinio-Piceetea* Br.-Bl. 1939 with 7 species, and *Oxycocco-Sphagnetea* Br.–Bl et R. Tx. 1943 containing the highest number of moss species, i.e. 9.

Gatmyren

Based on the field work carried out within the Gatmyren mire, 18 moss species classified into 4 classes were examined (*Table 9*). The richest in respect of species abundance is the *Oxycocco-Sphagnetea* Br.-Bl et R. Tx. 1943 class with 8 species, followed by the *Vaccinio–Piceetea* Br.-Bl. 1939 class with 5 species and the *Scheuchzerio-Caricetea* (Nordh. 1937) R.Tx. 1937 class with 4 species. The last one is *Molinio-Arrhenatheretea* R. Tx. 1937 with only one species.

4.2 Vascular plants analysis

4.2.1 Statistical analysis

During the field work carried out within the investigated mire areas in the north-western Poland and the south-eastern Sweden, 142 vascular plant species were recorded. In the Linkowo mire, 134 species were found, constituting 94.36% of all species examined in four study areas. In the Sarbinowo peatland area, 24 vascular plant species were found, which makes 16.90% of the total number of examined species. Based on the field work carried out within the Lommaflyet peatland, 32 vascular plant species were found; this is 22.53% of the vascular plant species present in four examined mires. In the Gatmyren peatland area, 25 vascular plant species were found, making 17.60% of the total number of examined vascular plant species.

Table 10. The number and percentage of vascular plant species examined in the Linkowo, Sarbinowo, Lommaflyet and Gatmyren study areas

		Poland		**Sweden**		**Total**
		Linkowo	**Sarbinowo**	**Lommaflyet**	**Gatmyren**	
Species	Number	134	24	32	25	142
	%	94.36	16.90	22.53	17.60	100

4.2.2 List of threatened vascular plant plants species

During the field work carried out in the Linkowo, Sarbinowo, Lommaflyet and Gatmyren study areas, 8 species of threatened vascular plants were recorded (*Table 11*). These plant species are separated into two categories:

- vulnerable (V); and
- declining, critically endangered.

Table 11. The list of threatened vascular plant species examined in the Linkowo, Sarbinowo, Lommaflyet and Gatmyren study areas

Latin name	Poland (Zarzycki 2006)		Sweden (Gärdenfors 2005)		Unified category
	Linkowo	Sarbinowo	Lommaflyet	Gatmyren	
Carex limosa L.	V	V	X	–	V
Drosera rotundifolia L.	V	V	X	X	V
Dryopteris cristata (L.) A.Gray	V	–	–	–	V
Liparis loeselii (L.)L.C.M.Rich.	E	–	–	–	E
Scheuchzeria palustris L	E	–	–	–	E
Utricularia australis R. Br.	V	–	–	–	V
Utricularia intermedia Hayne	V	–	–	–	V
Utricularia minor L.	V	–	–	–	V

Description:

X - present V - vulnerable

– - absent E - declining, critically endangered

According to the Polish Red List and the unified categories, the species given below are classified under vulnerable category (V):

- *Carex limosa* L.
- *Drosera rotundifolia* L.
- *Dryopteris cristata* (L.) A.Gray
- *Utricularia australis* R. Br.
- *Utricularia intermedia* Hayne
- *Utricularia minor* L.

Based on the Polish Red List and the unified categories, the following species are classified under declining, critically endangered category (E):

- *Scheuchzeria palustris* L.
- *Liparis loeselii* (L.)L.C.M.Rich.

All taxa specified above are not included in the Swedish Red List.

4.2.3 Valuable vascular plant at the European scale

As mentioned in Methods, the list of threatened species at the European scale was based on Appendix II of the Habitats Directive 92/43/EEC. During the field work, only one species was recorded:

- *Liparis loeselii* (L.) L.C.M.Rich

It is a priority plant species, marked by asterisk (*).

4.2.4 Division of vascular plant flora into histo-geographical groups

Table 12. The number and percentage of vascular plants species separated into histo-geographical groups examined in the Linkowo, Sarbinowo, Lommaflyet and Gatmyren study areas

	Histo-geographical group		Non-synanthropic spontaneophytes	Holoagrophytes	**Total**
Species	**Linkowo**	Number	131	3	**134**
		%	97.76	2.24	**100**
	Sarbinowo	Number	23	1	**24**
		%	95.83	4.17	**100**
	Lommaflyet	Number	32	–	**32**
		%	100	–	**100**
	Gatmyren	Number	25	–	**32**
		%	100	–	**100**

Description:

– - absent

Poland

Linkowo

Based on the field work carried out in the Linkowo mire, two histo-geographical groups of plants were distinguished among the vascular plant examined:

- Non-synanthropic spontaneophytes – native species which occur only in natural and semi-natural plant communities; 131 vascular plant species were classified into this group;
- Holoagrophytes – foreign species settled in natural plant communities; they constitute 2.24% of the examined vascular plant species.

The vascular plant species classified into this group are: *Elodea canadensis* Michx, *Picea abies* (L.) Karsten, and *Spiraea tomentosa* L.

Sarbinowo

The vascular plant species examined during the field work carried out in the Sarbinowo mire were classified into two histo-geographical groups.

- Non-synanthropic spontaneophytes – native species which occur only in natural and semi-natural plant communities; 95.83% of vascular plant species were classified into this group;
- Holoagrophytes – foreign species settled in natural plant communities, they constitute 4.17% of the examined vascular plant species. The plant classified into this group is *Picea abies* (L.) Karsten.

Sweden

Lommaflyet

32 species examined, constituting 100% of the Lommaflyet mire flora, were classified into the histo-geographical group of non-synanthropic spontaneophytes.

Gatmyren

Based on the field work led in the Gatmyren mire, all examined vascular plant species (25) were classified into the histo-geographical group of non-synanthropic spontaneophytes.

4.2.5 Division of vascular plant flora into plant distribution groups

Table 13. The number and percentage of vascular plant species divided into plant distribution groups examined in the Linkowo, Sarbinowo, Lommaflyet and Gatmyren study areas

		Eurosiberian region	Circumboreal region	Eurosiberian-Boreoamerican region	Central European province	Central European-Subatlantic region	Boreoamerican region	Central European-Mediterranean region	Subatlantic province	**Total**
Linkowo	Number	53	49	11	11	6	2	1	1	**134**
	%	39.55	36.57	8.21	8.21	4.48	1.49	0.75	0.75	**100**
Sarbinowo	Number	7	15	–	2	–	–	–	–	**24**
	%	29.17	62.5	–	8.33	–	–	–	–	**100**
Lommaflyet	Number	10	21	1	–	–	–	–	–	**32**
	%	31.25	65.63	3.13	–	–	–	–	–	**100**
Gatmyren	Number	7	15	1	2	–	–	–	–	**32**
	%	28	60	4	8	–	–	–	–	**100**

Description:

– - absent

Poland

Linkowo

134 vascular plant species examined in the Linkowo mire were classified into 8 distribution groups (*Figure 6*)

The examined vascular plant species belong to the following distribution groups:

- Eurosiberian region – 53 vascular plant species were classified into this group, which constitutes 39.55% of all examined plant species in the Linkowo mire;
- Circumboreal region – 49 vascular plant species were included into this group, being 36.57% of all examined plant species in the Linkowo mire;
- Eurosiberian-Boreoamerican region – 11 vascular plant species were included into this group; they make 8.21% of all examined plant species in the Linkowo mire;
- Central European province – 11 vascular plant species were classified into this group, accounting for 8.21% of all detected plant species in the Linkowo mire;
- Central European–Subatlantic region – 6 species belong to this group, representing 4.48% of all examined plant species in the Linkowo mire;
- Boreoamerican region – 2 species were found and classified into this group, consituting 1.49% of all plant species examined in the Linkowo mire;
- Central European–Mediterranean region – 1 species was classified into this group, making 0.75% of all examined plant species in the Linkowo mire;
- Subatlantic province – 1 species was classified into this group, accounting for 0.75% of all examined plant species in the Linkowo mire.

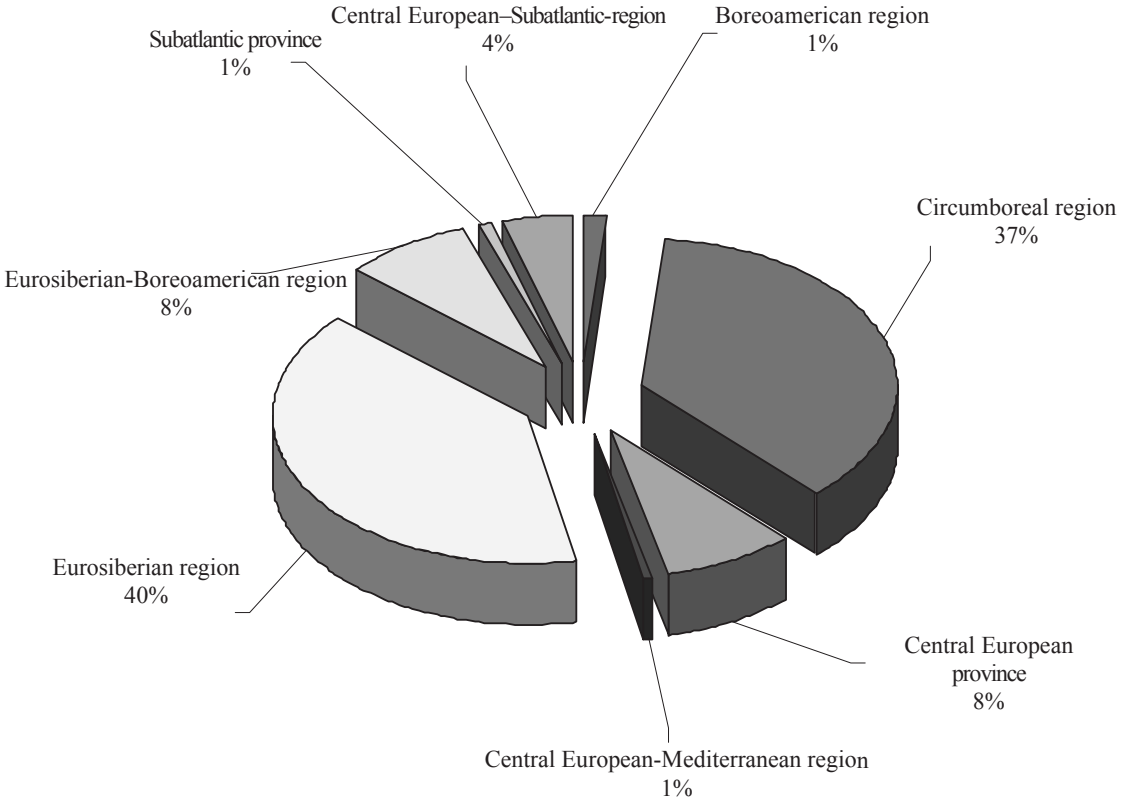

Figure 6. The number and percentage of vascular plants species divided into plant distribution groups examined in the Linkowo study area.

The most abundant species groups are Eurosiberian and Circumboreal regions. Together, they constitute 88% of all examined vascular plant species. Two foreign species found in the Linkowo mire are worthy of particular notice. They are *Elodea canadensis* Michx and *Spiraea tomentosa* L., classified into the Boreoamerican region.

Sarbinowo

24 examined vascular plants were classified into 3 distribution groups (*Figure 7*).

- Circumboreal region – 15 species were classified into this region, constituting 62.5% of the species examined in the Sarbinowo mire;
- Eurosiberian region – 7 species were included into this region, accounting for 29.17% of the vascular plant species examined in this mire;
- Central European province – 2 taxa were included into this group; they make 8.33% of the species examined in the Sarbinowo peatland area.

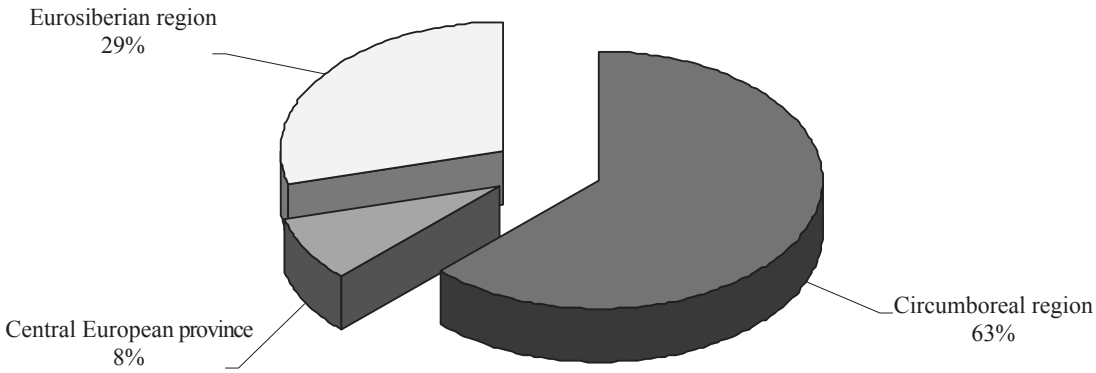

Figure 7. The number and percentage of vascular plant species divided into plant distribution groups examined in the Sarbinowo study area.

The Circumboreal and Eurosiberian regions constitute together 92% of all species examined in the Sarbinowo mire. The remaining 8% is classified into the Central European province.

Sweden

Lommaflyet

32 investigated vascular plant species examined in the Lommaflyet study area were classified into 3 distribution groups (*Figure 8*).

- Circumboreal region – 21 species were included into this group, accounting for 65.63% of all species examined in the Lommaflyet mire;
- Eurosiberian region – 10 species were included into this distribution group, which constitutes 31.25% of the species examined in the Lommaflyet peatland;
- Eurosiberian-Boreoamerican region – 1 species was classified into this region, which makes 3.13% of the species found in the examined mire;

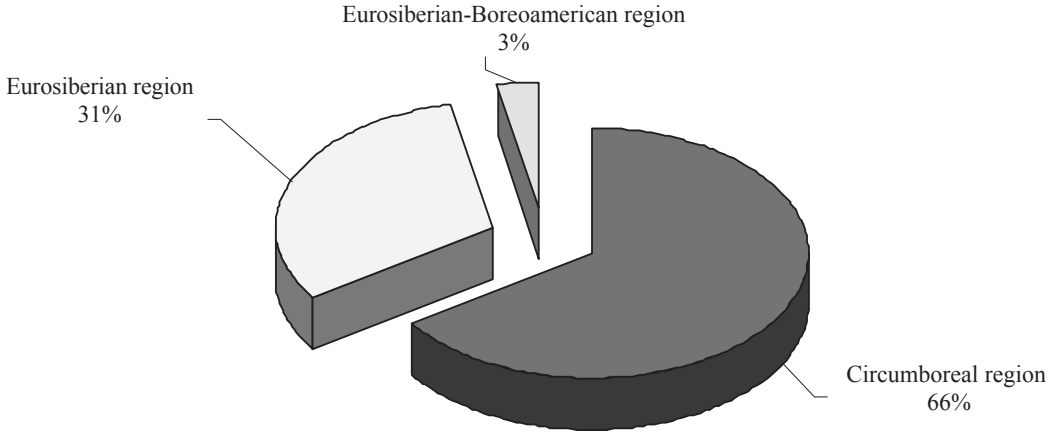

Figure 8. The number and percentage of vascular plant species divided into plant distribution groups examined in the Lommaflyet study area.

The species classified into the Circumboreal and Eurosiberian regions constitute together 97% of all species examined in the Lommaflyet peatland area; the other 3% of species are classified into the Eurosiberian-Boreoamerican region.

Gatmyren

The vascular plant species examined in the Gatmyren mire were classified into 4 distribution groups (*Figure 9*).

- Circumboreal region – 15 species were classified into this region, constituting 60% of all examined species in the Gatmyren mire;
- Eurosiberian region – 17 vascular plant species, making 28% of the examined vascular plant species in the Gatmyren mire, were included into this group;
- Central European province – 2 vascular plant species were classified into this group;
- Eurosiberian-Boreoamerican region – 1 vascular plant species, accounting for 4% of all species examined in the Gatmyren mire, was included into this group.

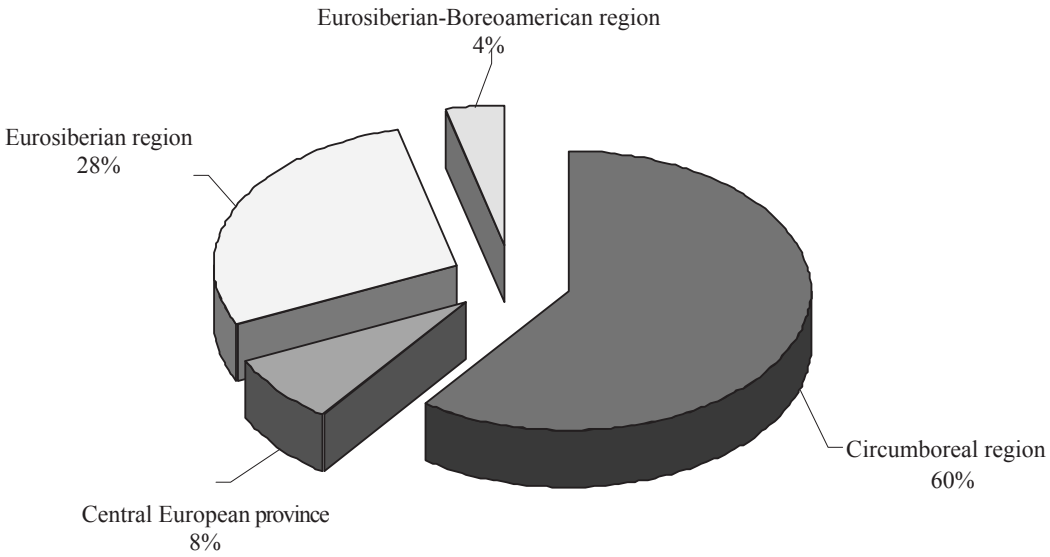

Figure 9. The number and percentage of vascular plant species divided into plant distribution groups examined in the Gatmyren study area.

The Circumboreal, Eurosiberian and Central Europe regions, taken as a whole, constitute 96% of all examined vascular plant species in the Gatmyren mire, while 8% of species are classified into the Central European province.

4.3 Analysis of real vegetation

4.3.1 Statistical analysis

As mentioned in Methods, the nomenclature and taxonomy of plant communities are based on Wojterska (2001), with the exception of two plant communities, i.e. *Drepanoclado–Cladietum* Succ. et Knapp 1985 and *Eriophorion latifolii* Bl.&Tx.1943.

Table 14. The number and percentage of plant communities examined in the Linkowo, Sarbinowo, Lommaflyet and Gatmyren study areas

		Poland		**Sweden**		**Total**
		Linkowo	**Sarbinowo**	**Lommaflyet**	**Gatmyren**	
Plant community	Number	18	11	6	5	**23**
	%	78.26	47.82	30.43	26.08	**100**

During the field work carried out in the Linkowo, Sarbinowo, Lommaflyet and Gatmyren mires, 23 plant associations were examined (*Table 14*). In the Linkowo study area, 18 plant communities were examined during the field work. They constitute 78.26% of all examined plant associations. On the other hand, 11 plant communities occured in the Sarbinowo mire, amounting to 47.82% of plant communities examined in four study areas. Based on the field work carried out in the Lommaflyet mire, 11 plant communities were identified, which accounts for 30.43 % of the total number of plant communities. In the Gatmyren peatland area, only 6 plant communities were examined during the field works carried out there.

Table 15. The number and percentage of plant communities divided into classes examined in the Linkowo, Sarbinowo, Lommaflyet and Gatmyren study areas

Class	**Poland**				**Sweden**			
	Linkowo		**Sarbinowo**		**Lommaflyet**		**Gatmyren**	
	Number	%	Number	%	Number	%	Number	%
Vaccinio–Picetea	1	5.55	1	9.09	1	16.66	1	20
Oxycocco–Sphagnetea	2	11.11	2	18.18	1	16.66	2	40
Potametea	2	11.11	–	–	1	16.66	–	–
Littorelletea uniflorae	2	11.11	–	–	–	–	–	–
Scheuchzerio–Caricetea fuscae	5	27.77	6	54.54	3	50	2	40
Phragmitetea australis	6	33.33	2	18.18	–	–	–	–
Total	**18**	**100**	**11**	**100**	**6**	**100**	**5**	**100**

Description:

– - absent

Poland

Linkowo

The class ranking according to a decreasing number of species is as follows: *Phragmitetea australis* (Klika et Novàk 1941) R.Tx. et Prsg. 1942 – 6 communities, *Scheuchzerio–Caricetea fuscae* (Nordh. 1936) R. Tx. 1937., *Littorelletea uniflorae* Br.–Bl. et R. Tx. 1943, *Potametea* R. Tx. Et Prsg. 1942 ex Oberd. 1957, *Oxycocco–Sphagnetea* Br.–Bl. et R.Tx. 1943 – with the same number each, i.e. 2 communities, *Vaccinio–Picetea* Br.–Bl. in Br.–Bl. et al. 1939 – 1 community (*Table 15*).

Sarbinowo

The highest percentage (54.54%) of plant communities is classified into the *Scheuchzerio–Caricetea fuscae* (Nordh. 1936) R. Tx. 1937. class. The lowest percentage (9.09%) of plant communities is located in the *Vaccinio–Picetea* Br.–Bl. in Br.–Bl. et al. 1939 class, while the *Oxycocco–Sphagnetea* Br.–Bl. et R.Tx. 1943 class is 18.18% (*Table 15*).

Sweden

Lommaflyet

The *Oxycocco–Sphagnetea* Br.-Bl. et R.Tx. 1943, *Potametea* and *Scheuchzerio–Caricetea fuscae* (Nordh. 1936) R. Tx. 1937. classes are represented by 2 plant communities each. One plant community was classified into the *Vaccinio–Picetea* Br.–Bl. in Br.–Bl. et al. 1939 class.

Gatmyren

The *Oxycocco–Sphagnetea* Br.-Bl. et R.Tx. 1943 and *Scheuchzerio–Caricetea fuscae*(Nordh. 1936) R. Tx. 1937 classes constitute together 80% of all examined plant communities, whereas 20% of these plant communities is located in the *Vaccinio–Picetea* Br.–Bl. in Br.–Bl. et al. 1939 class.

4.3.2 List of valuable habitats at the European scale

As mentioned in Methods, the valuable plant communities at the European Union scale were combined. The classification was based on the Habitats Directive 92/43/EEC.

Table 16. The number and percentage of habitats examined in the Linkowo, Sarbinowo, Lommaflyet and Gatmyren study areas

	Linkowo		**Sarbinowo**		**Lommaflyet**		**Gatmyren**	
	Number	%	Number	%	Number	%	Number	%
Natura 2000 Habitat	11	61.11	7	63.63	5	71.42	3	60
Priority Natura 2000	3	16.66	4	36.36	2	28.57	2	40
Other habitats	4	22.22	0	0	0	0	0	0
Total	**18**	**100**	**11**	**100**	**7**	**100**	**5**	**100**

In the Linkowo peatland area, 11 Natura 2000 habitats were examined. These communities represent 61.11% of all habitats occurring in this study area. The highest percentage (71.42%) of the Natura 2000 habitats was examined in the Lommaflyet mire. The Priority Natura 2000 habitats were found in all four examined peatlands. The habitats in this category are of the highest frequency in the Sarbinowo mire. All communities examined in the Sarbinowo, Lommaflyet and Gatmyren study areas are classified into the Natura 2000 habitats.

4.3.3 Map of real vegetation

Poland
Linkowo

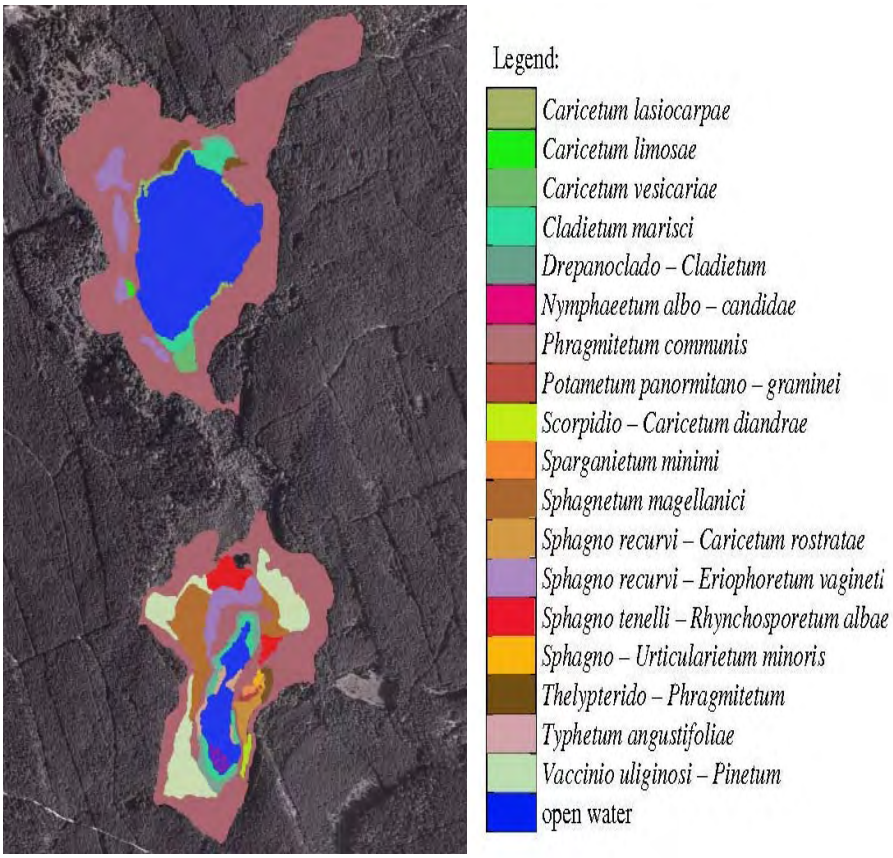

Figure 10. Map of plant communities distribution in the Linkowo study area. Not to original scale.

The area of Linkowe mire is mainly covered by the *Phragmitetum communis* (W. Koch 1926) Schmale 1939 plant association. The open plant communities like *Sphagno recurvi–Eriophoretum vaginati* Hueck (1925), *Caricetum limosae* (Begerd 1922) Osvald 1932 em. Dierssen 1982, *Sphagnetum magellanici* (Macuti 1929) Kästn. et

Flössn. 1933 and *Sphagno tenelli–Rhynchosporetum albae* Osvald 1923 *Cariceutm vesicariae* Br.–Bl. et Dennis 1926 are covered or have started to be overgrown with a very expansive *Phragmitetum communis* (W. Koch 1926) Schmale 1939 plant association. The southern part of the mire complex is richer in plant associations when compared to its northern part. The Linkówko Lake (smaller one, situated in the southern part of the Linkowo mire) is surrounded by a rich mosaic of plant communities. The banks of Linkówko Lake are overgrown with a mixed belt of *Typhetum–angustifoliae* Soó 1927 ex Pignatti 1953, *Drepanoclado–Cladietum* Succ. et Knapp 1985, *Cladietum marisci* Allorge 1922 ex Zorbist 1935 and *Phragmitetum communis* (W. Koch 1926) Schmale 1939 plant communities

Sarbinowo

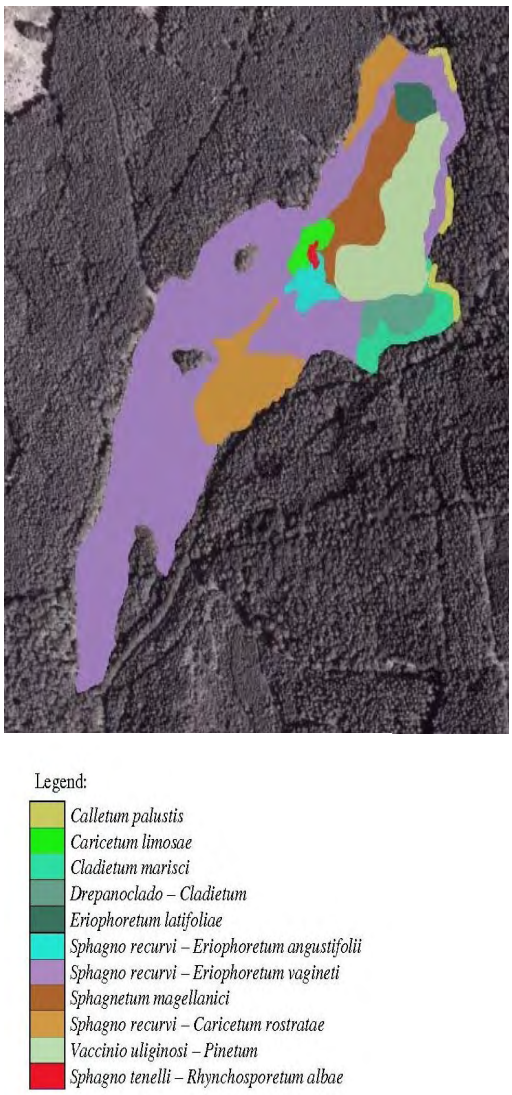

Figure 11. Map of plant communities distribution in the Sarbinowo study area. Not to original scale.

A large area of the Sarbinowo mire is covered by the *Sphagno recurvi–Eriophoretum vaginati* Hueck (1925) plant community. In the central and northern parts of the study area, *Sphagno recurvi–Caricetum rostratae* Steffen 1931 was recorded. This meso- and oligotpopic plant community has started the regeneration process of mires. The *Drepanoclado–Cladietum* Succ. et Knapp 1985 and *Cladietum marisci* Allorge 1922 ex Zorbist 1935 plant communities occur in places that are rich in calcium. The *Sphagnetum magellanici* (Macuti 1929) Kästn. et Flössn. 1933 plant community has been cover by a juvenile form of the *Vaccinio uliginoso–Pinetum* Kleist 1930 em W. Mat. 1962 plant association. The *Caricetum limosae* (Begerd 1922) Osvald 1932 em. Dierssen 1982, *Sphagno recurvi–Eriophoretum angustifolii* Hueck 1925 and Sphagno tenelli–*Rhynchosporetum* albae Osvald 1923 plant communities form a kind of habitat mosaic near the central part of the mire. The *Calletum palustris* (Osvald 1923) Vanden Berghen 1952 plant association was recorded in wet places in the northeast part of the mire.

Sweden

Lommaflyet

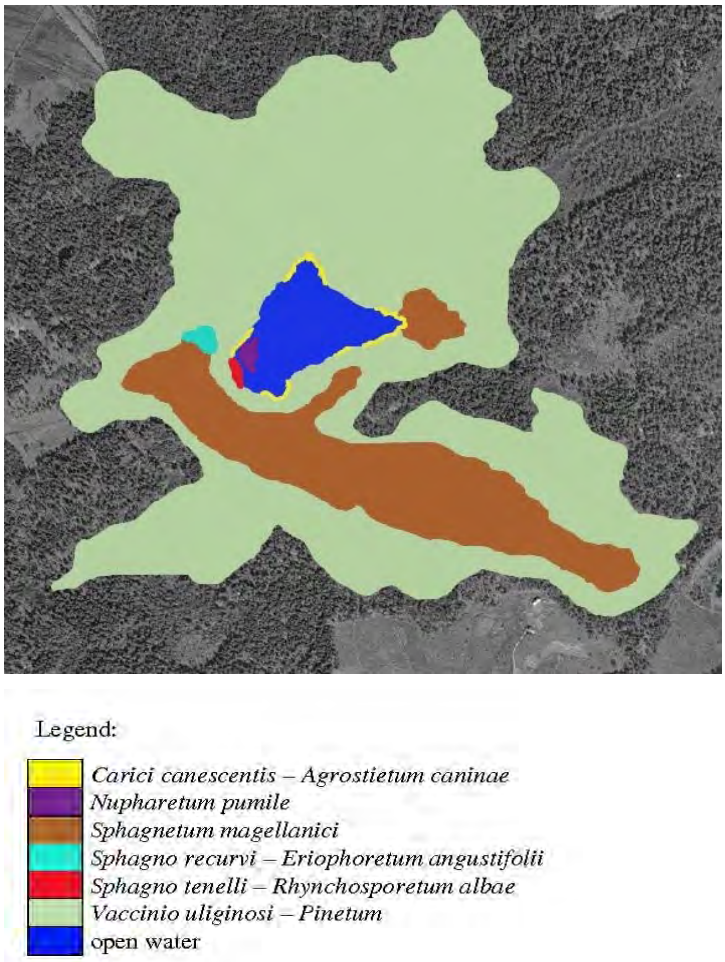

Figure 12. Map of plant communities distribution on Lommaflyet study area. Not original scale.

A great part of this mire is covered by the *Vaccinio uliginoso–Pinetum* Kleist 1930 em W. Mat. 1962 and *Sphagnetum magellanici* (Macuti 1929) Kästn. et Flössn. 1933 plant communities. In some places, these two plant associations are overlap one another and form a specific mixture of habitats. The *Nuphatetum pumile* Oberd. 1957 ex Th. Müller plant association occurs in the southwest bay of the Lommagölen Lake. The *Carici canescentis–Arostietum canianae R. Tx. 1937* plant community was recorded around the Lommagölen Lake in a form built by *Agrostis caninae* L. and *Juncus effusus* L. The *Sphagno tenelli–Rhynchosporetum albae* Osvald 1923 plant association covers about 10m^2. This habitat occurs on the southwest bank of the Lommagölen Lake on the edge of a quaking bog. The *Sphagno recurvi–Eriophoretum angustifolii* Hueck 1925 plant community occurs in places which are characterised by changes in the water level.

Gatmyren

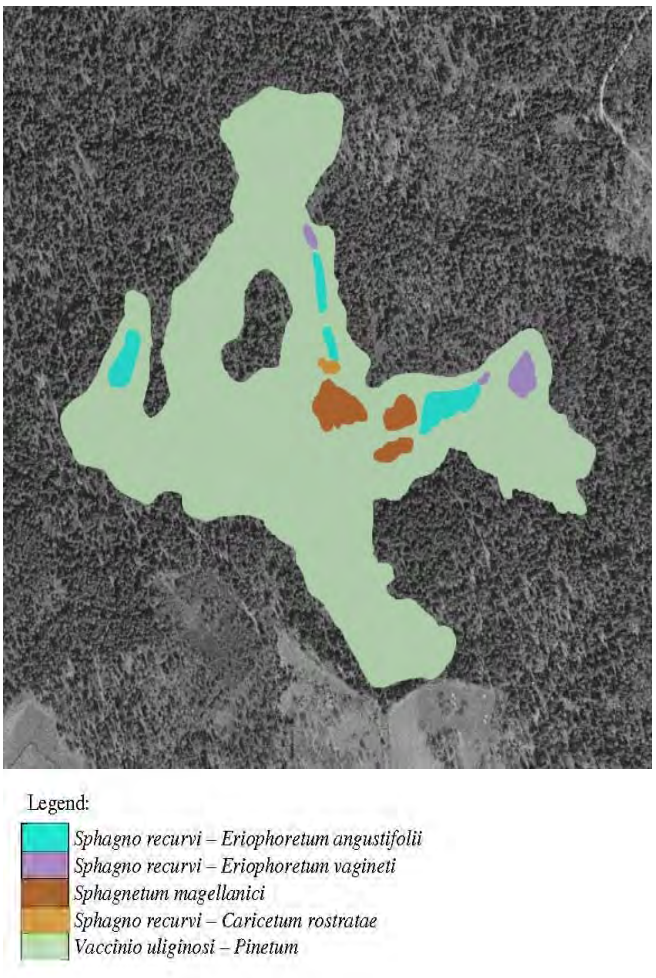

Figure 13. Map of plant communities distribution in the Gatmyren study area. Not to original scale.

The main part of the Gatmyren mire is covered by the *Vaccinio uliginoso–Pinetum* Kleist 1930 em W. Mat. 1962 plant association. This plant community forms a mosaic with *Sphagnetum magellanici* (Macuti 1929) Kästn. et Flössn. 1933. In specific places,

the *Vaccinio uliginoso–Pinetum* Kleist 1930 em W. Mat. 1962 plant community sets up the formations with *Betula* spp and *Polytrichum* spp. The *Sphagno recurvi–Eriophoretum vaginati* Hueck (1925) plant association is built by higher elevated clusters of *Eriophorum vaginatum* L., while the floor community is covered by *Sphagnum* mosses. This plant community covers small separated localities in the north-eastern part of the Gatmyren mire. The *Sphagno recurvi–Eriophoretum angustifolii* Soó 1927 ex Pignatti 1953 and *Sphagno recurvi–Caricetum rostratae* plant communities are commonly found in places where the water level fluctuates.

4.4 Stratigraphic analysis of peat deposit

Bores in the peat layer were made with a Russian type borer; the peat nomenclature was based on the Polish Standard 85-G-02500 (Tołpa 1985).

Poland

Linkowo

Bore No. 1

The bore was located within the *Sphagnetum magellanici* (Malc. 1929) Kästn. et Flössn. 1933 plant community. The stratigraphic analysis of peat deposit in the bore site No. 1 was based on the Polish Standard 85-G-02500 (*Table 17*).

Localisation: latitude N 52º 95' 19.0''
longitude E 15º 93' 10.1''

Water parameters in the bore site:
pH = 4.13;
temperature = 8.9°C;
conductivity = 56µS/cm.

Table 17. The peat stratification in the bore site No. 1 situated in the Linkowo study area. Peat classification and nomenclature based on Tołpa 1985

Sample depth [m]	Peat genus		Peat species		Peat type
	Name	Symbol	Name	Symbol	
0.00–1.30	SPHAGNUM PEAT *Ombro–Sphagnioni*	**20**	COTTON GRASS–SPHAGNUM PEAT *Eriophoro–Sphagneti*	**ERS**	**RAISED BOG PEAT**
1.30–3.00	TALL SEDGE PEAT+GYTTJA *Magnocaricioni*	**2**	SEDGE–REED PEAT *Carici–Phragmiteti*	**CAP**	**LOW–MOOR PEAT**

Bore No. 2
The bore was located within the *Sphagnetum magellanici* (Malc. 1929) Kästn. et Flössn. 1933 plant community. The stratigraphic analysis of peat deposit in the bore site No. 2 was based on the Polish Standard 85-G-02500 (*Table 18*).
Localisation**:** latitude N 52º 95' 42.1''
longitude E 15º 93' 12.0''

Table 18. The peat stratification in the bore site No. 2 situated in the Linkowo study area. Peat classification and nomenclature based on Tołpa 1985

Sample depth [m]	**Peat genus**		**Peat species**		**Peat type**
	Name	**Sym bol**	**Name**	**Sym bol**	
0.00–0.50	SPHAGNUM PEAT *Ombro–Sphagnioni*	**20**	COTTON GRASS–SPHAGNUM PEAT *Eriophoro–Sphagneti*	**ERS**	**RAISED BOG PEAT**
0.50–1.80	SEDGE–SPHAGNUM PEAT *Minero–Sphagnioni*	**10**	MOSS–SEDGE PEAT *Sphagno–Cariceti*	**SPC**	**TRANSITION PEAT**
1.80–2.00	ORGANIC GYTTJA				

Bore No. 3
The bore was located within the *Sphagnetum magellanici* (Malc. 1929) Kästn. et Flössn. 1933 plant community. The stratigraphic analysis of peat deposit in the bore site No. 3 was based on the Polish Standard 85-G–02500 (*Table 19*).
Localisation: latitude N 52º 95' 43.0''
longitude E 15º 93' 0.5''

Table 19. The peat stratification in the bore site No. 3 situated in the Linkowo study area. Peat classification and nomenclature based on Tołpa 1985

Sample depth [m]	**Peat genus**		**Peat species**		**Peat type**
	Name	**Sym bol**	**Name**	**Sym bol**	
0.00–1.50	SPHAGNUM PEAT *Ombro–Sphagnioni*	**20**	COTTON GRASS–SPHAGNUM PEAT *Eriophoro–Sphagneti*	**ERS**	**RAISED BOG PEAT**
1.50–2.50	RUSH-PEAT *Limno–Phragmitioni*	**2**	REED PEAT *Phragmiteti*	**PHR**	**LOW–MOOR PEAT**
2.50–6.00	ORGANIC GYTTJA				

The data collected in the stratigraphic profiles provided information about the history of the Linkowo mire. The origin of peatland is connected with terrestrialistion of water reservoir. The lake was formed about 10,000-12,000 years ago at the end of the last glacial period. Based on the present-day physiography of the mire, the Linkowo and

Linkówko lakes were probably one water reservoir once. This water reservoir has been changing during the succession process. Organic material has sedimented in the form of a gyttja deposit at the bottom of the lake. The open water has been overgrown with plant communities consisting of sedges and reeds. These types of vegetation have formed a low-moor peat type. The next stage was a shift in plant communities, i.e. sedges and *Sphagnum* mosses started to prevail and transition peat was formed. This was then followed by an increase in the *Sphagnopsida* class. The effect is a raised bog peat on the upper layer of the profile.

Sarbinowo

Bore No. 1

The bore was located within the initial *Vaccinio uliginosi–Pinetum* Kleist 1930 em W. Mat. 1962 plant community. The stratigraphic analysis of peat deposit in the bore site No. 1 was based on the Polish Standard 85-G-02500 (*Table 20*).

Localisation**:** latitude N 52º 92' 24.4''
longitude E 15º 88' 30.4''

Water parameters in the bore site:
pH = 5.11,
temperature = 7.6°C;
conductivity = 46µS/cm.

Table 20: The peat stratification in the bore site No. 1 situated in the Sarbinowo study area. Peat classification and nomenclature based on Tołpa 1985

Sample depth [m]	Peat genus		Peat species		Peat type
	Name	Symbol	Name	Symbol	
0.00–1.75	SPHAGNUM PEAT *Ombro-Sphagnioni*	**20**	COTTON GRASS–SPHAGNUM PEAT *Eriophoro–Sphagneti*	**ERS**	**RAISED BOG PEAT**
1.75–1.90	ORGANIC GYTTJA				
1.90–2.00	SPHAGNUM PEAT *Ombro–Sphagnioni*	**20**	COTTON GRASS–SPHAGNUM PEAT *Eriophoro–Sphagneti*	**ERS**	**RAISED BOG PEAT**
2.00–4.00	ORGANIC GYTTJA				

The information from the stratigraphic description shows a similar origin of peat deposit to that of the Linkowo mire. The Sarbinowo peatland was formed in the terrestrialisation process of deep water reservoir, which is evidenced by a deep organic deposit of gyttja. The lake basin began to be filled with a raised bog peat type, consisting of the humified *Sphagnum* mosses and *Eriophorum* species remnants. During the analysis of stratigraphic profile, a gyttja layer was found in the raised bog peat type at a depth of 1.75–1.90 m. This is pointing at a rapid increase in the water level – gyttja is formed under limnic conditions during the sedimentation process of organic material.

Sweden

Lommaflyet

Bore No. 1

The bore was located within the *Vaccinio uliginosi–Pinetum* Kleist 1930 em W. Mat. 1962 plant community. The stratigraphic analysis of peat deposit in the bore site No. 1 is based on the Polish Standard 85-G-02500 (*Table 21*).

Localisation: latitude N 56º 25' 09.6''
longitude E 15º 38' 05.5''

Table 21. The peat stratification in the bore site No. 1 situated in the Lommaflyet study area. Peat classification and nomenclature based on Tołpa 1985

Sample depth [m]	**Peat genus**		**Peat species**		**Peat type**
	Name	**Symbol**	**Name**	**Symbol**	
0.00–0.60	SPHAGNUM PEAT *Ombro-Sphagnioni*	**20**	PINE–SPHAGNUM PEAT *Pino–Sphagneti*	**PIS**	**RAISED BOG PEAT**
0.60–1.00	SEDGE–SPHAGNUM PEAT *Minero–Sphagnioni*	**10**	SCHEUCHZERIA PEAT *Sphagno–Scheuchzerieti*	**SPC**	**TRANSITION PEAT**
1.00–1.30	ALDER PEAT *Alnioni*	**5**	ALDER SWAMP FOREST PEAT *Alneti* WILLOW PEAT *Saliceti*	**ALN** **SAL**	**LOW–MOOR PEAT**
1.30–1.40	ORGANIC GYTTJA				

Bore No. 2

The bore was located within the *Vaccinio uliginosi–Pinetum* Kleist 1930 em W. Mat. 1962 plant community. The stratigraphic analysis of peat deposit in the bore site No. 2 is based on the Polish Standard 85-G-02500 (*Table 22*).

Localisation: latitude N 56º 25' 09.6''
longitude E 15º 38' 05.5''

Table 22. The peat stratification in the bore site No. 2 situated in the Lommaflyet study area. Peat classification and nomenclature based on Tołpa 1985

Sample depth [m]	**Peat genus**		**Peat species**		**Peat type**
	Name	**Sym bol**	**Name**	**Sym bol**	
0.00–1.60	SPHAGNUM PEAT *Ombro–Sphagnioni*	**20**	COTTON GRASS–SPHAGNUM PEAT *Eriophoro–Sphagneti*	**ERS**	**RAISED BOG PEAT**
1.60–2.07	SEDGE–SPHAGNUM PEAT *Minero–Sphagnioni*	**10**	MOSS–SEDGE PEAT *Sphagno–Cariceti*	**SPC**	**TRANSITION PEAT**
2.07–5.00	ALDER PEAT *Alnioni*	**5**	ALDER SWAMP FOREST PEAT *Alneti*	**ALN**	**LOW–MOOR PEAT**
			WILLOW PEAT *Saliceti*	**SAL**	
			ALDER–BIRCH PEAT *Alno–Betuleti*	**ALB**	
1.30–1.40	CLAY GYTTJA				

Bore No. 3
The bore was located within the *Sphagnetum magellanici* (Malc. 1929) Kästn. et Flössn. 1933 plant community. The stratigraphic analysis of peat deposit in the bore site No. 3 is based on the Polish Standard 85-G-02500 (*Table 23*).
Localisation: latitude N 56º 25' 02.9''
longitude E 15º 37' 97.0''

Table 23. The peat stratification in the bore site No. 3 situated in the Lommaflyet study area. Peat classification and nomenclature based on Tołpa 1985

Sample depth [m]	**Peat genus**		**Peat species**		**Peat type**
	Name	**Sym bol**	**Name**	**Sym bol**	
0.00–3.35	SPHAGNUM PEAT *Ombro–Sphagnioni*	**20**	COTTON GRASS–SPHAGNUM PEAT *Eriophoro–Sphagneti*	**ERS**	**RAISED BOG PEAT**
3.35–4.00	SEDGE–SPHAGNUM PEAT *Minero–Sphagnioni*	**10**	MOSS–SEDGE PEAT *Sphagno–Cariceti* SCHEUCHZERIA PEAT *Sphagno–Scheuchzerieti*	**SPC** **SPC**	**TRANSITION PEAT**
4.00–4.60	ALDER PEAT *Alnioni*	**5**	ALDER SWAMP FOREST PEAT *Alneti* WILLOW PEAT *Saliceti* ALDER–BIRCH PEAT *Alno–Betuleti*	**ALN** **SAL** **ALB**	**LOW–MOOR PEAT**
4.60–5.30	ORGANIC GYTTJA				
5.30	CLAY				

The analysis of the bores made in the Lommaflyet mire demonstrated that the origin of peat deposit is connected with terrestrialisation of a shallow water reservoir. The gyttja deposit is thin, about 1 meter in thickness. The depression was formed during the last glacial period and then filled up with water. The deepest peat layer is mainly formed by alder, willow and birch tree remnants, which form a low moor peat. The next stage was formation of transition peat type, consisting of sedges and *Sphagnum* mosses. The surface layer of peat is formed by a raised peat bog type.

Gatmyren

Bore No. 1

The bore was located within the *Vaccinio uliginosi–Pinetum* Kleist 1930 em W. Mat. 1962 var *Betula* (*Politrichum*) plant community. The stratigraphic analysis of peat deposit in the bore site No. 1 is based on the Polish Standard 85-G-02500 (*Table 24*).

Localisation: latitude N 56º 21' 98.3''
longitude E 15º 05' 58.5''

Table 24. The peat stratification in the bore site No. 1 situated in the Gatmyren study area. Peat classification and nomenclature based on Tołpa 1985

Sample depth [m]	**Peat genus**		**Peat species**		**Peat type**
	Name	**Symbol**	**Name**	**Symbol**	
0.00–0.60	SPHAGNUM PEAT *Ombro–Sphagnioni* Numerous fragments of charcoal	**20**	PINE–SPHAGNUM PEAT *Pino–Sphagneti*	**PIS**	**RAISED BOG PEAT**
0.60	MINERAL FORMATIONS				

Water parameters in the bore site:
pH = 3.95;
temperature = 14.3^{o}C;
conductivity = 116 μS/cm.

Bore No. 2
The bore was located within the *Vaccinio uliginosi–Pinetum* Kleist 1930 em W. Mat. 1962 plant community. The stratigraphic analysis of peat deposit in the bore site No. 2 is based on the Polish Standard 85-G-02500 (*Table 25*).
Localisation: latitude N 56º 21' 97.6''
longitude E 15º 05' 69.7''

Table 25. The peat stratification in the bore site No. 2 located in the Gatmyren study area. Peat classification and nomenclature based on Tołpa 1985

Sample depth [m]	**Peat genus**		**Peat species**		**Peat type**
	Name	**Symbol**	**Name**	**Symbol**	
0.00–1.25	SPHAGNUM PEAT *Ombro–Sphagnioni*	**20**	PINE–SPHAGNUM PEAT *Pino–Sphagneti*	**PIS**	**RAISED BOG PEAT**
1.25–1.35	PINE PEAT *Ledo–Pinioni*	**22**	PINE PEAT *Pineti*	**PIN**	
1.35–2.60	SPHAGNUM PEAT *Ombro–Sphagnioni*	**20**	COTTON GRASS–SPHAGNUM PEAT *Eriophoro–Sphagneti*	**ERS**	
2.60–2.75	SEDGE–SPHAGNUM PEAT *Minero–Sphagnioni*	**10**	MOSS–SEDGE PEAT *Sphagno–Cariceti*	**SPC**	**TRANSITION PEAT**
2.75–3.35	ORGANIC GYTTJA				
3.35–3.50	CLAY				
3.50	MINERAL FORMATONS				

Bore No. 3
The bore was located within the *Sphagnetum magellanici* (Malc. 1929) Kästn. et Flössn. 1933 plant community. The stratigraphic analysis of peat deposit in the bore site No. 3 is based on the Polish Standard 85-G-02500 (*Table 26*).
Localisation: latitude N 56º 22' 00.2''
longitude E 15º 05' 85.3''

Table 26. The peat stratification in the bore site No. 3 located in the Gatmyren study area. Peat classification and nomenclature based on Tołpa 1985

Sample depth [m]	**Peat genus**		**Peat species**		**Peat type**
	Name	**Symbol**	**Name**	**Symbol**	
0.00–2.20	SPHAGNUM PEAT *Ombro–Sphagnioni*	**20**	COTTON GRASS–SPHAGNUM PEAT *Eriophoro–Sphagneti*	**ERS**	**RAISED BOG PEAT**
2.75–2.90	ORGANIC GYTTJA				
2.90–3.00	CLAY GYTTIA				

The origin of the Gatmyren mire started at the end of last glacial period. The thickness of gyttja layer, i.e. 0.30 m, demonstrates that the mire was a shallow water reservoir once. Then the process of terrestrialisaton started. Transition peat types built by sedges and *Sphagnum* mosses began to accumulate. The top layer of peat deposit is formed by *Eriophorum* species and *Sphagnum* mosses. These plants form a raised bog peat. Numerous charcoal fragments were found inside the peat profile, substantiating the fact that fires occurred frequently during the mire history.

4.5. Changes in the mire limits and the watershed area in the last 50 years

Poland
Linkowo

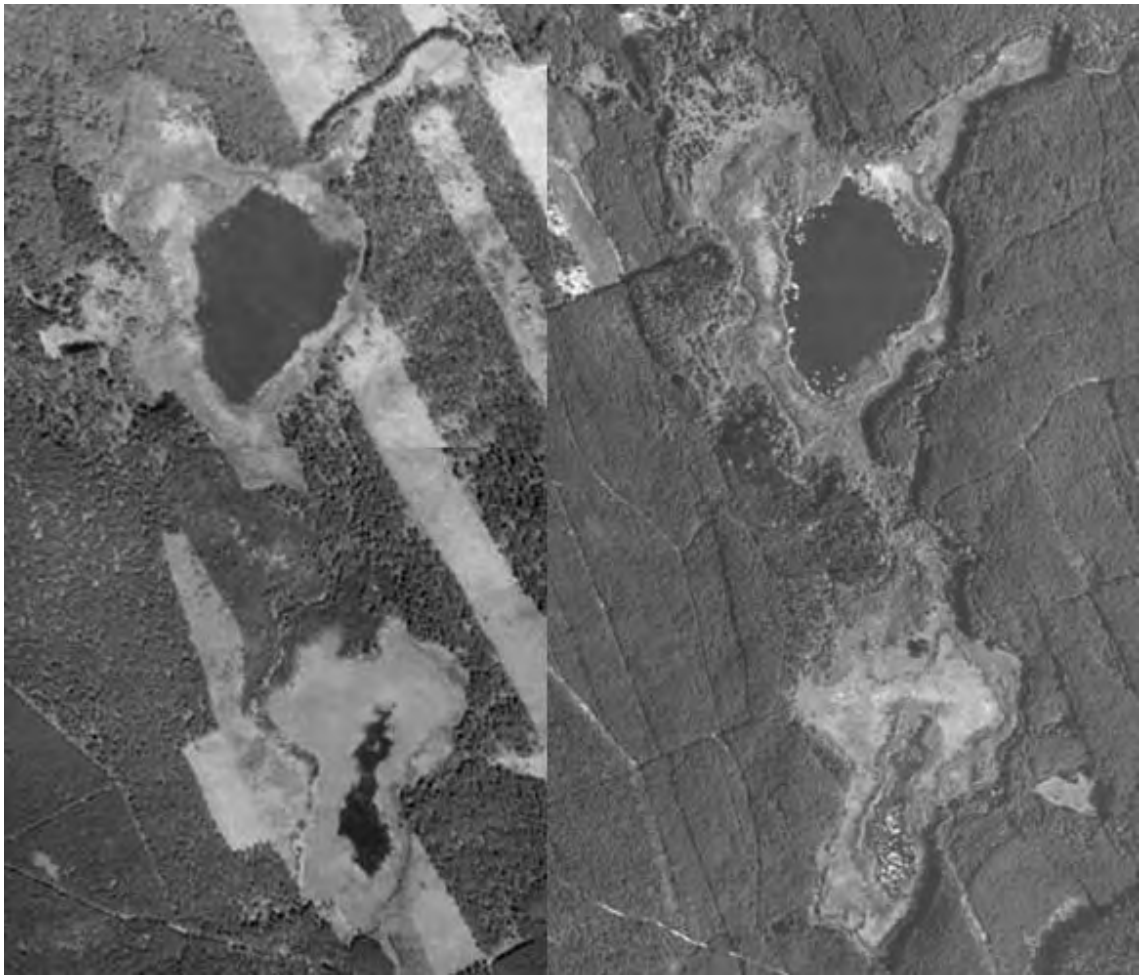

Figure 14. Aerial photograph of the Linkowo study are from 1963. Not to original scale.

Figure 15. Aerial photograph of the Linkowo study area from 2002. Not to original scale.

Basing on the analysis of historical and present-day aerial photographs, well visible changes in the watershed area are observed. A wide area around the mire is covered by clear cuts. On the surface of the mire, shifts in plant communities are observed. The proportion between open mire area and higher vegetation cover is changed. The area covered by higher vegetation has been enlarging since 1963. A drainage ditch is visible in the northern part of the mire. During the field work, a 2.5 ha area overgrown with *Spiraea tomentosa* L. was examined in the central part of the mire.

Sarbinowo

Figure 16. Aerial photograph of the Sarbinowo study area from 1963. Not to original scale.

Figure 17. Aerial photograph of the Sarbinowo study area from 2002. Not to original scale.

The analysis of aerial photographs of the Sarbinowo mire taken in 1963 and 2002 shows changes within the mire limits and its watershed area. In the northern part of the mire, the watershed area was used as arable land in the past, which was observed on the aerial photograph taken in 1963, contrasting with a 25 year-old stand of *Pinus sylvetris* L., which now occupies a part of it. A larger part of the watershed area of the Sabinowo mire is used for forestry purposes. High intensity silviculture treatments are observed here. Clear cuts are visible close to the boundary of the mire. A drainage ditch, cutting across the mire, is visible.

Sweden

Lommaflyet

During the analysis of the historical and present-day aerial photographs, a main change in the mire limits is a reduced area of open bog habitat with high vegetation being presently dynamic. Based on the field work, the open habitat is mainly represented by the *Sphagnetum magellanici* (Macuti 1929) Kästn. et Flössn. 1933 plant community, while higher vegetation is formed by the *Vaccinio uliginosi–Pinetum* Kleist 1930 em W. Mat. 1962 plant association. These two communities overlap each other in many places and form a specific mosaic of habitats. On the aerial photograph from 1956, drainage ditches are observed. On Figure 19, these ditches are overgrown with plant vegetation and not seen so well as on the former photograph.

Figure 18. Aerial photograph of the Lommaflyet study area from 1956. Not to original scale.

Figure 19. Aerial photograph of the Lommaflyet study area from 2006. Not to original scale.

Gatmyren

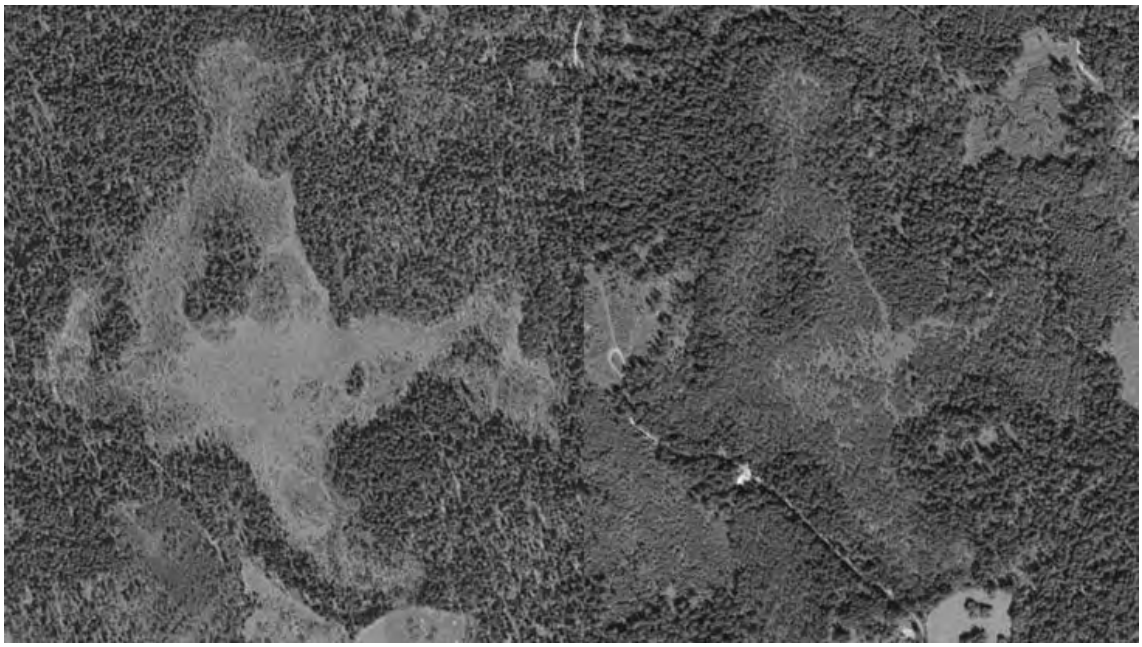

Figure 20. Aerial photograph of the Gatmyren study area from 1957. Not to original scale.

Figure 21. Aerial photograph of the Gatmyren study area from 1957. Not to original scale.

The main difference between the past and the present is the enlarged area of higher vegetation. Open bog habitats are covered by the *Vaccinio uliginosi–Pinetum* Kleist 1930 em W. Mat. 1962 plant community. Within the mire area, no drainage ditches are seen, which was also observed during the field work. The watershed area of the mire is covered by a forest, with silvicultural treatments being observed. In the southern part of the mire, its watershed area is under agricultural use. This area is probably used as a meadow or pasture.

5. Discussion

A species is a fundamental unit of plant vegetation. Particular species require and tolerate specific habitat conditions. The number of species per study area is the result of habitat variation within the mires. Some factors producing a variation within the plant cover were measured and identified during the field and laboratory works.

The high number of species examined in the Linkowo mire can be affected by many factors: the complex source of water, occurrence of open water, pH, and the alder forest between the Linkowo and Linkówko lakes. The high homogeneity of habitats, in the Sarbinowo, Lommagolen and Gatmyren mires influence on the low number of species. The Lommagolen and Gatmyren mires are covered in the main part by the *Vaccinio uliginosi–Pinetum* Kleist 1930 em W. Mat. 1962 plant association. This type of plant community is composed of only a low number of species. High moisture and low pH are typical factors that affect a low number of species in the mire habitats. A shady condition formed by *Vaccinio uliginosi–Pinetum* Kleist 1930 em W. Mat. 1962 lowers the number of species occurring within the mires.

In general, mires are the habitats that are resistant to foreign species settlement. The results obtained in the present study support this assumption. Only three foreign species were recorded in four study areas, being classified into the holoagrophytes group. *Picea abies* (L.) Karsten is one of the foreign species examined in the Linkowo and Sarbinowo peatbogs. In the northwest part of Poland, this species is outside its natural distribution range but is commonly planted in wet places by foresters. This coniferous tree species disturbs water conditions in the mire due to transpiration processes. The floristic naturalness of the Linkowo mire is also changed by *Elodea canadensis* Michx and *Spiraea tomentosa* L. These species were classified to the Boreoamerican region on the grounds of histo-geographical division of the flora. *Spiraea tomentosa* L. is a really expansive vascular plant species. Dryer conditions in the central part of the Linkowo mire (road across the narrow part of the mire complex) could have made easier the settlement of *Spiraea tomentosa* L**.** It forms dense bushy vegetation and replaces native plant communities. *Spiraea tomentosa* L. disturbs the water balance in the mire since it increases evapotranspiration from the surface of the mire. Peat starts to convert into moorsh when the water level drops down. Leaf litter increases the trophic status of the mire and accelerates peat decomposition. High mire resistance to foreign species settlement results from low pH of the surface [top] water level. *Sphagnum* mosses produce chemical compounds that lower the acidity. *Sphagnum* mosses are a characteristic element of the raised bogs fed by precipitation. No foreign species was recorded in the Lommaflyet mire. This may be the result of rich *Sphagnum* mosses flora which occurs in this mire. The Gatmyren mire has also 100% native species in the list of flora, which could be cause by unfavorable shady condition formed by the *Vaccinio uliginosi–Pinetum* Kleist 1930 em W. Mat. 1962 plant association.

The comparison of red-listed species was possible after unification of threat categories, as the latter are different for the Polish and Swedish Red Lists.
The Red Lists of species for Poland and Sweden differ. Many plant species were examined both in the Polish and the Swedish study areas but classified as red-listed for Poland only. A total of 10 species of mosses and vascular plants were classified as red-listed ones. All of them were classified based on the Polish Red Lists whereas none was classified according to the Swedish Red List. The main reason is the availability of potential habitats for settlement. Relative peatland occurrence in Sweden is 23.1 % of total area. This factor reaches 3.9% of total area in Poland (Ilnicki 2002) The criteria for including a species into Red List are regulated by IUCN – the World Conservation Union, and they are equal for all countries. This is why they have no influence on the number of red-listed species examined in different countries. The conclusion is that many species are threatened by extinction in Poland but their situation in Sweden is stable and they do not need special protection. Probably, the result would be more precise if regional, but not national, Red Lists were used to determine the treat category of species.

The origin, stratigraphy, source of water and hydrological mire type are in close relation to each other. The genesis of mire is results from complex climatic, topographic and geological factors. This determines the source of water and influences the stratigraphy of peat layers and hydrological mire type. The exmined mires started to develop in a water reservoir. This mire type is topogenous. The Lommaflyet and Gatmyren mires are connected with a shallow lake (thin gyttja layer), while the Linkowo and Sarbinowo mires started to develop in a deep water reservoir (thick gyttja deposit). This can be seen in the bottom layer of the stratigraphic profile where gyttja deposit is located.

Water, rich in minerals, filled the water reservoir, which allowed the plants requirring eutrophic conditions to grow. These plants were alder, birch, willow and reed. They formed a low moor peat which was accumulated deep in the profile. Then, minerals were bound and accumulated in the form of peat, and the water trophy was dropping down. Changes in nutrient availability affected the plant cover, with sedges and other plants that tolerate mesotropic conditions starting to dominate. They built a transition peat, which is observed in the stratigraphic profile. When minerals dissolved in the lake water were reduced, plants communities forming a raised peat bog started to prevail. These plants were mainly *Sphagnum* mosses, *Eriophorum* spp. which tolerate oligotrophic conditions. That is the general trend in the development of ombrogenous mire type. In the stratigraphic profiles of the studied areas, some changes and modifications were observed. They were thoroughly explained in Section 4.4. Based on the stratigraphic profiles of all four examined mires, it was determined that they are at the stage of transition from a topogenous to ombrogenous type. During the analysis of the strtigraphic profiles, it was observed that the Lommaflyet and Gatmyren mires are advanced in the transition process (thicker raised bog peat layer) when compared to the Linkowo and Sarbinowo mires. The reason for this could be the depth of the former water reservoir and the capacity of dissolved minerals.

The phytosociologial affinity of mosses provide information on the current main type of the source of water and the type of mire. The *Oxycocco–Sphagnetea* Br.–Bl et R. Tx. 1943 and *Vaccinio–Piceetea* Br.–Bl. 1939 classes are characteristic of the ombrogenus (peatbog) mire fed by precipitation. On the other hand, the *Scheuchzerio–Caricetea* (Nordh. 1937) R.Tx. 1937 class occurs mainly in mires fed by compound sources of water – a transition mire type. Based on the phytosociological classification of mosses, the examined mires were divided into two groups. The Linkowo and Sarbinowo mires were classified to a mixture type. The water feeding in the Polish mires comes from precipitation (obrogenous type), a former lake (topogenous type) and from ground water (soligenous type). The Lomaflyet and Gatmyren mires were classified as topogenous ones but still in transition into the ombrogenus type.
There were significant changes in the last 50 years within the mire limits in all four examined study areas. The shift is manifested in the enlarged area of the *Vaccinio uliginosi–Pinetum* Kleist 1930 em W. Mat. 1962 plant community in the Lommaflyet and Gatmyren mires. Mires are more stable habitats when compared to terrestrial environments and shifts in plant associations are characterised by lower dynamic (Klinger 1996, Gunnarson et al. 2002 after Pellerin & Lavoile 2003). The fifty years is a short period in the scale of natural succession within peatlands. The human impact, nitrogen air deposition, climate changes and recent fires are the most important factors which accelerate the forest expansion in ombrotrophic mire (Pallerin & Lavoile 2003). During the analysis of present-day and former aerial photographs, a system of drainage ditches on the surface of Linkowo, Sarbinowo and Lommaflyet mires was observed. The lowering of water level due to drainage accelerates the oxidation process – nutrients are easily made available and temperature of the upper peat layer increases. The vitality of moss vegetation diminishes due to the lack of water. These conditions allow pine seeds to germinate and support the growth of seedlings. Pines that grow on peatbog with maintained drainage can have similar growth parameters as those growing on mineral soil. (Linderholm 1999). Drainage is not only one factor which favours the *Vaccinio uliginosi–Pinetum* Kleist 1930 em W. Mat. 1962 plant association. The drainage system was not observed on the surface of the Gatmyren mire, nevertheless a severe decrease in open bog plant communities was detected. The explanation for this could by events of

fire in the past. *Pinus sylvestris* L. is one of the best species adapted to a fire regime as a control factor in this environment. This hypothesis is supported by charcoal layers found during the stratigraphic analysis of peat deposit.
The watershed area of all four examined areas is overgrown with commercial forests. Silviculture treatments are well visible on the aerial photographs and their intensity could have affected the quality of and the changes in water level in the mire. It is also an important factor which could influence the current situation of the plant cover.
The changes observed within the mire limits and the watershed areas result from socio-economical transitions in the last 50 years. Village inhabitants have migrated into cities in past decades. This fact has substantiated the changes in land use, from agricultural to forestry purposes. Air pollution and atmospheric deposition of sulphur and nitrogen increase the trophy. Agricultural and forest production have increased in intensity.
It is important to take into consideration that, according to current studies, peatlands have been severely affected by human activity and may change their role as net sinks into a net carbon source (Franzén 2006).
It is also important to take into account that the examined peatlands, the topography of which seemed to look similar on the map, demonstrated many differences during a thorough field work. The analysis of map can not give precise information about the richness in taxa occurring in the peatland, whereas a precise review of aerial photographs can provide information on the level of plant communities. Nevertheless, only a careful field and laboratory work can make the receiving of reliable and satisfactory results referring to peatland flora, origin and history possible.
The examined mires are in the time of transition. Future scientific research carried out on the basis of similar methods might provide the interesting results about vegetation dynamics and direction in changes.

6. Conclusions

1. The *Vaccinio uliginosi–Pinetum* 1930 em W. Mat. 1962 plant community affects a decreasing number of species in the Gatmyren and Lommaflyet mires;
2. Different factors have affected the enlarged area of the *Vaccinio uliginosi–Pinetum* 1930 em W. Mat. 1962 plant community. (Gatmyren fire regime, Lommaflyet drainage)
3. A mixture of water sources has increased the number of species in the Linkowo mire;
4. Disturbed water condition in the central part of the Linkowo mire could have enabled the settlement of *Spiraea tomentosa* L., which is a foreign species;
5. The origin and the source of water determine the stratigraphic profile of peat deposit;
6. The origni of the Lommaflet and Gatmyren mires is in a shallow water reservoir, while that of the Linkowo and Sarbinowo mires in a deep water reservoir
7. The Linkowo, Sarbinowo and Lomaflyet mires were drained in the past, while the Gatmyren mire has no evidence of drainage.
8. The number of red-listed species is different for the study areas located in Poland and Sweden. It depends on the availability of potential habitat to settlement.
9. Based on the phytosociological classification of mosses, the Lommaflyet and Gatmyren mires represent the ombrogenous (peatbog) mire type, while the Linkowo and Sarbinowo mires are classified as a mixture (transition) mire type.
10. The Lommaflyet, Gatmyren and Sarbinowo mires are more resistant to foreign species than the Linkowo mire.

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