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Asbjørn Moen (ed.)

REGIONAL VARIATION AND CONSERVATION OF MIRE ECOSYSTEMS

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INTERNATIONAL MIRE CONSERVATION GROUP

ABSTRACT

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This volume contains papers based on lectures and posters presented at the 6th field symposium of the International Mire Conservation Group, held in Norway in 1994. The 24 contributions plus an introduction deal with variations in the vegetation, flora, hydrology, hydromorphology, distribution and conservation of mires as well as factors threatening them. For instance: regional differences (worldwide) in the water chemistry of bogs, and implications for vegetation classification; regional variation in boreal mire ecosystems in Canada through time; comparisons of boreal mire ecosystems in western Europe and eastern North America; work on a small-scale mire vegetation map of Europe; methods for small-scale mapping of mire complexes in Russia; hydrology and restoration of raised bogs after peat-cutting in Austria and Ireland; restoration of mires drained for forestry in Finland; Ellenberg's indicator values for temperature and continentality for mire plants used in regional studies in Norway. A number of papers deal with descriptions of mire ecosystems and the conservation situation in various countries: Estonia, Poland, Ukraine, the Fennoscandian countries, Canada, Lesotho (rare and threatened types of soligenous fens with flarks) and Japan. Papers on criteria for protection of mires, a survey of the international peat trade; comments on IMCG work, as well as the Trondheim Declaration and the 18 national resolutions are also included.

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INTERNATIONAL MIRE CONSERVATION GROUP

PREFACE

The International Mire Conservation Group (IMCG) is an international organisation of mire (peatland) specialists who have a particular interest in conserving mire ecosystems. The 6th IMCG field symposium was held in Norway from 4th to 15th July 1994. The symposium was divided into a three-day conference in Trondheim, a nine-day excursion in central Norway and a concluding day dealing with IMCG matters. The conference had about 80 participants from 25 different countries. For the first time in an IMCG symposium, eastern Europe was well represented with 19 participants from 11 countries.

Before the conference, all the participants received: 1) a «Summary of papers» (53 summaries of talks and posters presented at the conference), 2) an «Excursion guide», 3) «Norwegian Sphagna», and 4) «European mires» (a preliminary report on the distribution, exploitation and conservation of mires in 22 countries). Nos. 1, 2 and 3 are published in the Botany Department report series. A summary in Norwegian of experience gained from the field symposium (including all the resolutions and the Trondheim Declaration) has been published in a report series from the Centre for Environment and Development at the University of Trondheim.

This particular volume contains 25 papers (including the Introduction) based on lectures and posters given at the symposium, as well as some supplementary material, partly based on experience gained during the meeting.

A primary aim of the IMCG symposium, and of this volume, is to present factual information about the variation and conservation of mire ecosystems worldwide. Contributors were asked to submit papers that are factual in content, presenting either primary data, a synthesis of existing information, or conceptual developments. The papers that were submitted were scrutinised by referees and the editor, and the authors revised their manuscripts in response to the recommendations they made. The authors are thanked for their valuable co-operation. I am particularly grateful to those who have acted as referees, improved the language or given other forms of assistance regarding the manuscripts: Egil I. Aune, Gerry Doyle, Peter Foss, Richard Lindsay, Kamil Rybníček, Stein Singsaas, Hugo Sjörs, Sigurd Såstad and Philip Tallantire. The main language correction has been done by Richard Binns, who has also participated in the final processing of the manuscripts, and altogether done an excellent job as a technical editor. Inger Marie Growen and Arild Krovoll have also assisted greatly in typing, preparing data files, figures, etc.

The field symposium was arranged by the Museum of Natural History and Archaeology (VM) and the Centre for Environment and Development (SMU), both at the University of Trondheim; and the Directorate for Nature Management (DN) in Trondheim. Responsibilty for the scientific content of the symposium was in the hands of Kjell Ivar Flatberg, Asbjørn Moen and Stein Singsaas (VM). In addition, the organising committee consisted of Ingerid Angell-Petersen (DN) and Sølvi Hansen and Eirik Lind (SMU).

Financial support for the field symposium was given by the Directorate for Nature Management, the Ministry of the Environment and the University of Trondheim. The Royal Norwegian Society of Sciences and Letters Foundation provided funding for publication of the proceedings.

This volume is dedicated to Hugo Sjörs, in admiration of his pioneering contributions to research and conservation of mire ecosystems.

Trondheim 1995

Asbjørn Moen

Introduction: regionality and conservation of mires

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1 BACKGROUND, THE NEED FOR MIRE PROTECTION

Mire ecosystems, taken as a whole, are not endangered, but this is by no means the case for all types of mire when viewed separately. In the nemoral (temperate) and the southern parts of the boreal zones of Europe, in some of the most industrialised countries of the world, vast tracts of mire landscape have vanished during the last two centuries. In many cases, these changes undoubtedly helped to transform the economies of certain regions and even whole nations. However, the environmental costs of this progress were high, as shown by «The Dutch Experience» (Schouten 1991, Joosten 1994 and this volume): In the **Netherlands**, about 1/3 of the land surface was once covered with mires (about 1.5 million ha), about 2/3 of which were bogs. These mires have been exploited for centuries, the severe impacts resulting in not a single mire remaining unaffected by drainage, cutting, burning, farming and constructional work. The conservation value of bogs and fens has been recognised in recent decades, and great attempts are being made to restore mires, at a high cost. Some 37,500 ha of mire remnants are protected in about 300 reserves. As much as 150 million Dutch guilders have been spent on restoring a few «bog» areas (and *Sphagnum* growth has started again!), but it will never be possible to re-create what has been lost.

In countries like **Denmark** and **Switzerland**, and large parts of **Austria, Germany, Great Britain** and **Poland**, nearly all mires are damaged (cf. Succow & Jeschke (1990), articles and resolutions in Grünig (1994), and Grünig and Sienkiewicz & Kloss, this volume).

The raised bogs of **Ireland** (apart from a few protected areas, partly established with money from the Netherlands) may be gone in a few years, the main threat being fuel peat extraction (Foss 1991).

Finland carried out the world's most extensive programme of mire drainage for forestry purposes two to three decades ago; around 1970 as much as 300,000 ha were drained annually. In Finland, mires once covered 1/3 of the land area, about 10 million ha. Nearly 70% of this area (i.e. more than double the total Norwegian mire area) has been exploited, the greater part for forestry, but large areas have also been used for peat extraction, agriculture and water-supply reservoirs. Before the enormous drainage programme started, Finnish researchers had documented the regional structure of mire ecosystems (e.g. Ruuhijärvi 1960, Havas 1961, Eurola 1962), and the Finns started extensive conservation programmes earlier than any other nation. At present, about 800,000 ha of mires are protected in nearly 500 areas, covering the main variation of mires in Finland. However, in southern Finland only 2% of the former mire area is protected, and important mire types need to be added to the conservation plan. In this part of Finland as much as 20% of the protected mires are affected by ditches, so restoration work has to be carried out (Aapala et al., Eurola & Hanhela, Heikkilä & Lindholm, this volume).

Destruction of peatlands for forestry, agriculture and fuel peat extraction, altogether more than ½ million ha per year, is being promoted by international subsidies and by export of expertise and technology, for instance in Indonesia where Finnish companies are operating. The destruction of mire ecosystems may be expected to increase in the near future, resulting in loss of biodiversity and a more unfavourable balance in carbon cycles (Joosten, this volume).

Perhaps the most confusing situation is to be found in some eastern European countries, where mires with existing protection are threatened by eastward expansion of western peat mining companies and land-ownership reforms (Ilomets & Kallas, Sienkiewicz & Kloss, this volume).

2 THE INTERNATIONAL MIRE CONSERVATION GROUP AND THE 6TH FIELD SYMPOSIUM

Mires suffer from limited scientific understanding and, perhaps more important, poor public perception of their true natural heritage and functional value. These factors compound and help to explain the scale of the losses. Against this backdrop, the need for an organisation such as the International Mire Conservation Group (IMCG) was agreed upon by a number of international mire specialists at a field symposium on mire classification held in Finland in 1983 (Eurola & Huttunen 1985).

The International Mire Conservation Group was formally established in 1984 at its first field symposium in Austria. Subsequently, field symposia have been arranged in Scotland, Sweden, Ireland (Foss 1991), and in 1992 in Switzerland (Grünig 1994). The 6th field symposium was held in Norway on 4th to 15th July 1994.

The programme for the 6th field symposium, and a summary of the 53 papers (talks and posters) presented at the symposium are to be found in Moen & Binns (1994); the excursion guide (Moen & Singsaas 1994) contains a survey of the mire terminology and classification systems used in Norway, as well as a description of the variations found among mires in central Norway. A field guide to Norwegian Sphagna (Flatberg 1994) was also published before the field symposium. A summary of practical experience gained in arranging the symposium, as well as budgets, resolutions, etc. are presented in Angell-Petersen et al. (1994).

It was intended to publish an IMCG review of mire areas and the conservation status of European mires before this volume. However, copies of a draft including descriptions from 22 countries in Europe were given to the participants of the 6th field symposium (Löfroth & Moen 1994), and it is planned to complete the final report in 1996 (Löfroth, this volume).

3 STRUCTURE OF THIS VOLUME

The structure of this volume largely reflects the symposium programme, although IMCG activities, perspectives and resolutions were taken up both at the start of the symposium and during the final session. All this latter material, including a summary and comments on the conference prepared by the IMCG leader, Richard Lindsay, the Trondheim Declaration, the resolutions, etc., is gathered in the last part of the volume, following the scientific papers.

The publication starts with five papers on classification and regionality on the large scale (beyond a national situation); continues with two papers on hydrological studies and restoration of raised bogs, which are followed by 13 papers dealing primarily with studies on a national scale. These are concerned with areas of different size, and vary in regard to the methods, etc. used. The first four papers concern eastern Europe, and these are followed by six from Fennoscandia, and finally papers from Canada, Lesotho and Japan. The one dealing with Japan (by Iwakuma) briefly presents the area which will be the venue of the next IMCG field symposium in 1996. The paper by Joosten gives worldwide perspectives on the peat trade, and stands in its own category ahead of papers dealing with protection work and IMCG topics.

The plant nomenclature follows standard floras, mainly Flora Europaea (Tutin et al. 1964-80) for vascular plants and Corley et al. (1981), Corley & Crundwell (1991) and Grolle (1983) for bryophytes; some papers give references to other floras.

4 MIRES AND PEATLANDS

A **mire** is defined as an area with a high water table and usually having peat-forming vegetation. A **peatland** is an area covered by peat of a certain minimum depth, usually 30 cm (some countries use higher values for peat depth). This differentiation between the terms mire and peatland has been in common use (e.g. Sjörs 1948) and means that some areas of mire (e.g. a shallow sloping fen) are not peatland, and vice versa, peatlands drained for agriculture, used intensively as pasture, or harvested for peat, qualify as peatland (until the peat becomes too thin), but are no longer mire ecosystems.

The greatest difficulty in delimiting mires and peatlands stems from the shallowness of many peat deposits. Particularly large areas of thinly-peated mires occur in the arctic and alpine zones, but also in boreal zones, for instance in hilly areas. Consequently, globally there is definitely a larger area of mires (potential peat-forming ecosystems) than (geologically defined) peatlands. However, the criterion «peatforming» is difficult since, at present, many mires seem to be accumulating very little peat.

In addition to these problems, there are certain other difficulties when it comes to delimitation and definition, for instance:

- Transitions exist between areas of mire series and heath series (Sjörs 1967), both open and forested types. Moreover, there are transitions between peat and raw humus, and the latter may reach a depth qualifying for peatland.
- Definitions vary concerning the demarcation of moist grasslands and mires, both open and forested types, and there is a gradual transition from mineral soil to peat.
- There are gradual transitions between mires and springs, lakes and other occurrences of fresh water. Mires drowned by reservoirs may still be peatlands, when the peat has not been destroyed.
- Mires drained for forestry usually remain as peatlands, but as ecosystems they often gradually change from mire towards the state of a true forest (Heikkilä & Lindholm, this volume).

All these problems affect estimates of the areas of mire and peatland in a country, a region, and globally.

Several authors have tried to give figures for the area of peatland worldwide. These figures have tended to grow as better estimates have been made, especially for the peatlands of Canada, Russia and tropical areas.

The most recent summary has been provided by the International Peat Society, which estimates the total area of peatlands throughout the world to be a little under 500 million ha, about 3.5% of the world's land surface (Lappalainen 1994). It is likely that the area covered by mires is greater, but mire areas have been more reduced by exploitation than peatland areas over recent decades (cf. the situation described in Finland). Another example is Canada where as much as 20 million ha of wetlands (of a total area of 127 million ha, 90% of which are peatlands) are utilised, mostly drained for agricultural purposes (Rubec, this volume).

Because peat formation is generally linked to climate, most of the mire area lies in the northern high latitudes, more than half of it being in Russia and Canada.

Restoration of damaged mires is a rather recent activity, stimulated by an increased awareness of the great importance mire ecosystems have in nature (cf. Wheeler et al. 1995). The development of restoration strategies is often hampered by lack of knowledge, particularly important being an understanding of the dynamics of mire hydrology. The peat of intact bogs is differentiated into a surface active layer (acrotelm), typically 25-30 cm thick with aerobic peat, overlying the catotelm which is permanently waterlogged (Ivanov 1981, Ingram 1983). The raised bog creates a groundwater mound in the catotelm, and lowering the water table by partial drainage affects the water table elsewhere. The «groundwater mound theory» explains the domed shapes of raised bogs, in terms of physical and biological processes. Bragg & Steiner and van der Schaaf (this volume) report results from projects concerning restoration work on damaged (ditched) raised bogs.

Restoring mires drained for forestry often seems easier than restoring those drained and used for agriculture or peat production. However, as pointed out by Heikkilä & Lindholm (this volume), success depends on factors like the time elapsing after drainage, the degree of change in the vegetation and the peat, and the technical possibilities for restoration.

5 MIRE TERMS, REGIONALITY

An obvious problem when comparing mire information from different countries is the variation in mire terminology and mire classification. The terms used are sometimes very different, and one and the same term can be attributed different meanings. Important contributions towards solving these problems of terminology and classification have appeared in some symposium proceedings and books (e.g. Kivinen et al. 1979, Moore 1984, Eurola & Huttunen 1985, Succow 1988, Bragg et al. 1992 and Grünig 1994). The books edited by Gore (1983) are the main sources for the terminology used by the IMCG and this volume.

Achieving agreement on a common terminology and understanding of different classification systems is one of the central aims of IMCG work. However, there are so many different approaches to mire ecology and regionality that a single standard classification system is not desirable (Sjörs 1985). In this volume, the authors have been allowed to use the terminology of their own tradition, and synonymous terms even occur. This section considers the application of some terms and classification systems, emphasis being placed on those discussed during the IMCG field symposium in Norway and those which were not taken up by Moen & Singsaas (1994). The Scandinavian approach evolved by Sjörs (e.g. 1983) is my basis.

Mires are subdivided into two natural types:

1. **Ombrotrophic/ombrogenous**/ombrophilous/bog (ombros = rain), 2. **Minerotrophic/minerogenous**/geogenous/fen.

The Scandinavian tradition has been to use the suffix «-trophic»(= fed) as a geographical/biological term (ombrotrophic is synonymous with bog, minerotrophic with fen); and «-genous»(= made) as a geological/hydrological term. The difference between 1 and 2 as an important limit is generally accepted. The use of the terms, however, differs very much. In this volume, Damman uses ombrotrophic and minerotrophic in the wide sense, whereas Sienkiewicz & Kloss use ombrophilous and rheophilous (after Kulczyński 1949); rheophilous is often used in a more restricted sense, as a synonym for soligenous (cf. Gore 1983).

Most regional subdivisions are based on the typification of defined geographical units of the mire. Here, different scales or levels have been in use, and different synonymous terms are applied (see Moen & Singsaas 1994:30 ff). Today, most researchers agree on four levels of local geographical units, in addition to the regional level, as pointed out by Masing (1984). The following set of terms is commonly used for these four levels (e.g. Sjörs 1948, Ivanov 1981, Yurkovskaya, this volume): microform (mire feature), microtope (mire site), mesotope (mire massif = synsite), and macrotope (mire system = complex).

The different geographical levels have been subjected to typification, classification and mapping of distribution. The mesotope level is especially important when classifying mires on the basis of their hydrology, morphology (shape), hydromorphology and development (Ivanov 1981).

Yurkovskaya (this volume) presents methods for small-scale mapping of the macrotope level.

Three different modes of origin of mires can be distinguished

1. The filling in (terrestrialisation) of shallow lakes.
2. Primary mire formation, when peat forms directly on fresh, moist or wet, mineral soil (e.g. after the melting of an ice sheet, on alluvial plains and deltas, on land emerging from the sea).
3. Paludification of originally less wet land.

Hydrologically, mires can be subdivided into different types. In addition to **ombrogenous** mires, von Post & Granlund (1926) added two minerogenous types: **topogenous** mires which are influenced by stagnant, minerogenic water (the water table is more or less horizontal); and **soligenous** mires which are influenced by seepage water (the water table is not horizontal). A fourth, less well-defined type, is **limnogenous** mires, which receive periodical supplies of flood water from watercourses (Sjörs 1948, 1983). Kloss & Sienkiewicz (this volume) use the first three of these terms, but refer to the fourth type as «fluvigenous mires».

These four hydrological types, and the three types of genesis, have a different regional distribution, and can be mapped, as in the classical work of von Post & Granlund (1926) who published maps from southern Sweden. However, the hydrological types, types of origin and of development (e.g. as defined by Moore & Bellamy 1973) can be laborious to determine in detail for large areas.

By using the hydrological conditions and the peat-forming processes connected with them, Succow & Lange (1984) and Succow (1988) subclassified the minerotrophic mires into seven «hydrologic-biogenetical» mire types for central Europe:

1. Ancient lake mires (limnogenous; Verlandungsmoore)
2. Transgression mires (Überflutungsmoore)
3. Swamp mires (Versumpfungsmoore)
4. Kettlehole mires (Kesselmoore)
5. Percolating mires (rheogenous; Durchströmungsmoore)
6. Spring mires (Quellmoore)
7. Sloping mires (Hangmoore)

By adding ombrogenous mires (raised bogs), Succow defined altogether 8 mire types, and their distribution was used to make regional maps (Succow 1988). This system of hydrological mire types is widely used in central Europe (e.g. Steiner 1992).

«Transitional mire» is a term sometimes used for a hydrological type. Ilomets & Kallas (this volume) divide them into transitional fen and transitional bog. Other workers (e.g. Grünig 1994) distinguish transitional mires as hydromorphological types. The term transitional is linked to the successional aspect, the mire will (is believed to) develop into an ombrotrophic mire. However, the term is often used in a much wider sense (cf. Übergangsmoore in Steiner (1992)).

Hydromorphological mire types are based upon the external shape of the mires and their hydrology. Many of these mire types are easily recognised and mapped by studying aerial photographs (e.g. concentric raised bogs, palsa mires, etc.). A number of publications define different types and their distribution (e.g. Ivanov 1981, Botch & Masing 1983, Ruuhijärvi 1983); examples are also found in this volume (e.g. Damman, Rybníček & Yurkovskaya and Yurkovskaya).

It is evident that the age and history of mires and peatlands have an influence on their regionality. All mires start as minerogenous features, and in areas with young mires (e.g. in the Baltic area, on low ground recently emerged from the sea) the mires have not had sufficient time to develop into ombrogenous mires. The distribution, area and type of mire reflect past climate, even the present mire ecosystems are determined by the current ecological conditions. Zoltai (this volume) shows that the mire types and the development of the mires in different vegetational zones in Canada are a response to long-term climatic changes.

The plant communities can be described and mapped at different levels, the descriptions mostly being based on homogenous plots at the microform level.

The central European approach (e.g. Rybníček 1985) to classification is based solely on floristic criteria, producing a phytosociological, hierarchical system. A number of papers in this volume refer to such units (e.g. Bragg & Steiner (Table 2) and Rybníček & Yurkovskaya). Damman (in his first paper here) argues, using a worldwide perspective on ombrotrophic mire vegetation, that the major floristic differences in mire vegetation do not correspond with the mineral soil water limit, as the difference between poor fen and rich fen is greater than that between ombrotrophic and poor fen vegetation. He suggests (as a parallel to the central European differentiation between the classes *Oxycocco-Sphagnetea* and *Scheuchzerio-Caricetea nigrae*) that major mire vegetation units, such as bog and fen, should be classified on the basis of vegetation criteria rather than the source of mire water.

The Scandinavian tradition (Du Rietz, Sjörs) makes use of a more ecologically based conception, distinguishing between ombrotrophic and minerotrophic vegetation as the main limit, and making further differentiation into three local vegetational gradients (poor - rich, expanse - margin, hummock - mud bottom). This system is commonly used in Scandinavia (e.g. Moen & Singsaas 1994).

The Finnish mire site type classification also draws attention to these three main, local ecological gradients, also adding traditional physiognomic criteria (cf. Ruuhijärvi (1983), Eurola et al. (1984), and the Finnish papers in this volume).

Succow (1988) subdivided the mire vegetation of central Europe into five ecological mire types based on productivity, trophic value and pH value. These are oligotrophic - acid, mesotrophic - acid, mesotrophic - subneutral, mesotrophic - calcareous and eutrophic. A somewhat similar system is used in the description of mires in Ukraine (Movchan & Vakarenko, this volume).

Regional subdivision of mires may also be based on floristic criteria and mapping. Forslund (this volume) presents plot maps of mire species for a county in Sweden. Damman (this volume, second paper), shows that there are a number of common species with similar occurrences, and many floristic differences in the ombrotrophic vegetation, when mire ecosystems in eastern North America and Norway are compared. Damman draws on experience gained from the IMCG field excursion in Norway in 1994 (Moen & Singsaas 1994). Further information on the floristic regionality of Norwegian mires is given here in the paper by Såstad and Moen, which includes a list of 372 mire species from central Norway, with Ellenberg's indicator values (for temperature and continentality), and calculations of zonal, sectional and climatic scores.

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Major mire vegetation units in relation to the concepts of ombrotrophy and minerotrophy: a worldwide perspective

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ABSTRACT

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Peatland development depends on water and its chemical composition. Ombrotrophic peatlands, which depend on precipitation, show regional differences in response to changes in precipitation chemistry. The purpose of this paper is to point out the nature and magnitude of these changes in precipitation and vegetation, and to discuss the implications for mire classification.

The chemical composition of precipitation follows well-known trends from the coast inland. Within coastal areas, precipitation chemistry varies greatly. In exposed coastal locations, K, Ca, Mg and S concentrations can be surprisingly high. This is especially obvious in the Southern Hemisphere. Compared with precipitation, ombrotrophic bog water has much higher Na and Cl and lower Ca concentrations. Because ombrotrophic bogs are extremely nutrient-deficient, differences in precipitation chemistry are reflected in the floristic composition of the vegetation.

The mineral soil water limit indicates fundamental changes in the hydrology and ecology of a mire ecosystem. However, its use for the major breakdown of the mire vegetation into bogs and fens creates problems when applied on a worldwide scale. Ombrotrophy indicates only the source of the mire water and not its actual nutrient content. Since the chemical composition of ombrotrophic water changes geographically, a definition of bog and fen based on the mineral soil water limit will define different ecological conditions, and thus vegetation that is floristically dissimilar, if applied on a continental scale. I suggest that major mire vegetation units, such as bog and fen, should be classified on the basis of vegetation criteria rather than the source of the mire water.

1 INTRODUCTION

Peatland development is controlled by water. The amount of water available and its chemical composition affects the morphology and surface pattern of a peatland as well as the floristic composition and productivity of its vegetation, the distribution of microtopes and its peat accumulation. The importance of the type and quality of the water for peatland development was recognised by von Post & Granlund (1926) when they distinguished topogenous, limnogenous, ombrogenous, and soligenous peatland formation. Sjörs (1948) further refined this distinction.

Because peatland development depends on water, climate controls regional differences in peatland to a greater extent than in any other ecosystem. This relationship between climate and mire development has long intrigued peatland ecologists (Granlund 1932, Osvald 1925, 1949). As a result, we now have a reasonable understanding of the relationship between climate and peatland zonation in oceanic and suboceanic regions (Ruuhijärvi 1960, Eurola & Ruuhijärvi 1961, Eurola 1962, Damman 1979, Eurola & Vorren 1980), but less so in continental regions. This relationship between climate and peatland development provides an excellent geographical framework for the classification of mires, which has been used very successfully in Norway (Moen 1973, 1985).

The dependence of raised bogs on precipitation and dew rather than groundwater was recognised already by Dau (1823). The distinction between ombrotrophic and minerotrophic water has played a prominent role in Scandinavian mire ecology (Thunmark 1942, Witting 1947, 1948, Du Rietz 1949, 1954) and has influenced mire terminology worldwide. Du Rietz (1949, 1954) used the mineral soil water limit (Thunmark 1942) for the major subdivision of mire vegetation into fens and bogs.

In raised bogs, especially plateau bogs, this limit coincides with obvious physiognomic differences in the vegetation and it also affects the balance between production and decay. Therefore, the mineral soil water limit is hydrologically, chemically, and ecologically a very important dividing line. Since it can be recognised also floristically, Du Rietz's (1949, 1954) suggestion to use the mineral soil water limit for the primary subdivision of the mire vegetation appears to be a good idea. However, there are two problems with this approach:

1) Ombrotrophic sites in different geographical regions are not ecologically equivalent. We tend to overlook this because the distinction between ombrotrophic and minerotrophic sites is so clear and useful locally, and because most detailed vegetation studies cover geographically limited areas.

2) The major floristic differences within the mire vegetation do not correspond with the mineral soil water limit. Floristically, the differences between poor and rich fen vegetation are much greater than between poor fen and bog vegetation as defined by the mineral soil water limit, as was pointed out by Malmer (1968, 1985).

The purpose of this paper is to: 1) show the magnitude of the regional differences in water chemistry of ombrotrophic sites, 2) discuss the effect of precipitation chemistry on ombrotrophic vegetation, and 3) point out some of the implications for mire classification and conservation.

2 DIFFERENCES BETWEEN OMBROTROPHIC AND MINEROTROPHIC WATER

Rainwater and mineral soil water are chemically very different. A comparison of rainwater, soil and fresh water (Fig. 1) illustrates these differences. In rainwater, Na and Cl ions dominate, whereas Si, Al and Fe are the most common elements in the mineral soil. Fresh water, which is rainwater that has percolated through the mineral soil, becomes enriched in ions that are easily leached from the soil, such as Ca, Mg and K, but also in Si. In addition, ions with very low concentrations in rainwater, such as Al, Fe and Mn, have much higher concentrations in mineral soil water, especially on acid soils.

The chemical composition of bog water differs from that of precipitation. When rain falls on the bog surface, its ionic composition changes quickly (Boatman et al. 1975, Damman 1988, 1990) due to evaporation at the bog surface, uptake by plants, adsorption on the peat, and, to a lesser extent by mineralisation in the peat and leaching from plants. The combined effect of these processes is an increase in Na and Cl and a decrease in Ca concentrations compared to rainwater (Fig. 2). Magnesium, and especially K, are strongly removed by plant uptake and show clear seasonal changes (Malmer 1962, Damman 1988).

3 REGIONAL DIFFERENCES IN IONIC COMPOSITION OF PRECIPITATION AND BOG WATER

The chemical composition of precipitation shows large regional differences. The highest concentrations of sea-derived ions, such as Na and Cl, occur in coastal areas, whereas Ca, Mg and K supplied in soil dust show the highest concentrations in mid-continental precipitation. Superimposed on this is a pattern of pollution-derived ions, such as SO_4, NO_3, NH_4 and heavy metals (Munger & Eisenreich 1983). In regions where peat bogs are common in the landscape, soil derived inputs are lower, but Ca is still higher than in most coastal areas and locally concentrations can be high (Fig. 3). Bog surface waters show similar trends (Gorham et al. 1985).

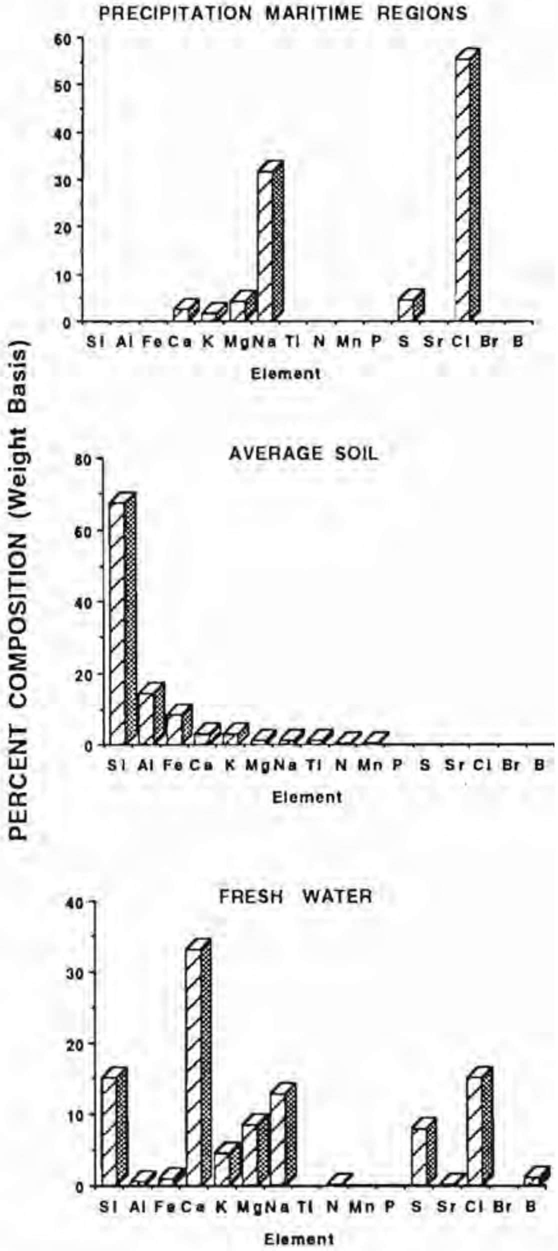

Fig. 1. Relative concentrations of the most abundant elements, excluding C, H and O, in precipitation, average soil and fresh water. Calculated from values reported by Berner & Berner (1987) for precipitation of maritime regions (world average for areas <100 km from the coast) and by Bowen (1979) for soils and fresh water.

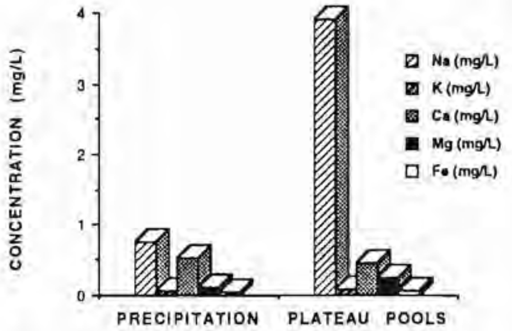

Fig. 2. Composition of precipitation and water in pools of a plateau bog near Stephenville Crossing, western Newfoundland. Based on 2-weekly sampling from 29 May to 8 Sept. 1980. Precipitation data are volume-weighted means for 4 collectors; pool water data are the means of 6 pools on the bog plateau.

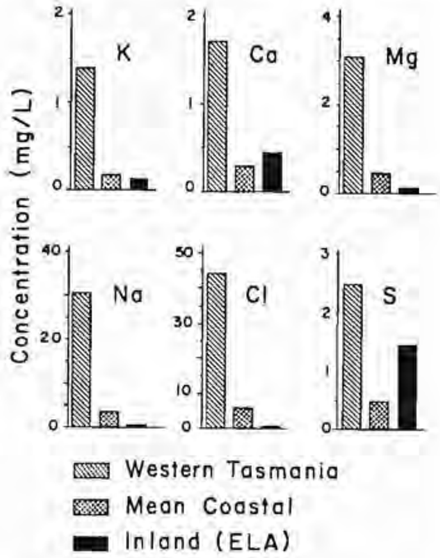

Fig. 3. Concentration of elements in precipitation of extreme coastal (Cape Grim, Tasmania), average coastal (<100 km from the coast, world-average) and inland areas (Experimental Lakes Area, Ontario, Canada). Calculated from data in Atmospheric Program Australia (1978), Berner & Berner (1987) and Schindler et al. (1976), respectively.

Within coastal areas the composition of the precipitation varies greatly depending mostly on the distance airmasses have travelled over the sea. This is particularly obvious when one considers coastal areas in the Southern Hemisphere. Here landmasses occupy very little area at temperate and northern temperate latitudes, where most ombrotrophic mires are found, so that air masses pass over very long stretches of open ocean. Inputs of Ca, Mg, K and S in these coastal areas can be surprisingly high when compared with continental areas (Fig. 3). This is further illustrated in Table 1, which shows the changes in chemical composition of the precipitation with distance from the coast. It also provides a comparison with Northern Hemisphere sites. Obviously, input of major nutrients to ombrotrophic mires can vary greatly depending on the geographical position. Although ombrotrophy defines the nutrient status of a mire locally, it should not be used to indicate nutrient status when making regional comparisons of mire vegetation.

Table 1. Chemical composition (mg/L) and pH of bulk precipitation. The locations from Macquarie Island, a subantarctic island, to the Central Plateau, Tasmania, represent increasingly less oceanic conditions in the Southern Hemisphere. The other three Northern Hemisphere stations are added for comparison. Data are weighted mean concentrations for the collection periods: Macquarie Island (23-30 Oct., 1981), Cape Grim (April 1977-Dec. 1978), Maatsuycker Island (June 1977-Nov. 1978), Scotts Peak Dam and Central Plateau (Nov. 1981-May 1982), Hubbard Brook (1963-1974). The data for Rosscahill are unweighted averages and will somewhat overestimate ionic concentrations because concentrations tend to be highest for light rains.

Location	pH	Na	K	Ca	Mg	Cl	SO_4	Source
Macquarie Island	6.2	438	24.0	16.0	54.0	776	95.0	Damman (unpubl.)
Cape Grim, Tasmania	6.2	30	1.4	1.7	3.1	44	7.5	Atmosph. Progr. Australia (1978)
Maatsuycker Island, Tasmania	5.6	13	0.7	0.7	1.7	24	3.1	Atmosph. Progr. Australia (1978)
Scotts Peak, Tasmania	6.0	2.6	0.9	0.7	0.4	4.6	1.5	Damman (unpubl.)
Central Plateau, Tasmania	5.9	1.1	0.15	0.9	0.2	1.8	1.3	Damman (unpubl.)
Rosscahill, Ireland	6.5	3.2	0.5	1.7	0.5	4.5	2.9	Gorham (1957)
Stephenville Crossing, Newfoundland, Canada	4.3	0.4	0.04	0.3	0.08	--	--	Damman (unpubl.)
Hubbard Brook, N.H., USA	4.1	0.12	0.07	0.16	0.04	0.47	2.9	Likens et al. (1977)

4 EFFECT OF PRECIPITATION CHEMISTRY ON OMBROTROPHIC BOG VEGETATION

Anyone familiar with the Swedish or Finnish mire vegetation visiting the British Isles, and also Norway, will realise that what is considered ombrotrophic vegetation in Ireland or Britain would not be called ombrotrophic in the suboceanic parts of Fennoscandia. This is partly because a blanket bog, the archetype of ombrogenous bog development, is not everywhere truly ombrotrophic since peat depth varies and soil and rock crop out here and there. However, even on genuinely ombrotrophic sites one can find poor fen species, such as *Narthecium ossifragum*, *Nymphaea odorata*, *Sphagnum papillosum*, etc.

Similarly, in continental and northern mires species occur that we usually associate with weakly minerotrophic mires in southern oceanic regions, e.g. *Scheuchzeria palustris*, *Carex pauciflora*, *Sphagnum lindbergii*, or in North America also *Carex oligosperma* or *Smilacina trifolia*.

These changes in habitat preferences could be due to differences in competition pressure resulting in shifts in the ecological amplitude or realised niche of a species, as Rydin (1986, 1993) showed in experiments with *Sphagnum* species on a moisture gradient. However, there appears to be more involved here.

A comparison of ombrotrophic bog water with the minerotrophic water in its lagg (Fig. 4) shows that ionic concentrations in ombrotrophic bog water are very low even in comparison with water of an extremely poor fen.

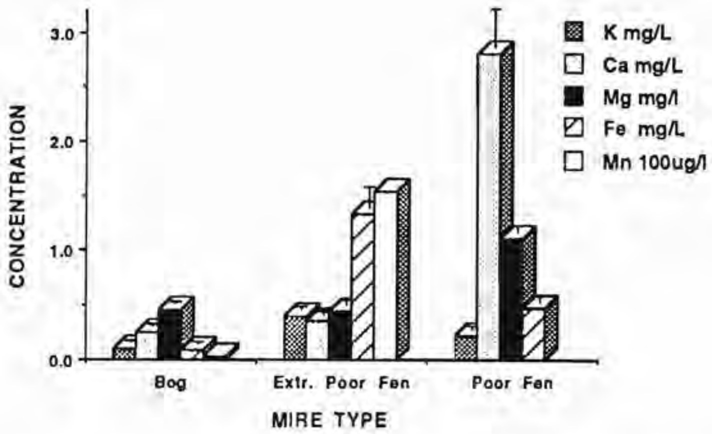

Fig. 4. A comparison of ionic concentrations in surface water on the bog plateau and in the lagg fens of a plateau bog near Stephenville Crossing, western Newfoundland. Data are based on 2-weekly collections from 29 May to 8 Sept. 1980.

Because nutrient concentrations are so low in ombrotrophic water, small differences in precipitation chemistry are clearly reflected in the vegetation. In contrast, in minerotrophic fens and upland ecosystems differences in precipitation chemistry are unimportant because of higher nutrient concentrations in the soil water and more efficient nutrient cycling. As a result, differences in precipitation chemistry that are clearly expressed in the species distribution on ombrotrophic sites are not reflected in minerotrophic fen and upland vegetation, except perhaps in highly polluted areas.

In areas with extremely high sea-derived nutrient inputs, the vegetation of ombrotrophic bogs resembles that of minerotrophic fens, as for example, on Macquarie Island. In most oceanic areas, it results in the occurrence of so-called fen species in ombrotrophic bogs. Based on the occurrence of species in ombrotrophic bogs, we can recognise three zones in North America (Fig. 5).

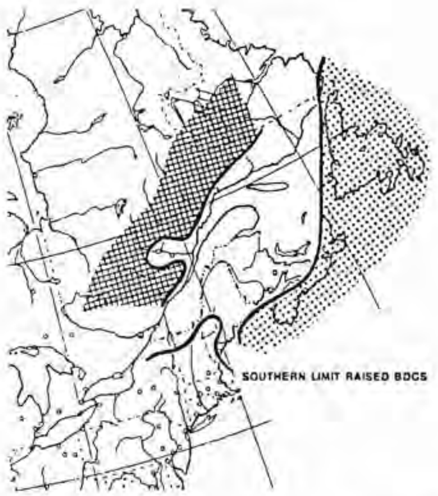

Fig. 5. Nutrient-related changes in plant distribution in ombrotrophic mire vegetation of eastern North America. In the stippled area plants that are restricted to minerotrophic sites in most of their range also occur in ombrotrophic bogs. In the cross-hatched area, species restricted to weakly minerotrophic sites in southern oceanic mires start to appear in ombrotrophic bog vegetation.

1) along the Atlantic coast, species restricted to minerotrophic sites also occur in ombrotrophic bogs; these include species such as *Carex exilis*, *Aster nemoralis*, *Vaccinium macrocarpum*, *Myrica gale*, *Juniperus communis*, *Sphagnum papillosum* and *S. pulchrum* (Damman 1977, 1978), and are the ecological counterpart of a similar group of fen species occurring in bogs of the British Isles (Tansley 1939, Osvald 1949)

2) in continental and northern bogs, we find species that are restricted to weakly minerotrophic sites in the southern oceanic mires (Damman 1978); these include: *Carex oligosperma*, *C. pauciflora*, *Scheuchzeria palustris*, *Smilacina trifolia*, *Eriophorum chamissonis*, *Sphagnum majus*, *S. angustifolium*, *S. lindbergii*, *Calliergon stramineum* and *Aulacomnium palustre*

3) between these two zones, neither of these species groups are part of the ombrotrophic bog vegetation.

Judging from the ecological requirements of the species involved, these zones appear to be defined by changes in nutrient availability. In the northern, continental zone peat resides longer in the acrotelm which increases mineralisation and nutrient supply (Damman 1990). In the coastal zone, the occurrence of these species could be attributed to increased atmospheric deposition. However, other explanations have been advanced, and the cause is still controversial (Santelmann 1991).

These zones (Fig. 5) cut across the major climatic zonation of peatlands (Damman 1979) as well as across plant community ranges (Damman 1978). Consequently, the floristic composition of the ombrotrophic vegetation changes geographically even if we consider comparable habitats on the same hydromorphological mire type.

5 IMPLICATIONS FOR MIRE CLASSIFICATION

In Scandinavia, following Du Rietz (1949, 1954), the mineral soil water limit is used for the primary subdivision of mires into bogs and fens. This concept of bogs and fens has now become widely accepted in mire ecology. Hydrologically and chemically we can distinguish ombrotrophic from minerotrophic water, but floristically this is not everywhere so clear, especially in hyperoceanic and continental regions, but also in areas too dry for raised bog development.

The vegetation of topogenous mires in kettles in glaciofluvial deposits can be floristically very similar to the vegetation of what are called ombrotrophic bogs in continental areas, although the former are hydrologically and chemically fens. Similarly, ombrotrophic vegetation in oceanic regions can resemble the vegetation of poor fens in sub-oceanic and continental areas.

The problem is that we cannot use floristic criteria to distinguish bogs from fens unless we work within a restricted geographical area. Since the vegetation of extremely poor and poor fens is floristically much closer to that of ombrotrophic bogs than to rich fens (Malmer 1968) it would cause much less confusion if the primary subdivision of the mire vegetation was drawn between poor and rich fens and based on vegetation criteria. Bog vegetation could be simply defined as a vegetation in which *Sphagnum*, ericaceous dwarf shrubs or *Cyperaceae*, and conifers play a major role in the moss, field and tree strata, respectively. This definition could be used worldwide, except that *Epacridaceae* and *Restionaceae* replace *Ericaceae* and *Cyperaceae* in some Southern Hemisphere peatlands. Locally, this definition could be further refined, using additional floristic criteria. In Europe, this definition of bog would correspond closely to vegetation included in the class *Oxycocco-Sphagnetea* Br.-Bl. et Tux. 1943 of the Zürich-Montpellier School.

This would provide a clear definition of bog vegetation that requires no detailed ecological and floristic knowledge of mires to be identified correctly. Within bogs one could then recognise ombrotrophic and oligotrophic bogs on the basis of hydrological or chemical criteria. At present, bog is considered synonymous with ombrotrophic vegetation, but the term is often misused.

6 CONCLUSIONS

Ombrotrophy is a well-established and useful term in mire ecology. Many ecologically and hydrologically fundamental changes in a mire ecosystem occur at the mineral soil water limit. However, ombrotrophy only indicates the source of the mire water and not its actual nutrient content, except within a geographically limited area. This should be considered in comparisons on a regional or continental scale. It is especially important to realise that relationships among vegetation, hydrology and water chemistry established in one area cannot be assumed to hold in other areas.

Since the chemical composition of ombrotrophic bog water changes with geographical location, a definition of bog and fen based on the mineral soil water limit will define different ecological conditions, and thus vegetation that is floristically dissimilar, if applied on a continental scale. Mire vegetation should be classified on the basis of vegetation criteria rather than the source of the mire water. This would lead to a clearer definition of bog and fen that is less likely to be misused. Similarly, we need to use chemical and hydrological criteria to classify the nutrient-richness and the hydrology of mires, respectively. Using these three criteria we will achieve a much clearer characterisation of mires than by implying relationships among these criteria that are valid only within narrow geographical limits.

In selecting mire preserves, it is not sufficient to select good examples of each hydromorphological mire type. Precipitation chemistry or floristic composition of the mire vegetation needs to be considered in selecting sites representative of the range of conditions occurring within the same hydromorphological mire type.

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Regional variations in peatland ecosystems of west-central Canada through time

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ABSTRACT

Zoltai, S.C. 1995. Regional variations in peatland ecosystems of west-central Canada through time. *Gunneria 70*: 35-42.

Peatland ecosystems respond to major changes in their environment induced by prolonged changes in climate. In the western boreal region of Canada, permafrost occurs only in *Sphagnum*-dominated peatlands. In the north, the palsas and peat plateaus are associated with well-defined, circular collapse scars. Further south, the collapse scars are replaced by indistinct, roughly circular internal depressions in bogs and fens with or without remnant permafrost bodies. In the most southern areas, no internal depressions occur in the fens and bogs. Peat macrofossil analyses show that in many collapse scars several permafrost development and subsidence cycles have taken place, beginning about 3700 yrs B.P. In the internal depressions, a layer of forest peat occurs below the fen or bog surface, indicating the presence and ultimate collapse of a permafrost peat landform. This collapse began about 150 years ago and is proceeding at the present. In the southern peat bogs, the peat stratigraphy shows that bog formation was initiated long after the original fens were established, about 2000 to 3000 years ago. Basal dates of fen peat along the southern margin of the boreal zone indicate that fen development began only about 6000 years ago, covering marsh and shallow pond deposits.

1 INTRODUCTION

Peatlands are dynamic ecosystems where the physical, chemical and biotic environments can change due to internal (autogenic) processes. The responses to such changes are reflected in the composition of the vegetation that is at least partially preserved in the peat. The study of the peat components can define the peatland ecosystem that formed the mire (Gignac et al. 1991) at various times in the past. Regional trends in the autogenic process can be determined within climatic regions. Major deviations from such trends indicate responses to external influences, such as changes in hydrology, climate, fire regime or influences by human actions.

The peatlands of west-central Canada extend from the prairie border, south of which no peatlands occur, northward through the boreal region to the tundra. Climatic stresses imposed on the peatland ecosystems are lack of sufficient precipitation in the south and low temperatures in the north, manifested in the increasingly common occurrence of permafrost towards the north. Prolonged changes in the thermal or precipitation regime is reflected in the peatlands, especially those in the transitional, ecotonal positions.

In this paper, regional influences of climate changes on peatland ecosystems as shown by their internal stratigraphy, are described. Regional trends in peatland development and permafrost dynamics are related to major changes in climate, with chronology provided by radiocarbon dates.

2 RESULTS AND DISCUSSION

2.1 BASAL PEAT

The basal peat deposits are usually composed of well-humified organic matter with few macrofossils. The ash content is high, similar to that of presently forming marsh deposits. Occasionally, the basal deposit is a lake sediment (gyttja), indicating that the wetland originated as a pond that was later invaded by peat-forming vegetation.

2.2 FEN INITIATION

In peatlands, the next layers of peat were formed in fens, indicating minerotrophic influences. However, the age of basal fen peat shows that 2000 years or more have elapsed since glaciation before fen development commenced. This delay may be an autogenic signature (lag in plant migration), or may signify an arid environment where the basins were filled only temporarily, creating conditions unsuited for fen development.

Many different types of fens were formed in the ensuing millennia, each with characteristic plant assemblages. Some were dominated by brown mosses and sedges, others developed a *Betula pumila* or *B. glandulosa* shrub cover. Others had a sparse tree cover of *Larix laricina*, often mixed with *Picea mariana, Sphagnum warnstorfii* and even hummocks of *S. fuscum*.

It was noted that basal fen development did not commence until after 6000 yrs B.P. in a zone bordering the present prairies (Zoltai & Vitt 1990) (prairie border zone, Fig. 1). This was interpreted as a consequence of a warmer/drier climate that prevailed in the mid-Holocene period.

The basal fen peat developed under non-permafrost conditions even in the present northern boreal zone (Fig. 1) where permafrost is now common in peatlands. This is indicated by the lack of frost churning of the peat. Peat that develops under permafrost conditions in the Arctic contains sand, pebbles and even boulders, mixed into the peat by frost churning. The lack of frost churning of the peat implies that permafrost was largely absent

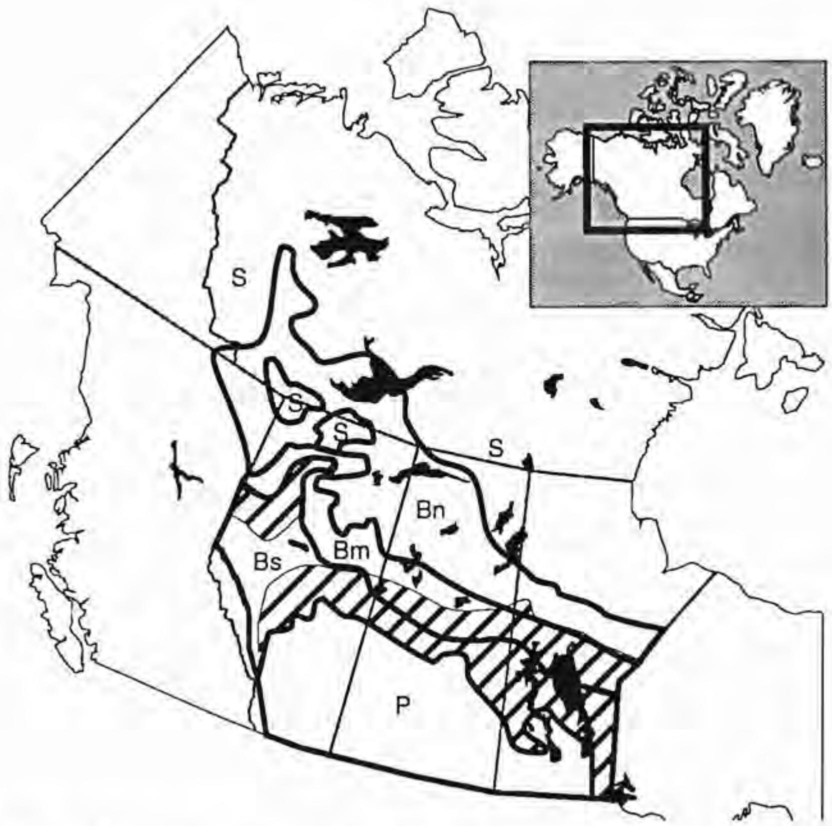

Fig. 1. Map of west-central Canada showing subdivisions of the boreal zone. Bs - southern boreal zone, Bm - middle boreal zone, Bn - northern boreal zone, Hatched - prairie border zone, P - prairie zone, S - subarctic zone.

from the present boreal zone during the Holocene warm period (Zoltai 1995).

2.3 BOG INITIATION

Bog initiation in the form of development of bog islands on fens began about 5000 years ago in the north (Nicholson & Vitt 1990), and reached the southern distribution limit of peatlands by about 2200 yrs B.P. (Zoltai & Vitt 1990). In peat sections, the bog peat, dominated by *Sphagnum fuscum* remains, occurs above fen peat, usually separated from the fen peat by woody *S. magellanicum* peat. In some cases, where a bog expanded laterally over a fen, the transition between fen and bog peat is sharp and abrupt.

The occurrence of bogs appears to be related to climate: a combination of summer precipitation below 250 mm and mean annual temperatures above 2° are associated with the absence of bogs in this region (Vitt et al. 1994). The gradual southward expansion of bog initiation implies a gradual cooling and moistening of the climate, beginning about 5000 yrs B.P.

2.4 PERMAFROST DYNAMICS

Permafrost occurs in peatlands where the mean annual temperature is lower than 0°C (Vitt et al. 1994). Permafrost formation induces specific landforms in the peat: high (2 m+), but small (< 100 m diameter) palsas and large (up to hundreds of km^2), but low (± 1 m) peat plateaus (Zoltai & Tarnocai 1975). Their distribution is localised in the south, occurring as small islands in bogs or fens, but becomes more widespread farther north. About 50% of the peatlands contain at least some permafrost at the -1.5°C isotherm, and all peatlands contain some permafrost at the -3°C isotherm (Halsey et al. 1995). In addition to the regional temperature regime, snowfall (amount, timing) is crucial for the development of permafrost at any specific location within a peatland.

The most common sequence of permafrost initiation begins with a small *Sphagnum fuscum* cushion on the surface of a fen (Zoltai & Tarnocai 1975). These cushions, when thick enough (40 cm+), insulate the seasonal frost against rapid summer thawing to the point where not all seasonal frost thaws. A repetition of this process results in the development of a permafrost lens under the peat surface. As the water changes to ice, the surface is elevated and becomes dry, allowing the growth of trees and ground lichen. This sequence of fen peat, capped by a thin *Sphagnum* peat is evident in the peat sections of most northern peat plateaus and palsas. The surface peat is formed by well decomposed forest (sylvic) peat, composed of needles, twigs and roots of *Picea mariana*.

Another mode of permafrost initiation occurs in tree-covered fens and bogs where small, dense clumps of *Picea mariana* trees may occur. The foliage intercepts much of the snow, resulting in a thin winter snow cover under them (Zoltai 1972). This results in deeper frost penetration, which may not thaw completely in the summer. The repetition of this process forms a permafrost layer, which elevates the surface as the permafrost lens thickens. The drier surface, being well above the water table, supports dense tree growth, usually with a nearly complete feather moss ground cover. The peat sections show a rapid transition from a woody fen peat, formed in a non-permafrost environment, to sylvic peat, formed on peat surface elevated by permafrost.

Regardless of the mode of initiation of the permafrost, the peat stratigraphy indicates that permafrost developed in previously unfrozen peat. Because peat is a post-glacial (Holocene) deposit in this part of Canada, the initial peatlands were free of permafrost for thousands of years, indicating a climate that was warmer than at present. The earliest indication of permafrost in peatlands in the northern boreal zone was about 3500 yrs B.P. (Zoltai 1993). Permafrost development was probably more delayed in that portion of the middle boreal zone which is within the prairie border region where the basal fen deposition did not begin until after 6000 yrs B.P. A single date from a sylvic layer of a collapsed palsa indicates that some permafrost existed by 2200 yrs B.P. in this area.

The permafrost peat landforms are subject to thawing, initiated by various allogenic factors, such as wildfires, rising water levels, warm summers, etc. When thawing occurs, the peat subsides to or below the water table, killing the vegetation. In the north, the subsided surface is over 1 m below the level of the permafrost peatland, with steep banks. Such collapse scars are readily recognisable from the air: they are usually circular in outline. In the northern boreal zone, permafrost is often regenerated in 500 or more years after the thawing and subsidence (Zoltai 1993).

In the south, near the southern distribution limit of permafrost, the permafrost lens is thin (1 to 3 m thick), being mostly in the peat (Zoltai 1972). When such permafrost bodies thaw, their surface subsides below the water table, but the resulting depression will be shallow, with indistinct borders. Sylvic peat, developed on the palsa surface, usually occurs 40 to 60 cm below the surface of the depressions (Fig. 2). Radiocarbon dates from the surface of subsided sylvic peat yield modern dates, being less than 200 years old. One date from the base of the sylvic layer showed that permafrost was present about 2100 yrs B.P. Dates of initiation of leaning in live trees growing on the borders of subsided depressions indicate that subsidence began about 150 years ago and continues to the present. In a few cases, small remnant permafrost lenses can be found at the edge of depressions (Fig. 3), indicating a recent and ongoing process.

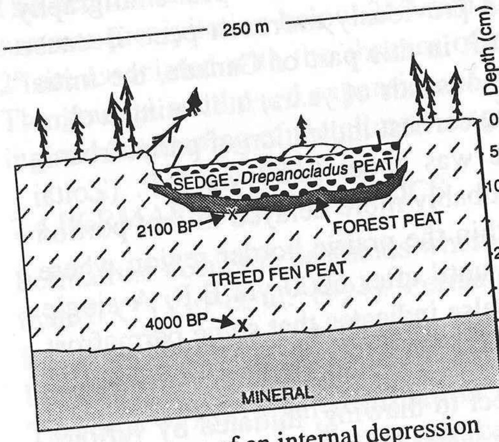

Fig. 2. Diagram of an internal depression in a fen, showing the submerged sylvic peat layer.

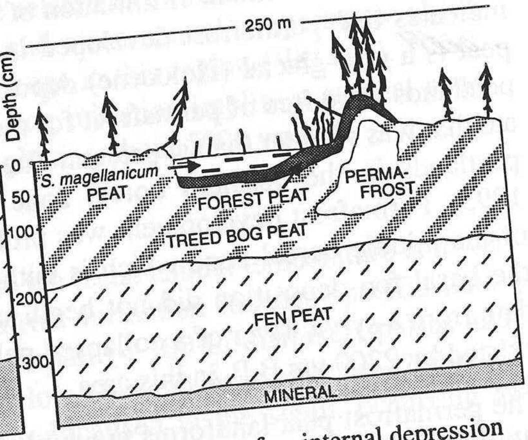

Fig. 3. Diagram of an internal depression in a bog, with remnant permafrost lens.

3 SUMMARY

Determination of the palaeoenvironments of peatlands indicates that major changes occurred in the past that triggered allogenic changes in peatland development. Changes that occur in peatland development on a regional scale indicate that the agents responsible for these changes acted on a continental, or perhaps on a global scale. Evidence from this and other studies points to fluctuations in climate during the post-glacial period (Bray 1971).

The analysis and dating of peat macrofossils indicate that major changes took place in the peatland development of west-central Canada (Fig. 1) in response to long-term climatic changes (Tables 1, 2 and 3). Evidence points to a warm, dry mid-Holocene period, ending about 5000 yrs B.P. These conditions were most severe in the prairie border regions (Tables 1 and 2) where no peatlands were formed before 6000 yrs B.P. A gradual cooling and moistening of the climate followed which was time transgressive: its effects first became evident in the north and progressively extended southwards. This permitted the formation of fens, then bogs and finally permafrost was initiated in some peatlands.

This study has shown that the study of chronosequence of peatland ecosystem development can be used to demonstrate major allogenic influences on peatlands. Similar studies can be oriented to identify other influences, such as anthropogenic changes, and the information could be applied in developing restoration, mitigation, or conservation strategies.

Table 1. Peatland development and implied climatic conditions in the southern boreal zone (years before present [B.P.]) within and outside the prairie border zone

Time period	Peatland development	Implied climate
Within prairie border zone		
Before 6000	No peatland development	Arid, warm
6000 - 3000	Fen formation	Cooler, moister
3000 to present	Bog formation	Continued cool, moist
Outside prairie border zone		
Before 6000	Fen formation	Warmer, drier
6000 to present	Bog formation	Cooler, moister

Table 2. Peatland development and implied climatic conditions in the middle boreal zone (years before present [B.P.]) within and outside the prairie border zone

Time period	Peatland development	Implied climate
Within prairie border zone		
Before 6000	No peatland development	Arid, warm
6000 - 3000	Fen formation	Cooler, moister
3000 - 2200	Bog formation	Continued cool, moist
2200 - 700	Sporadic permafrost formation	Cooler
700 - 150	Permafrost formation common	Cooler
150 to present	Thawing of permafrost	Warmer
Outside prairie border zone		
Before 6000	Fen formation	Warmer, drier
6000 - 700	Bog formation	Cool, moist climate
700 - 150	Sporadic permafrost formation	Cooler
150 to present	Thawing of permafrost	Warmer

Table 3. Peatland development and implied climatic conditions in the northern boreal zone (years before present [B.P.])

Time period	Peatland development	Implied climate
Before 5000	Fen formation, no permafrost	Warmer, drier
5000 - 3700	Bog formation, no permafrost	Cool moist
3700 to present	Permafrost development	Colder, moist

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Boreal peatlands in Norway and eastern North America: a comparison

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ABSTRACT

Damman, A.W.H. 1995. Boreal peatlands in Norway and eastern North America: a comparison. *Gunneria 70*: 43-66.

In this paper, I focus on the amphi-atlantic differences in peatland morphology and vegetation, with emphasis on the Norwegian boreal zone and its counterpart in eastern North America. The boreal zone and other vegetation zones occur at lower latitudes in eastern North America than in Europe. This is also reflected in the mire zonation, which is shifted 10-20° latitude to the south.

Oceanic mire types occurring in most of western Europe have a much more restricted distribution in North America. Conditions comparable to the boreal zone of Norway can be found only in the coastal areas of Newfoundland and Labrador. Blanket bogs are restricted to the most oceanic eastern and southern parts of Newfoundland, where winters are much more severe than in Norwegian blanket bogs. In the raised bog and patterned fen (aapa mire) zones of Newfoundland and Labrador, bogs with hollow-pools and fens with flark-pools predominate, whereas patterned fens with wide flark-fens, common in the Fennoscandian boreal zone, do not occur in Atlantic Canada.

The floristic differences between the two regions are most clearly reflected in: 1) the composition of the dwarf shrub vegetation and its greater diversity of ericaceous species in North America, and 2) the replacement of *Pinus sylvestris* by *Picea mariana*, and to a lesser extent *Larix laricina*, in North American mires. Southern, oceanic mires with *Sphagnum rubellum* and *S. magellanicum* as hummock species are absent in North America, where *S. fuscum* is the dominant hummock *Sphagnum* in the oceanic, raised bogs of both the boreal and boreonemoral zones.

1 INTRODUCTION

Peatlands throughout the Holarctic are physiognomically and ecologically very similar. Floristically, they also show less geographical variation than any other vegetation formation. Bryophytes, especially *Sphagnum*, Ericaceae and Cyperaceae dominate this vegetation. Most of the mosses and lichens have a circumpolar distribution, and many of the vascular plants are the same or are taxonomically closely related. This prompted Tüxen et al. (1972) to propose an expanded classification of the *Oxycocco-Sphagnetea* so that this class would include not only the plant communities of European peat bogs but also those of North America and Asia. However, there are also important differences (Damman 1978, 1979a) which have been less emphasised than the similarities, although Sjörs (1963a, 1985) has pointed them out.

This paper briefly compares the vegetation and habitat conditions in Norwegian peatlands with those in eastern North America. This comparison focuses on peatlands of the boreal zone in Norway (primarily those seen during the IMCG field symposium in Norway in July 1994 (Moen & Singsaas 1994)) and their eastern North American counterparts. It also includes comparisons of a general nature between the peatlands on opposite sides of the Atlantic Ocean.

The nomenclature of the vascular plants follows Fernald (1950) and Lid (1974) for European species not in Fernald (1950), for lichens Hale & Culberson (1966), for liverworts Stotler & Crandall-Stotler (1977) and for mosses Nyholm (1954-1969), except for *Polytrichum strictum* Menz. ex Brid., *Sphagnum austinii* Sull., *S. flavicomans* Warnst., *S. macrophyllum* Bernh. ex. Brid., *S. pylaesii* Brid. and *S. torreyanum* Sull. The terminology for the vegetation zones and subzones follows Ahti et al. (1968), except that their hemiboreal zone is called boreonemoral zone here, following Sjörs (1963b).

2 GEOGRAPHICAL DIFFERENCES AFFECTING PEATLANDS

The climatic conditions in the two regions differ greatly. Due to the west-east circulation of air masses, the climate of western Europe is strongly modified by the Atlantic Ocean whereas the American continent to a large extent controls the climate of eastern North America, even in coastal areas. This means that at comparable latitudes summer temperatures are much higher in eastern North America than in western Europe, but in winter the opposite is true. Ocean currents further increase these contrasts; the Gulf Stream raises winter temperatures in Europe whereas the cold Labrador Current has the reverse effect, especially in Labrador and Newfoundland, where it brings extensive ice floes along the shores (Fig. 1).

Fog banks developing at the contacts of the Gulf Stream and Labrador Current lower summer temperatures along the American east coast. This is most pronounced in the southern and southeastern parts of Newfoundland where prevailing southwestern winds keep the coastal areas fog covered and cold for much of the vegetative season (Hare 1952, Banfield 1983).

Warm humid air masses moving frequently from the Gulf of Mexico north along the North American east coast cause relatively high precipitation, 1000-1300 mm in most of the region. In winter, these air masses sometimes bring rain and this results in an erratic snow cover in coastal areas as far north as the eastern peninsulas of Newfoundland (Potter 1965).

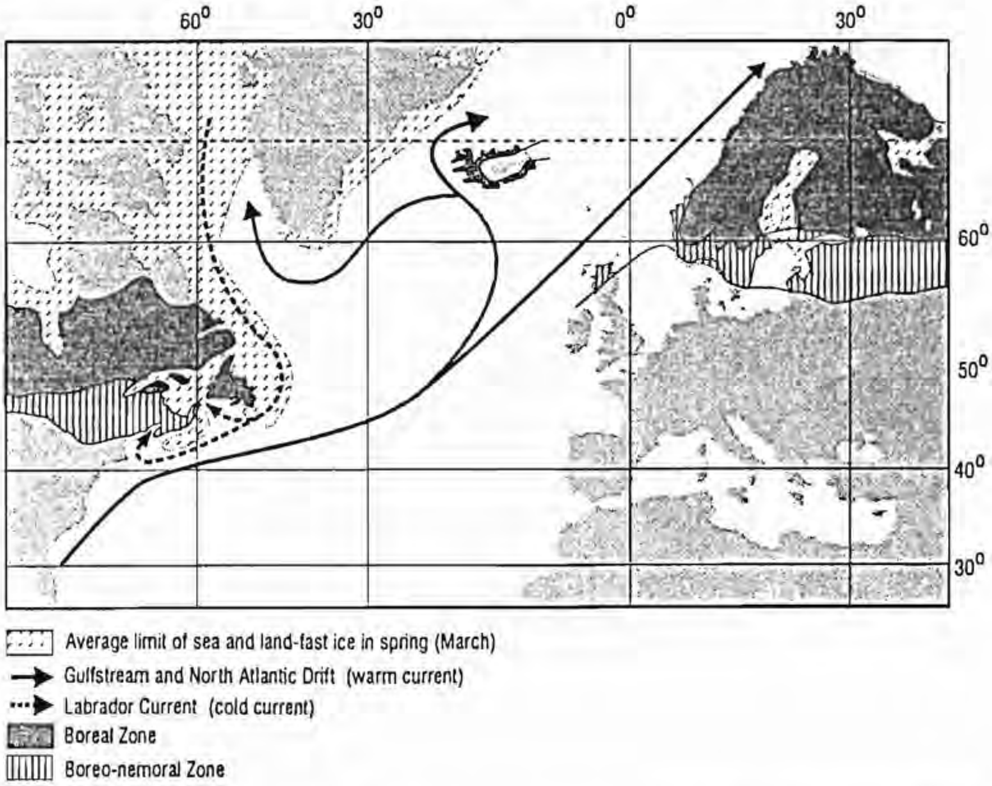


Fig. 1. Boundaries of boreal and boreonemoral zones in Europe and eastern North America (slightly modified after Hämet-Ahti (1981) and Sjörs (1963b)) in relation to the major sea currents and the average maximum extent of sea ice (U.S. Hydrographic Office 1946).

These climatic differences have three important effects:

1) Compared to Europe, the major vegetation zones are shifted far to the south in eastern North America (Fig. 1).
2) The gradient from oceanic to continental temperature regimes from the coast inland is very steep in eastern North America, whereas most of western Europe has an oceanic or suboceanic climate, with slightly continental conditions occurring east of a line drawn through eastern Poland, the Baltic Republics and along the eastern border of Finland. Based on mire vegetation and peatland morphology, a comparable line in North America would have to be drawn a few miles inland from the coast of Maine (Damman 1977), transect Nova Scotia roughly in a northeasterly direction and continue through eastern Cape Breton Island.

3) The raised bog and aapa mire zones occur about 15° latitude farther south in eastern North America than in western Europe, and thus temperatures during the vegetative season in the North American peatlands are higher than in comparable European ones, except in extreme coastal areas.
4) The frequent periods without a winter snow cover in the coastal areas of the North American boreal and boreonemoral zones expose the vegetation to extreme temperatures. This reduces the height and abundance of dwarf shrubs and increases the lichen cover.

3 MAJOR FLORISTIC DIFFERENCES

Differences in the flora of Europe and North America mean that the same ecological niche can be occupied by different species on the two continents. When this concerns dominant or abundant species it can result in major changes in the physiognomy of the mire vegetation and, in some cases, also ecological processes. Only the most important species replacements will be discussed here.

Tree species

Pinus sylvestris and *Picea abies* (subsp. *abies* is common and subsp. *obovata* occurs in northernmost Fennoscandia and Russia) are the major tree species on peatlands in northwestern Europe with *Pinus* on bogs and fens and *Picea* restricted to minerotrophic sites. In eastern North America, *Picea mariana* is the ecological equivalent of *Pinus sylvestris*, and *Abies balsamea* replaces *Picea abies*. Several other conifers can occur in addition in North American peatlands. *Larix laricina* occurs in bogs and fens throughout the boreal zone, and this is often the major tree species in wet, soligenic fens. *Pinus strobus* and *P. banksiana* occur in the bogs and nutrient-poor fens of the southern boreal zone and farther south, and *Thuja occidentalis* is commonly the dominant tree on minerotrophic mire margins in the same areas, except on the island of Newfoundland.

Open grown *Picea mariana* trees keep their lower branches, which frequently develop into new trees or shrubs by "layering", i.e., rooting of the lower branches. As a result the area under isolated *Picea mariana* trees is densely shaded, in contrast to the bog surface under *Pinus sylvestris*. In bogs with active *Sphagnum* growth, the shade severely limits *Sphagnum* growth under the trees whereas decay continues so that the trees are gradually drowned and die (Fig. 2).

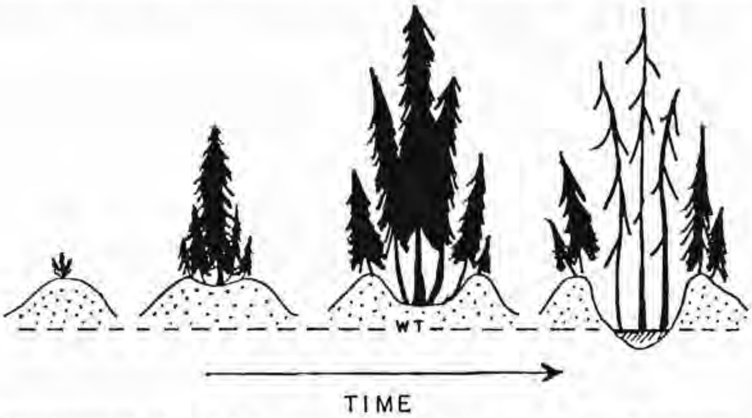


Fig. 2. Development of black spruce (*Picea mariana*) on bog hummocks. *Sphagnum* production is reduced in shade under black spruce and enhanced by litter fall and leachates at the edge of spruce clumps. WT = water table.

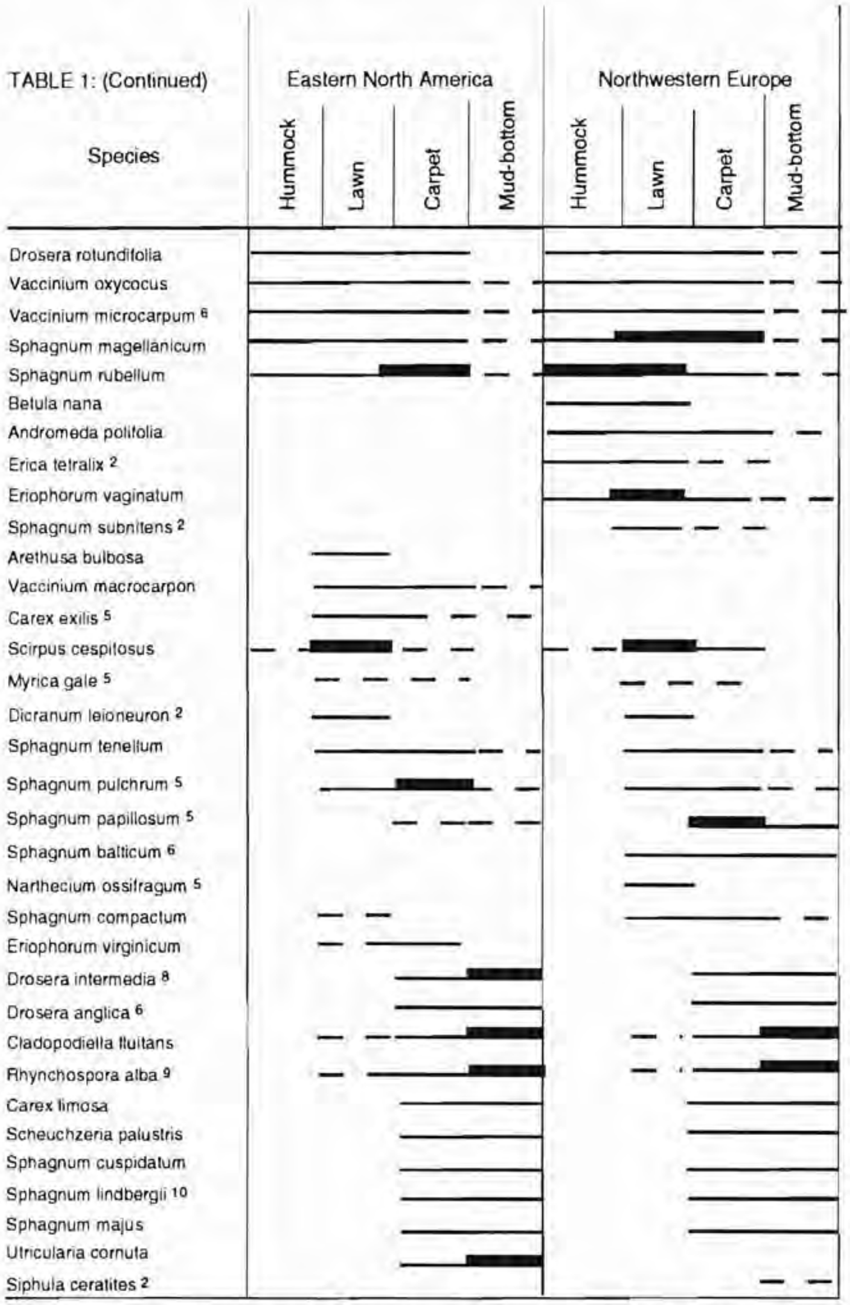
Shrubs and dwarf shrubs

The diversity of ericaceous dwarf shrubs in North America is far greater than in Europe. *Calluna vulgaris,* the dominant ericaceous dwarf shrub on European mires south of the northern boreal zone, is replaced by *Kalmia angustifolia* in eastern North America. Although *Calluna vulgaris* is introduced into North America and has become naturalised locally, it does not invade natural vegetation and never occurs in mires. *Chamaedaphne calyculata* has a distinctly continental distribution in Europe (Hultén 1971), but in eastern North America it occurs abundantly even in extreme coastal locations. It is a dominant species on sites that are occupied by *Erica tetralix* in the oceanic parts of Europe and also occurs on wetter sites. *Gaylussacia baccata* is a dominant species in the driest dwarf shrub heath vegetation of peat bogs in the southern boreal zone and farther south. Several other ericaceous dwarf shrubs are common: *Gaylussacia dumosa*, *Rhododendron canadense*, *Kalmia polifolia* and several low-bush *Vaccinium* spp. Other differences concern sister species, which are ecologically also very similar, e.g. *Andromeda glaucophylla* vs. *A. polifolia* and *Ledum groenlandicum* vs. *Ledum palustre*. Consequently, the hummock and dwarf shrub heath of the two regions have a rather different floristic composition and physiognomy (Table 1).

Two North American shrubs, *Nemopanthus mucronata* and *Viburnum cassinoides*, are common in peatlands of the boreonemoral, south and middle boreal zones, but they do not have an ecological equivalent in Europe. They occur as tall shrubs in mire margin forests and other peatland forests that are too nutrient-poor or marginal for *Alnus rugosa*.

Table 1. Comparison of the floristic composition of ombrotrophic bog vegetation in eastern North America and northwestern Europe. Only commonly occurring species are included. Heavy solid line = species with cover often > 25%; solid line = species usually present, cover mostly < 25%; dashed line = species regularly occurring, but always with few individuals and not in every plot.

Species	Eastern North America				Northwestern Europe			
	Hummock	Lawn	Carpet	Mud-bottom	Hummock	Lawn	Carpet	Mud-bottom
Picea mariana	—							
Kalmia angustifolia	▬							
Gaylussacia baccata [1]	▬							
Vaccinium angustifolium	—							
Ledum groenlandicum	—							
Rhododendron canadense	—							
Calopogon pulchellus	- -							
Solidago uliginosa	—	—						
Sphagnum austinii [2]	—				—			
Pinus sylvestris					—			
Calluna vulgaris					▬			
Vaccinium myrtillus					—			
Ledum palustre [3]					—			
Empetrum nigrum [4]	—				—			
Sphagnum fuscum	▬				▬			
Sphagnum nemoreum	—				—			
Dicranum bergeri	—				—			
Juniperus communis [5]	—							
Racomitrium lanuginosum [2]	—				—			
Pleurozium schreberi	—				—			
Cladonia arbuscula	▬				▬			
Cladonia mitis	—				—			
Cladonia rangiferina	▬				▬			
Cladonia alpestris	—				—			
Ptilidium ciliare	—				—			
Gaylussacia dumosa [1]	—	—						
Pyrus floribunda	—	—						
Schizaea pusilla		- -						
Andromeda glaucophylla	—	—	—	- -				
Kalmia polifolia	—	—	—					
Eriophorum spissum	—	—	- -	- -				
Sarracenia purpurea	- - —	—	—	- -				
Sphagnum flavicomans	—	—	- -					
Chamaedaphne calyculata [7]	—	—	—	- -				
Rubus chamaemorus	—	—			—	—		



1 Only in boreonemoral and southern boreal zone; 2 Restricted to oceanic bogs; 3 Not in oceanic boreal zone; 4 *Empetrum hermaphroditum* replaces this species in boreal uplands and alpine areas of Fennoscandia and at higher elevations in Newfoundland and coastal Labrador; 5 Oceanic distribution in ombrotrophic bogs, elsewhere minerotrophic; 6 Restricted to the northern boreal and subarctic zones in North America; 7 Not in Norway; distinctly continental in Europe; 8 In Fennoscandia only in southwest, elsewhere minerotrophic; 9 In Fennoscandia only in lowlands; 10 Primarily middle and northern boreal in eastern North America.

In eastern North America, *Betula nana* is an arctic species (Porsild 1957, Hultén 1971). Although several dwarf birches occur in eastern North America, none of these is the ecological equivalent of *Betula nana*. Only *Betula michauxii* and *B. pumila* occur in mires, but they are strictly fen species, with the latter having a preference for calcareous sites. *Betula glandulosa*, which is taxonomically closest to *B. nana*, is not a mire species but occurs in open forests, burnt areas and exposed barrens.

Other vascular plants

The lawn and fen communities are dominated mostly by the same Cyperaceae in eastern North America and Europe, e.g. *Scirpus cespitosus*, *Eriphorum angustifolium*, *Carex lasiocarpa*, *C. canescens*, *C. nigra*, *C. rostrata*, *C. livida*, *C. limosa*, *C. chordorrhiza* and *C. aquatilis* (although in Newfoundland, *C. chordorrhiza* is limited to a few localities in the northwestern part of the island). Therefore they have a similar physiognomy. Nevertheless, they also contain many different species, and these species differences become larger with increasing floristic diversity, i.e. from bog lawns to extremely rich fens.

The mud-bottoms of the two regions are floristically and physiognomically very similar, especially those of ombrotrophic bogs. The only major difference is the abundant occurrence of *Utricularia cornuta*, a terrestrial species with minute, simple linear leaves, which colours the mud-bottoms and wet lawns yellow in early summer. Other floristic differences between mud-bottoms and lawns of ombrotrophic bogs are shown in Table 1.

Eriophorum vaginatum is replaced in eastern North America by *E. spissum*, a very closely related species with a similar ecological amplitude as *E. vaginatum*. Two North American orchids, *Arethusa bulbosa* and *Calopogon pulchellus*, are common in the ombrotrophic lawn and dwarf shrub vegetation, respectively. The former is often abundant. In Europe, another orchid, *Dactylorhiza maculata*, occurs in the ombrotrophic hummock vegetation of the most oceanic bogs (A. Moen, pers. comm.).

***Sphagnum* species**

Although the bryophyte flora is rather similar on both sides of the Atlantic, a few interesting differences need to be pointed out. I will restrict myself to the boreal zone and ignore the southern species reaching only into the southern part of the raised bog zone.

Two species common in European mires are either absent (*Sphagnum subnitens*) in eastern North America or have a distinctly northern distribution (*S. balticum*), occurring mostly in subarctic and arctic mires. On the other hand, *Sphagnum pylaesii*, a species with a very restricted distribution in France and Spain (Maass 1966, Lavoie & Gauthier 1983), occurs abundantly in pools and mud-bottoms of open, weakly minerotrophic mires in oceanic eastern North America.

Several North American endemics also occur in the boreal zone. *Sphagnum flavicomans* (Osvald 1940) is a common species in both bogs and fens. It can form large hummocks, similar to *S. austinii* (*S. imbricatum s.l.*) in oceanic bogs. *S. torreyanum*, a coarse species in the Cuspidatae, occurs primarily in minerotrophic pools north to the middle boreal zone. *Sphagnum macrophyllum*, is an aquatic species of nutrient-poor pond margins along the east coast of North America, that reaches into the southern boreal zone of Newfoundland, where it occurs in bog pools (Maass 1967).

4 DIFFERENCES IN PEATLAND MORPHOLOGY

Peatland development is controlled by complex interactions among climate, hydrology, nutrient supply and vegetation. Among these, hydrology and nutrient regime of the mire water are most affected by local differences in topography and in surficial and bedrock geology. This can confound regional patterns in peatland development. Therefore, the zonation of hydromorphological mire types, i.e. "mire complex type" (myrkomplextyp) *sensu* Sjörs (1948), is most obvious in regions with little relief and uniform geology, such as Finland (Ruuhijärvi 1960, Eurola 1962). The zonation in Norway is exceptionally obscure because of large altitudinal differences and the associated changes in precipitation and temperature.

The effect of the climatic differences between western Europe and eastern North America on the structure and surface morphology of peatlands will be most clearly expressed in mire types in which hydrology and nutrient supply are primarily under climatic control. For this reason, in comparing the peatlands of the two regions, I will focus on the conditions in and distribution of hydromorphological mire types such as blanket bogs, raised bogs, aapa mires and palsa mires. In doing this, I will restrict myself to pointing out where comparable peatlands occur and how they differ. A detailed comparison requires a discussion of the processes controlling peatland development in oceanic regions. This is beyond the scope of this paper and will be the subject of a separate paper.

4.1 RAISED BOGS

Raised bogs (Fig. 3) are ombrotrophic bogs with their central plain clearly raised above the bog margin. This definition includes a wide variety of peat bogs ranging from the very slightly raised bogs of continental areas (Heinselman 1970, Zoltai et al. 1988) to genuine plateau bogs (Eurola 1962) and oceanic flat raised bogs (Osvald 1925a, b) or Atlantic plateau bogs (Wells & Hirvonen 1988). I will restrict myself to comparing raised bogs and related ombrotrophic bogs that are common in the Norwegian boreal zone (Moen 1985, Moen & Singsaas 1994) with bogs in the Atlantic parts of the North American boreal zone.

Plateau raised bogs with a well-developed lagg and a flat raised central plain occur mostly in the humid boreonemoral zone of eastern North America. This includes a very narrow coastal zone in Maine and New Brunswick (Damman 1977) and the Atlantic coastal part of Nova Scotia (Damman 1979b, Damman & Dowhan 1981). They are replaced to the north by a variety of other raised bog types (Damman 1979b, Glaser & Janssens 1986, Damman 1988, Wells & Hirvonen 1988) and to the west by concentric and eccentric raised bogs (Damman 1977, Davis & Anderson 1991).

Plateau bogs with mud-bottoms covering most of the flat, very wet plateau, such as Kaldvassmyra, Verdal (63°42' NL, 11°36' EL) (Moen & Moen 1977, Moen et al. 1983, Moen & Singsaas 1994) in the slightly oceanic southern boreal zone, are relatively rare in eastern North America. They are restricted to the most humid parts of the boreonemoral zone on eastern Cape Breton Island and the Atlantic coastal zone of the Nova Scotian mainland. Those on Cape Breton Island resemble the Norwegian ones most but, in contrast to Kaldvassmyra, hollow-pools are common. Farther south in Nova Scotia, hollow-pools become rare or absent in plateau bogs and mud-bottoms can cover much of the wettest parts of the plateau (Damman & Dowhan 1981). However, here bare peat is rare in the mud-bottoms and *Cladopodiella fluitans* and *Utricularia cornuta* cover most of the surface.

Domed raised bogs with eccentric or asymmetric ridge and hollow features are common in the less oceanic parts of the southern boreal and middle boreal zones. In Rørmyra, Trondheim, Sør-Trøndelag (63°23' NL, 10°15' EL), the areas between the peat ridges (strings) are covered with lawn and carpet vegetation, as is also common in many other Fennoscandian eccentric and concentric bogs (Eurola 1962, Sjörs 1983).

The most striking difference between the domed raised bogs of Fennoscandia and the Atlantic parts of North America is the prominence of hollow-pools in the latter. In these bogs, the central bog plain consists mostly of an alternating pattern of peat ridges (strings) and about 1.5 m deep pools (Damman 1979b, Zoltai & Pollett 1983, Damman 1986, 1988) that replaces the ridge-hollow pattern. Bogs with this ridge-pool pattern also occur in Fennoscandia, e.g. southeastern Värmland (Sjörs 1948, 1983), Satakunta (Aario 1932, Eurola 1962) and in some boreonemoral areas of southeastern Norway (Moen 1983), but here they are the exception rather than the rule.

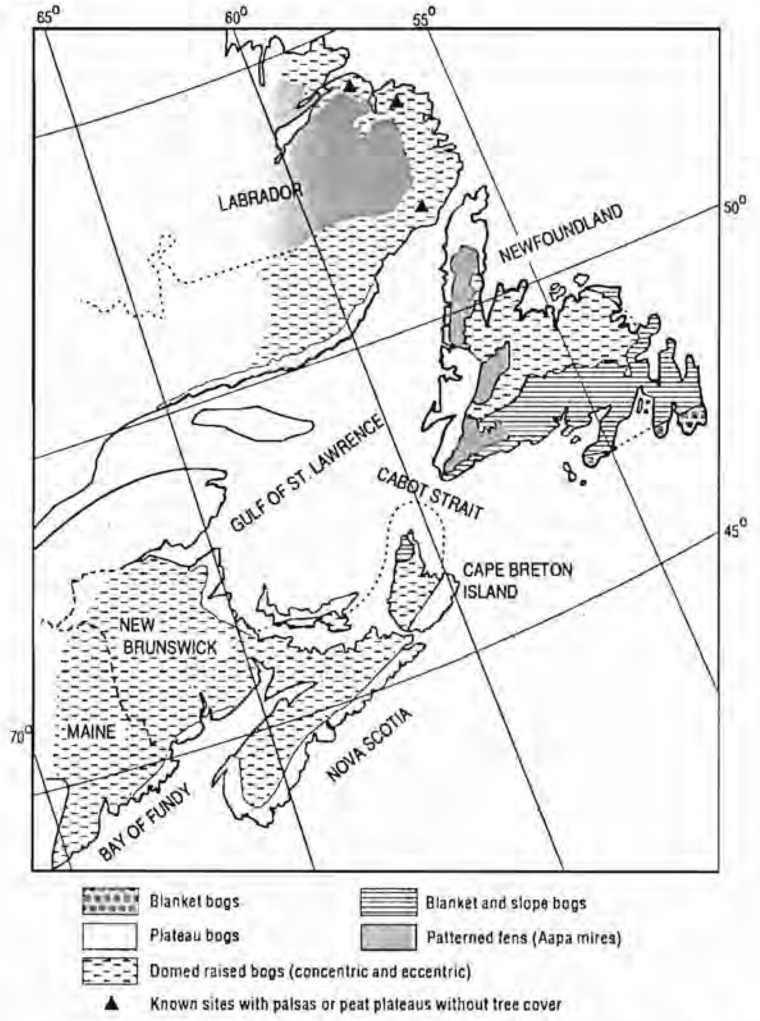


Fig. 3. Distribution of major hydromorphic mire zones in Atlantic parts of North America. Within each mire zone the vegetation on the mire surface shows clear geographical changes in floristic composition. The Cabot Strait and Gulf of St. Lawrence mark the boundary between the boreal and boreonemoral zones, except for sites at high elevation. For more detailed information on the subdivision of the boreal zone see maps in Hämet-Ahti (1981) and Damman (1983) for Newfoundland. Location of treeless palsas and peat plateaus based on Dionne (1984) and own observations.

The raised bogs of Andøya (68°50' NL, 17°00' EL) in northern Norway are only slightly raised and lack a clear lagg (Osvald 1925a). They were called flat raised bogs ("Flach Hochmoor") by Osvald (1925a) and plane bogs by Moen (1985). They most closely resemble the low plateau bogs of the west side of the Great Northern Peninsula of Newfoundland (Damman 1979b) and have developed on flat, marine deposits; in both cases, *Racomitrium lanuginosum* is one of the main peat formers. However, the winters are much colder and snowfall is greater in this part of Newfoundland than in the oceanic bog area of Andøya. At Daniels Harbour, mean snowfall is 1.87 m (no data available for Andøya, Norwegian Meteorological Institute), the mean temperature of the coldest month is -7.8°C (compared to -2.2°C on Andøya), and the absolute minimum temperature is -39.4°C (compared to -19.9°C on Andøya. These bogs have been included in the rather heterogeneous category of Atlantic plateau bogs by Wells & Hirvonen (1988) and in Maritime plateau bogs by Glaser & Janssens (1986).

4.2 BLANKET BOGS AND OCEANIC SLOPE BOGS

Blanket bogs (Fig. 3) develop in areas with high, evenly distributed precipitation where peat can accumulate on slopes as well as in valleys. They are ombrogenous peatlands but, because the underlying bedrock and soils outcrop locally, they contain minerotrophic sites.

In the nemoral and boreonemoral zones of eastern North America, the precipitation during the summer months is never high enough for blanket bog development. The southernmost blanket bogs occur in the most oceanic parts of the southern boreal zone of Newfoundland (Fig. 3) on the southern extremities of the Avalon and Burin Peninsulas (Damman 1979b, 1983, Wells 1981).

Precipitation is slightly higher and winters are appreciably colder here than in the southern boreal zone along the Norwegian coast. Whereas the mean temperature of the coldest month is slightly above freezing on Haramsøy, Smøla and Hitra, it is between -3° and -4°C in the blanket bog zone of Newfoundland and the absolute minimum temperature for Cape Race, a coastal station in this zone, is -24.4°C.

The mean temperature of the warmest month is 13-14°C in both areas, but the absolute maximum temperature is much higher in Newfoundland (30.6°C at Cape Race). Nevertheless, because the vegetative season is shorter in the Newfoundland blanket bog zone, the potential evapotranspiration is lower than on Haramsøy and Smøla; i.e. 350 vs 380 and 393 mm/year (Banfield 1983, Moen & Singsaas 1994). Thus, the southernmost blanket bogs in eastern North America experience colder winters than peatlands much farther north along the Norwegian coast, such as those of Andøya (Osvald 1925a), where the mean January temperature is -2.2°C. In spite of the cold winters, mild periods with rain occur commonly, and therefore the Newfoundland blanket bog zone can be snow free during any of the winter months, and the maximum winter snow accumulation at Cape Race is only 22.5 cm (Potter 1965).

Under these climatic conditions, dwarf shrub dominated blanket bogs comparable to those at Bakkedalen on Skuløy (62°40' NL, 6°21' EL) cannot occur, and such blanket bogs find no counterpart in eastern North America. The blanket bogs in Newfoundland are dominated by *Scirpus cespitosus* and are physiognomically similar to those of Smøla (Holmsen 1922, Osvald 1925a) and Hitra, but northern lichens such as *Alectoria ochroleuca, A. nigrans, Cetraria nivalis, C. cucullata* and *Sphaerophorus globosus* are abundant. In addition, *Eriophorum spissum* is much less common than *E. vaginatum* is in Norway, and *Sphagnum compactum* is infrequent.

Very different conditions can be found a short distance to the north on Newfoundland. Outside the narrow southern coastal zone with blanket bogs (Fig. 3), snow accumulates in winter and melt water is abundant in spring. This meltwater comes in contact with mineral soils and prevents ombrogenous bog development in valleys and parts of slopes under climatic conditions that otherwise favour blanket bog development. As a result, in much of southern and eastern Newfoundland, ombrotrophic peat occurs only on sites that do not receive melt water from higher areas. In this area blanket bogs develop only on hill tops, ridges and on flat terrain between rivers and along the coast (Damman 1979b). This is the same situation as in the middle and northern boreal zones of the moderately oceanic parts of Norway (Moen & Singsaas 1994).

Because of the frequent fog and high summer precipitation, ombrotrophic peatlands can develop on sloping sites not affected by minerotrophic water, usually on midslope and upper midslope positions. These are known as slope bogs (Damman 1979b, Wells 1981, Zoltai & Pollett 1983).

This zone of blanket bogs and slope bogs (Fig. 3) includes much of southern and southeastern Newfoundland (Damman 1979b). The coastal areas are southern boreal, but this zone reaches well into the middle boreal zone (Damman 1983). It includes part of what is called the Atlantic Subarctic Wetland Region in the Canadian Wetlands Classification (National Wetlands Working Group 1988).

Blanket bogs of the type occurring in this zone also occur in Norway. They are comparable to the blanket bog on the Salthammar drumlin (63°37' NL, 11°34' EL), Øvre Forra, Nord-Trøndelag (Hafsten & Solem 1976, Solem 1991), which also occurs as an azonal formation outside the blanket bog zone. This blanket bog is surrounded by rich slope fens (Moen & Singsaas 1994) because of the calcareous substrate, whereas bogs and nutrient-poor fens dominate the landscape of the slope and blanket bog zone of Newfoundland.

Some of the hill top blanket bogs in this zone are badly eroded, with deep gullies and bare peat surfaces that expose the tree stumps in the basal peat. These eroded areas resemble those shown in the Pennines of England (Tallis 1964, 1965). However, in contrast to the Pennines, the erosion of the Newfoundland blanket bogs appears to be entirely natural.

In a blanket bog landscape, some parts of a peatland can be clearly raised. This is well-illustrated in profiles of southern and central Norwegian blanket bogs investigated by Holmsen (1922). Moen (1985) recognised these as Atlantic raised bogs. Parts of Toppmyrane, Smøla (63°23' NL, 8°0' EL), are an example (Moen & Singsaas 1994). Such raised areas also occur in the blanket bogs of Newfoundland. However, I consider them as a regular feature of a blanket bog. A blanket bog has an undulating topography resulting from the relief of the underlying substrate as well as changes in peat depth. Since genuinely raised parts of a blanket bog cannot be distinguished by their vegetation or surface morphology, it does not seem practicable to separate them as a distinct hydromorphological mire type.

4.3 PATTERNED FENS

These are soligenous mires with a clear pattern of peat ridges (strings) alternating with flarks or flark-pools. They reach their optimal development in the northern boreal zone, where these mires can cover extensive areas and form the principal peatland type. They are also common in the middle and southern boreal zone and can occur farther south, if the supply of soligenous water is adequate, e.g. in the boreonemoral zone of Maine (Sorensen 1986) or southern Finland (Tolonen 1968). I have even seen a small, clearly patterned fen (Silver Lake Fen) in the prairies of northwestern Iowa, where a spring provided the water for a wetland.

In most Fennoscandian patterned fens (flark fens, string fens) the flarks are occupied by a soft-carpet or mud-bottom vegetation (Ruuhijärvi 1960, Sjörs 1983). Its floristic composition depends on the nutrient regime of the mire water. The flarks of the patterned fens of Tufsingdeltaet (62°12' NL, 11°50' EL), Os, Hedmark (middle boreal zone, Moen & Singsaas 1994), supported a poor and intermediate carpet vegetation with *Carex chordorrhiza, C. limosa, Menyanthes trifoliata* and *Sphagnum* species, such as *S. majus, S. compactum* and *S. lindbergii.*

Most patterned fens in the boreal zone of eastern North America (Fig. 3) have flark-pools rather than flarks. These pools have steep sides, are usually 1-2 m deep, and are separated by narrow peat ridges. In patterned fens with thin peat, the pools reach to the underlying mineral soil and can be very shallow. Such flark-pools with mineral soil bottoms and scattered boulders are especially common in the barrens of the Island of Newfoundland at elevations over about 400 m (Damman 1979b). These peatlands were called patterned veneer fens by Zoltai & Pollett (1983). In the Canadian Wetlands Classification System, these and other patterned fens with flark-pools are classified as either Atlantic ribbed fen or string bogs (Wells & Hirvonen 1988). The latter are actually mixed mires, i.e. fens with high, almost ombrotrophic strings.

In Fennoscandia, patterned fens with steep-sided flark-pools occur quite frequently in inland areas of the middle and northern boreal zones, and appear to be most common in Peräpohjola and Forest Lapland in northern Finland (Ruuhijärvi 1960, 1983), Dalarna and Värmland in Sweden (Fransson 1972) and Hedmark in Norway (Næss 1969). Patterned fens with well-developed flark-fens comparable to the Fennoscandian flark mires (Ruuhijärvi 1960, Sjörs 1983) occur commonly in central and western Canada, where they are classified as northern ribbed fens (Zoltai et al. 1988).

4.4 MIRES WITH PALSAS AND PEAT PLATEAUS

These are mires with discontinuous permafrost. The permafrost can occur in isolated palsas or in more extensive peat plateaus (Zoltai 1972). In Norway, these mires are most common between 68 and 70° NL (Vorren 1967), but no distinction is made between peat plateaus and palsas, although both occur. In Fennoscandia, they are always without tree cover (Ruuhijärvi 1960). Individual palsas can be up to 7 m high (Vorren 1967). In Norway, the southernmost palsa mire occurs on Dovrefjell at about 1000 m altitude in the northern boreal zone. The Haukskardmyrin on Dovrefjell (62°8' NL, 9°23' EL) is a peat plateau mire with collapse scars; the low peat plateau is lifted only about 2 m above the mire surface (Moen & Singsaas 1994).

Low, treeless palsas and peat plateaus, similar to those on Dovrefjell, occur in eastern North America in the coastal peatlands of Labrador (Fig. 3). The southernmost known treeless peat plateaus occur near Blanc Sablon (51°30'

NL) in southern Labrador (Dionne 1984) at about 60 m altitude. Palsas and peat plateaus become more common in the mires north of Cartwright (53° NL) and, according to Dionne (1984), especially in the subarctic in the southern part of the Ungava Peninsula west of Kuujjuaq (57°30' to 58°30' NL).

Thus, the palsa mire zone occurs about 10° farther south along the east coast of North America than in northwestern Europe. The palsas and peat plateaus in Labrador are always low (1-3 m). High palsas, comparable to the 6-7 m high ones reported from Fennoscandia and Russia (Vorren 1967, Botch & Masing 1988), have never been reported in Labrador.

Forested palsas occur occasionally in fens farther inland from the Labrador coast and north of about 51° NL; they are common farther west (e.g. in northern Ontario (Sjörs 1961)) and along the Hudson (Dionne 1978).

5 DIFFERENCES IN VEGETATION AND SPECIES DISTRIBUTION

The floristic composition of the mire vegetation is controlled by the same environmental factors on both sides of the Atlantic Ocean. In spite of this, the vegetation of comparable mire sites in eastern North America is not the mirror image of that in northwestern Europe. Differences in the flora of the two regions are partly responsible. However, even if one disregards these floristic differences, the relationship between hydromorphological mire types and the floristic composition of their vegetation is not identical (Damman 1979a). The differences are of three types:

1. Vegetation types reaching into a more southern vegetation zone in eastern North America than in Europe. Added to the southward shift in vegetation zones in eastern North America (Figs. 1 and 3), this means that these vegetation types are displaced exceptionally far southward.
2. Striking differences in species abundance in comparable vegetation types.
3. Bog species found in a more northern vegetation in North America because they occur at roughly the same latitude at opposite sides of the Atlantic Ocean.

I will illustrate these differences with a few examples.

Southward displacement of vegetation

Dwarf-shrub communities with *Sphagnum magellanicum* and *S. rubellum* as the dominant moss species form the hummock vegetation of bogs in most of the oceanic parts of Europe; south of about 65° NL in the blanket bogs along the Norwegian coast and southwest of about 59° NL in the raised bogs of southern Sweden (Du Rietz 1949, Eurola 1962). Farther north, in the boreal zones, *Sphagnum fuscum* is the dominant *Sphagnum* species in the ombrotrophic hummock vegetation. *S. fuscum* occurs here and there on boreonemoral hummocks in Fennoscandia, mostly in eastern parts.

In contrast, *Sphagnum fuscum* is the dominant moss in the hummock communities of all blanket bogs and oceanic raised bogs (Pollett & Bridgewater 1973, Damman 1978, 1979a, Wells 1981) in eastern North America south to about 44° NL or far into the boreonemoral zone (Damman 1977, Damman & Dowhan 1981). Farther inland *Sphagnum rubellum* gradually replaces *S. fuscum* as the dominant in the dwarf-shrub communities on hummocks of southern ombrotrophic bogs (Damman 1977) and in oligotrophic topogenous bogs, the latter with *Chamaedaphne calyculata* as the dominant dwarf shrub (Damman 1978, Damman & French 1987).

In the exposed coastal zone with little snow protection during the winter, the height of dwarf shrubs, such as *Kalmia angustifolia, Ledum groenlandicum* and *Chamaedaphne calyculata,* is usually only 5-10 cm. Here, *Empetrum nigrum* and *Sphagnum fuscum* dominate. This is the usual hummock vegetation in the boreonemoral zone along the Maine and Nova Scotian coast (Damman 1977, 1978). Similar to Europe, *Empetrum nigrum* is replaced by *E. hermaphroditum* north of the middle boreal zone. Farther north, lichens and *Racomitrium lanuginosum* play an increasingly more prominent role in coastal locations (Pollett & Bridgewater 1973, Wells 1981). North of about 49° NL (middle boreal zone), *Cetraria nivalis, C. cucullata, Sphaerophorus globosus, Dicranum elongatum, Alectoria nigricans, A. ocholeuca* and *Carex rariflora* become important components of this vegetation (Damman 1978). This vegetation is comparable to the exposed hummock vegetation described from alpine sites and the northern boreal zone, north of about 70° NL in Norway (Eurola & Vorren 1980, Dierssen 1982).

Differences in species abundance

Two species are conspicuously more abundant in Norway, and in European bogs in general, than in eastern North America. *Eriophorum vaginatum* plays a much more important role in the lawn and heath vegetation of European bogs than the very closely related *Eriophorum spissum* in eastern North America. The latter is a constant component of these vegetation types, but is never as abundant as *Eriophorum vaginatum*.

Sphagnum compactum is common in ombrotrophic lawn and mud-bottom vegetation in oceanic parts of Norway, but less so farther east (Osvald 1925a, Dierssen & Dierssen 1978, Dierssen 1982, Moen 1985). Although this species occurs commonly in slightly minerotrophic mires and wet heath vegetation in eastern North America, it is usually absent in ombrotrophic bog vegetation. *S. papillosum* is also far less common in North America than in Scandinavian ombrotrophic bogs, where it is common in oceanic sections (but absent from more continental areas).

Species in more northern vegetation zones

Most northern species occur at much lower latitudes in eastern North America than in Europe, as would be expected from the southward shift in vegetation zones in the former (Fig. 1). There are, however, several notable exceptions. Some species occur at roughly the same latitude in both regions. Consequently, these occur in a more "northern" vegetation in eastern North America. A few good examples of this distribution will be given below.

Sphagnum balticum, Siphula ceratites and *Vaccinium microcarpum* (*Oxycoccus microcarpus*) reach well into the boreonemoral zone of southern Scandinavia (Fægri 1952, Nyholm 1969, Hultén 1971), but these species have a subarctic and arctic distribution in eastern North America (Hultén 1971, Thomson 1984). A small-leaved *Vaccinium oxycoccus* subsp. *microphyllus* Lge. occurs throughout most of the North American boreal zone (Hultén 1971), and has sometimes been mistaken for *Vaccinium microcarpum*. However, at least east of the Hudson Bay, *Vaccinium microcarpum* is a subarctic and arctic species with a southern limit roughly at 55° NL, the same latitude at which *Ledum palustre* var. *decumbens* (Ait.) Max. starts to occur. This also applies to *Pinguicula villosa*, which reaches south into the boreal zone of Scandinavia (mainly the northern boreal zone), but has a subarctic and low arctic distribution east of the Hudson Bay (Hultén 1971).

Similarly, *Drosera intermedia* is replaced by *Drosera anglica* in the mud-bottom vegetation of the northern part of the boreonemoral zone (±62° NL) along the Norwegian coast. However, in eastern North America, *Drosera intermedia* reaches far north into the boreal zone and is still abundant in the mud-bottoms of mires in the middle boreal zone of Labrador, whereas *Drosera anglica* has a primarily subarctic distribution (Rousseau 1974).

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Bogs and fens on the vegetation map of Europe

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ABSTRACT

Rybníček, K. & Yurkovskaya, T. 1995. Bogs and fens on the vegetation map of Europe. *Gunneria 70*: 67-72.

This contribution gives information about the 1:2 500 000 scale vegetation map of Europe that is currently being prepared, and in particular about the way mires are being represented on this map. Problems relating to the classification of units and the drawing up of a key for a map of this kind are discussed. A classification recognising 22 mire types subdivided into three major groups (ombrotrophic bogs, mixed ombro-minerotrophic mires and minerotrophic fens) has been established to express the regional variations of European mires. A combination of indicator plant species has been used to briefly characterise these units.

1 INTRODUCTION

In 1979, P. Ozenda (Grenoble), W. Trautmann (Bonn-Bad Godesberg) and R. Neuhäusl (Průhonice u Prahy) took the initiative to compile a vegetation map of Europe on a scale of 1:2 500 000. Originally, it was intended to combine existing maps from the western and eastern bloc countries (Ozenda 1979, Bondev et al. 1985). However, subsequent discussions during several meetings led to a new project for an entirely new map of European natural vegetation, with a new key. More than 150 mapping units grouped into 19 vegetation formations (A - U) were established to achieve an expression of all the major zonal and azonal vegetation types on the European continent, including the Caucasian region. The map, to be comprised of 15 sheets, is intended to express the diversity and spatial distribution of European vegetation, its environmental variability and indicator value for determining the natural biological potential of different habitats or landscapes, etc. The project is being supported by IUBS and sponsored by ESF. For further information see Neuhäusl (1991) and Bohn (1992). A general map of the natural vegetation of Europe and Turkey on a scale of 1:15 000 000 has already been produced by Bohn (1993) as a preliminary result of earlier editorial discussions.

2 REPRESENTATION OF MIRES ON THE MAP

Mires are mapped as the formation "S", but only bogs and fens are included. Other types of mires, such as alder, birch or spruce carrs (swamp forests), salt marshes, littoral reed and tall-sedge swamps are incorporated in other vegetation formations, although often they can accumulate and/or cover a peat substrate. Only those mires are taken into account which are still in a more or less intact and natural state or, at least, are still suitable for revitalisation, i.e. they still have some remnants of their natural mire vegetation.

The need to follow the general methodological bases for the map and respect the instructions of the editorial board has meant that several conditions and limitations have influenced the construction of the key and the delimitation of the mapping units recognised in our formation:

1. The characterisation of the mapping units had to be based primarily on the vegetation, and a combination of diagnostic plants had to be used to delimit and differentiate the units.
2. Simultaneously, the units needed to reflect the geographical specificity of the mapping units or their groups, and their relationship to the major vegetational zones of Europe.
3. The key had to respect and take into account already existing national, or multinational, systems of mapping units, especially those developed for the European territory of the former USSR, which covers more than half the continent and is very rich in peatlands.

Given this situation, the present authors had only one choice, namely to enlarge and adapt the original key for the map of the former COMECON states (Council of Mutual Economic Aid) - see Bondev et al. (1985) - and the Russian typological classification of mires (Yurkovskaya 1980). Thus, in fact, only those new mapping units were set up which were necessary to represent the mire types absent in the east but present in central and western Europe, including Scandinavia.

As the work proceeded it was found that some units occur over very limited areas and could not be expressed using contour lines on the given scale of the map. These units were therefore omitted and their numbers are missing from the classification. On the other hand, some additional units had to be delimited following recommendations from national experts. This explains why some numbers have been given additional letters.

As part of the general key for all the formations, this key was distributed to those national representatives who were responsible for carrying out the mapping in their countries. Unfortunately, most of them were by no means specialists in the study of mire vegetation, nor did they contact their national experts. Consequently, countries such as Poland, Austria and even the Scandinavian countries either did not map mires at all, or expressed them in a way that was not fully representative. In an attempt to correct this fault, the present authors have been collecting new information from several colleagues who are national mire specialists. Their contributions are now being evaluated, amalgamated and plotted on the maps.

3 THE KEY FOR MIRE UNITS

The key for the units representing mires on the vegetation map of Europe is presented here. All the units are divided into three major trophic groups:

1. Ombrotrophic bogs
2. Ombro-minerotrophic mire complexes
3. Minerotrophic fens

Assemblage of the mapping units into higher echelons should help to express their zonal and/or geographical relationships.

1 Ombrotrophic bogs

1.1 Boreal *Sphagnum fuscum* raised bogs

- S-1 Central Scandinavian-western Finnish *Sphagnum fuscum* raised bogs with *Calluna vulgaris*, *Empetrum hermaphroditum*, and *Pinus sylvestris* in the east.
- S-2 Eastern Finnish-western Russian *Sphagnum fuscum* raised bogs, with *Calluna vulgaris* and *Chamaedaphne calyculata*, often occurring in complexes with *Pinus sylvestris* bog stands (282 on the CONECOM map).
- S-3 *Sphagnum fuscum* raised bogs with *Chamaedaphne calyculata* between Lake Onega and the Pechora Basin (283).
- S-3a Lichen-rich *Sphagnum fuscum* raised bogs of the White Sea region (*Cladina* spp., *Cetraria* spp., *Calluna vulgaris*, *Empetrum hermaphroditum*) (284).

1.2 *Sphagnum papillosum* blanket and raised bogs of oceanic regions, with *Erica tetralix* and *Narthecium ossifragum*

- S-4 *Sphagnum papillosum* and *S. imbricatum* blanket bogs with *Molinia caerulea, Schoenus nigricans, Sphagnum auriculatum* and other *Sphagna* sect. *subsecunda* (lowland blanket bogs).
- S-4a Blanket bogs with *Eriophorum vaginatum, E. angustifolium, Trichophorum cespitosum ssp. germanicum, Empetrum nigrum, Calluna vulgaris, Rubus chamaemorus* and *Sphagnum capillifolium* (mountain blanket bogs).
- S-5 Oceanic-suboceanic treeless raised bogs with *Sphagnum papillosum, S. magellanicum, Trichophorum cespitosum ssp. germanicum, Calluna vulgaris, Rhynchospora alba* and *Drosera anglica.*

1.3 *Sphagnum magellanicum* raised bogs of the boreonemoral and nemoral zones

S-7 Baltic *Sphagnum magellanicum* raised bogs with *Calluna vulgaris, Empetrum nigrum, Rhynchospora alba, Trichophorum cespitosum ssp. cespitosum* (285).

S-8 Central European *Sphagnum magellanicum* raised bogs with *Vaccinium uliginosum, Carex pauciflora, Dicranum bergeri*, often with *Pinus mugo* agg.

S-9 Central-east European tree-rich *Pinus sylvestris-Sphagnum magellanicum* raised bogs, with *Ledum palustre* (286).

S-10 Central European, tree-rich *Pinus rotundata-Sphagnum magellanicum* raised bogs, with *Melampyrum pratense ssp. paludosum* (287).

2 Ombro-minerotrophic mires

2.1 Palsa mires

S-12 Subarctic palsa-mire complexes (*Sphagnum fuscum* and dwarf shrubs). *Empetrum hermaphroditum, Betula nana, Rubus chamaemorus* on palsas; *Eriophorum russeolum, Carex rotundata, C. rariflora, C. aquatilis, Sphagnum lindbergii* on minerotrophic fens between palsas (288).

2.2 Polygonal mires

S-12aNortheastern European polygonal mires with *Ledum palustre, Salix reptans, Rubus chamaemorus, Hierochloë pauciflora, Dicranum angustum, D. elongatum* and *Cetraria cuculata.*

3 Minerotrophic mires

3.1 Boreal aapa mire complexes

S-13 Fennoscandian aapa mire complexes (*Carex lasiocarpa, C. rostrata, C. livida, Menyanthes trifoliata, Sphagnum papillosum, S. majus, S. balticum*), with *Molinia caerulea* on ridges with *Betula nana* (289).

S-14 Northeastern European aapa mire complexes (*Trichophorum cespitosum* ssp. *cespitosum, Menyanthes trifoliata, Sphagnum papillosum*), with *Sphagnum jensenii* and *S. magellanicum* in the region between Lake Onega and the Pechora Basin. *Molinia caerulea* and *Carex livida* are absent in the east (290).

3.2 Transitional and poor (oligo-mesotrophic) fens

S-15 Central, northern and eastern European transitional fens (*Carex limosa, C. rostrata, C. lasiocarpa, C. chordorrhiza, Rhyncho-*

spora alba, Sphagna sect. *subsecunda, S. fallax, S. papillosum* (291).

S-17 Eastern European (and western Siberian) wooded transitional fens *(Betula pubescens* agg., *Pinus sylvestris, Carex lasiocarpa, Sphagnum flexuosum, S. centrale*) (292).

3.3 Brown-moss rich (eutrophic and calcitrophic) fens

3.3.1 European low-sedge brown-moss fens

S-18 Arctic-subarctic (alpine-subalpine) brown moss fens (*Carex parallela, C. atrofusca, C. stans, C. saxatilis, Juncus arcticus, J. biglumis, J. castaneus, Eriophorum medium, E. scheuchzeri, Dupontia fischeri, Salix myrsinites, S. arbuscula, Thalictrum alpinum, Scorpidium turgescens, Calliergon sarmentosum, Drepanocladus exannulatus* agg.) (293).

S-21 Low-sedge brown-moss rich fens (*Schoenus ferrugineus, Carex hostiana, C. flava* agg., *C. dioica, Blysmus compressus, Pinguicula vulgaris, Tofieldia pusilla, T. calyculata, Primula farinosa, Equisetum variegatum, Drepanocladus revolvens, D. intermedius, Chrysohypnum stellatum, Tomenthypnum nitens, Cratoneurum* spp., *Sphagnum warnstorfianum*). *Carex davalliana* is present in the central European and eastern Baltic regions (295).

3.3.2 Tall-sedge fens of Europe

S-19 Boreal tall-sedge fens (*Carex lasiocarpa, C. rostrata, C. chordorrhiza, Calamagrostis neglecta, Scorpidium scorpioides, Drepanocladus aduncus, Calliergon giganteum*) (294).

S-22 East European (Polesian) tall sedge fens (*Carex omskiana, C. vesicaria, C. gracilis, Calamagrostis neglecta, Drepanocladus aduncus, Calliergon giganteum, Calliergonella cuspidata*) (296).

S-23 Tall sedge and herb-rich fens of Kolchis (*Carex gracilis, C. nigra, Juncus effusus, Cladium mariscus, Ludwigia palustris* in alternation with *Sphagnum imbricatum* and *S. papillosum. Rhododendron luteum, Osmunda regalis, Rhynchospora caucasica, Alnus barbata* and *Pterocarya pterocarpa* are also present (297).

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Mire system typology for use in vegetation mapping

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ABSTRACT

Yurkovskaya, T. 1995. Mire system typology for use in vegetation mapping *Gunneria 70*: 73-82.

The author proposes to distinguish between three groups of mire systems based on the floristic composition of the plant communities, the vegetation patterns and the dynamic interrelationships of the mire massifs (units) forming the systems (complexes). The mire systems are formed by the fusion of several separate mire massifs during their evolution. This typology of the mire systems has been worked out with the object of using it in small-scale vegetation mapping. The three groups of mire systems distinguished are: 1. those formed by mire massifs of one and the same type; the massifs comprising this system develop similarly and their plant communities have the same spectrum of characteristic, dominant and highly constant species; 2. those formed by mire massifs of different types, whose differences are related to their different ages, although they form a unified dynamic sequence; their communities have a similar spectrum of essential species; 3. those produced by fusion of types of mire massifs belonging to different classes, with different courses of development and greatly differing plant community compositions.

1 INTRODUCTION

The concept of several levels of mire structure complexity developed in line with the progress of mire science itself (e.g. Abolin 1914, Osvald 1925, Bogdanovskaja-Guiheneuf 1928, 1949, Aario 1932, Galkina 1946, Sjörs 1948, Lopatin 1954, Masing 1960, 1969, 1993, L'vov 1977). These levels have been named differently by different researchers and differ in extent. However, the essential units can be assigned, following Galkina (1946), to three levels: micro, meso and macro.

2 TERMINOLOGY

The various types of mire massifs (mire complex types *sensu* Cajander) represent the meso level. They have been studied in some detail, also the different approaches to their classification, beginning with the classic works of Cajander (1913), Osvald (1925), Bogdanovskaja-Guiheneuf (1928, 1949), Paasio (1933, 1939) and others. The lower level units (phytocoenoses, biogeocoenoses, mire sites, etc.) have also been studied and classified thoroughly enough.

My communication deals with the units at the macro level, the systems of mire massifs, a term now used by investigators in Russia and Estonia. The term "mire complex" (macrotope) is used in the same sense by Moen (Moen & Singsaas 1994). The best English equivalent is probably "the system of mire complex types", but in the following I shall use the term "mire system", for the sake of brevity.

A **mire system** is a mire complex formed from the coalescence of several simple massifs in the process of their development. A mire system is not simply the sum of several massifs. Parts of the system interact closely with each other, due to water movement. Characteristic structural elements are formed which have a corresponding vegetation, and these are peculiar to specific mire systems and are absent from simple mire massifs.

The term "mire system" was introduced by Gerasimov (1921) in his description of the Shatura mire system. A fresh impulse to their investigation has been given by subsequent work on deciphering aerial photographs.

The need for a typification of mire systems has arisen from the requirements of small-scale maps (from 1:1 000 000 and less), on which only mire systems may be shown in general.

To learn about the variety of mire systems, many sources of information have been analysed, including aerial and satellite photographs. The various approaches to the classification of mire systems, as well as published maps and numerous descriptions, have been taken into account.

I propose to distinguish three groups of mire systems:

1. Mire systems formed by mire massifs of one and the same type. The differences between massifs which comprise the systems of this group lie within the limits of variation of a given type of mire massif, being largely a response to the extent of the watershed. The massifs develop in similar ways and their plant communities have the same spectrum of characteristic, dominant and highly constant species.
2. Mire systems formed by mire massifs of different types whose differences are related to their different ages, but which form a unified dynamic sequence. Their communities have a similar spectrum of essential species.
3. Mire systems formed by massifs of different types that belong to different classes. They have a specific course of development and their plant community composition differs greatly one from another.

3 MIRE SYSTEMS

3.1 ONE TYPE OF MIRE MASSIFS

This group of mire systems varies and can be formed by mire massifs of any one type. The separate massifs may coalesce simultaneously, or at different times, but generally have the same, or almost the same, age. Let us consider two systems of this group distributed in the European part of Russia. The mire system "Shirinskaya Mkhi" (Solonevich 1960, Yurkovskaja 1980) is situated in the southern taiga subzone and is typical of the northwestern mire region (Tyuremnov 1976). The main part of the system consists of mire massifs of the western Russian type, located in the south and centre of the system, with some smaller-scale massifs in the northern part. Numerous domes are characteristic of mire systems formed by the coalescence of raised bog massifs (Bogdanovskaja-Guiheneuf 1969), and "Shirinskaya Mkhi" has many such domes. On the whole, the structure of the vegetation cover and the predominant communities are the same in systems of this type as in the simple mire massifs. They have the following dominant species in common: *Sphagnum fuscum, S. magellanicum, S. balticum, S. cuspidatum, S. majus,* and also the co-dominants: *Calluna vulgaris, Chamaedaphne calyculata, Vaccinium uliginosum, Ledum palustre, Eriophorum vaginatum, Rubus chamaemorus, Scheuchzeria palustris, Carex limosa, Rhynchospora alba.*

The second example of a system belonging to the first group is one situated in northern Karelia. This was formed by the coalescence of 6 mire massifs of the Karelian aapa (string fen) type. It has no domes, since mires of this type are concave. A peculiarity of the system is the discontinuity of the string-pool-flark sites, whereas in simple mire massifs they occupy the entire central part (Fig. 1). In addition, plant communities that are characteristic for the marginal parts of the mire massifs occupy the central parts of the system, as in the previous example. Mesotrophic and meso-oligotrophic herb-*Sphagnum* mats (*Eriophorum-Sphagnum, Carex-Sphagnum, Trichophorum-Sphagnum*), as well as oligotrophic and meso-oligotrophic *Carex*-dwarf shrub-*Sphagnum* communities are present.

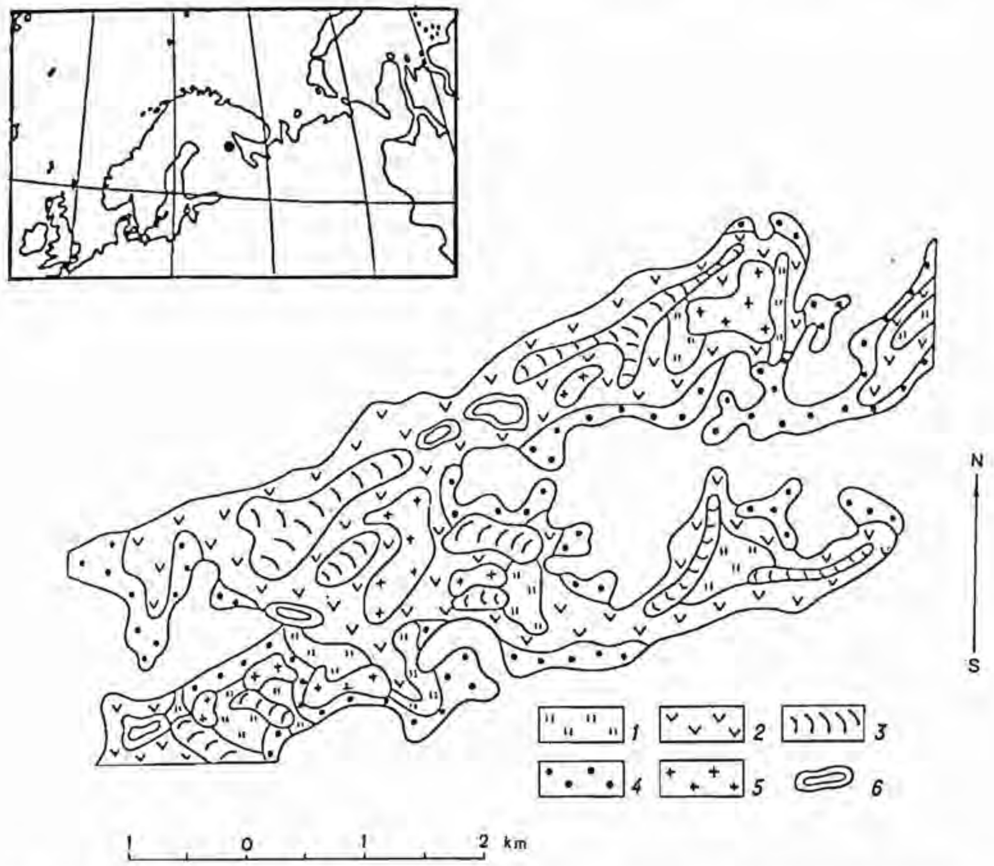

Fig. 1. The mire system at the railway station Polyarny Krug. 1 - eutrophic herb-*Hypnum* communities; 2 - mesotrophic and meso-oligotrophic herb-*Sphagnum* communities; 3 - eutrophic-mesotrophic string-flark-pool communities; 4 - oligotrophic and meso-oligotrophic pine-dwarf shrub-*Sphagnum* communities; 5 - islands of mineral soil; 6 - lakes.

3.2 MIRE MASSIFS OF DIFFERENT AGES

This group combines the systems formed by massifs of different types and different ages, but which are closely related dynamically, representing the individual parts of a single ecological-dynamic sequence. The vegetation cover of these mire massifs must have a single type of potential vegetation *sensu* Tüxen (1956), although they now have different structures, a different set of communities and some dominant species. A system of this kind, formed by mire massifs of the southern White Sea and maritime types (Fig. 2), was described by Yelina & Yurkovskaja (1965) and Yelina (1971).

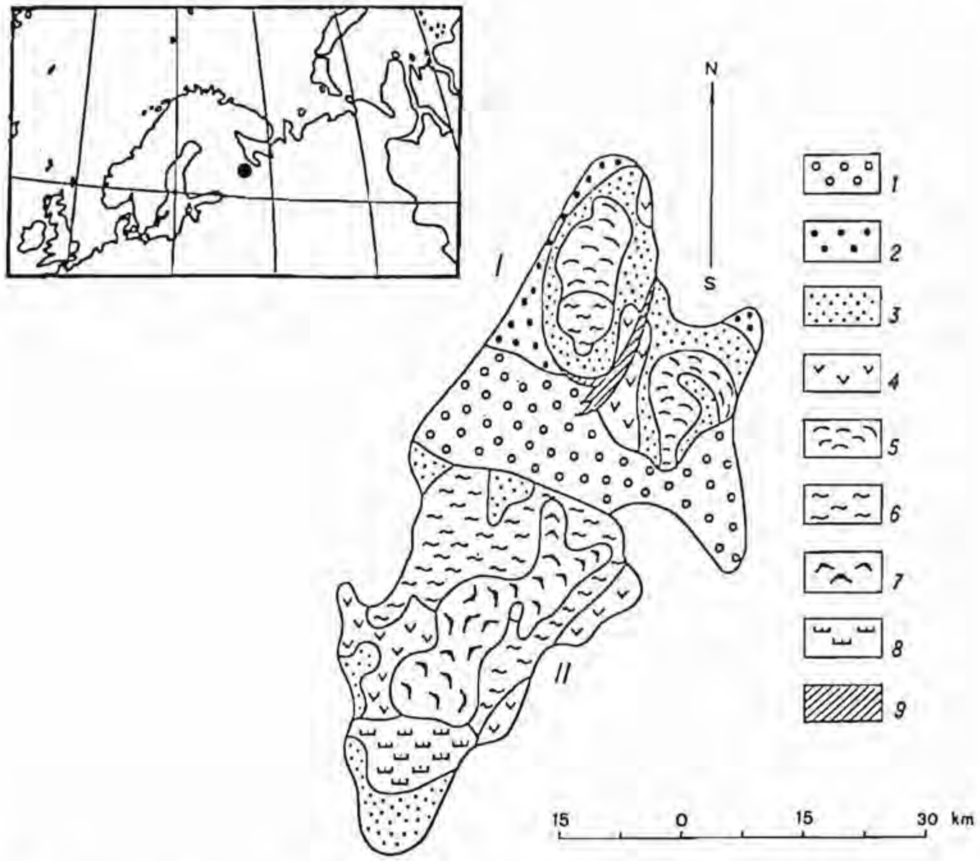

Fig. 2. Vegetation cover of a mire system on the White Sea lowlands. I - mire massifs of maritime type; II - mire massif of southern White Sea type. Mesotrophic: 1 - pine-*Sphagnum* communities; Oligotrophic: 2 - pine communities; 3 - pine-*Sphagnum fuscum* communities; 4 - dwarf shrub-*Sphagnum fuscum* communities, ridge-flark complexes; 5 - *Sphagneta fusci + S. baltici* and *S. fusci + S. lindbergii*, 6 - *Cladineto fusci Sphagneta + S. baltici (S. lindbergii)*, ridge-pool complexes; 7 - *Cladineta* + pools, 8 - lichen communities; 9 - transitional fens with eutrophic and mesotrophic herb communities.

The *Sphagnum* raised bogs, with ridges and hollows of maritime type, are located on the second terrace of the White Sea lowlands, at similar altitudes. The mixture of essential species of these mires is similar to that of mires of the southern White Sea type. However, the maritime mires were formed at the end of the Subboreal and the beginning of the Subatlantic period (Yelina 1971), whereas the mire massifs of the southern White Sea type arose in the Boreal period. Because the maritime-type mires differ strongly from the southern White Sea mires with regard to their community structure and surface morphology, phytocoenoses with a prevalence of liverworts, lichens and *Trichophorum cespitosum* are either absent or extremely rare in the maritime type, whereas they predominate in the southern White Sea type. Secondary lakes (pools) are highly characteristic for the southern White Sea type. The vegetation cover of the maritime type changes from the seashore to the margin of the third terrace. The composition and structure of the vegetation approximates to those of the mire massifs of the southern White Sea type. The vegetation of the terminal stage of development of the maritime mires will be the same as that of the southern White Sea ones (Fig. 2).

On the small-scale maps, we propose to show the mire systems of the first and second groups as simple mire massifs. Mire systems of the second group are designated according to the most advanced (in the course of development) type. In the above-mentioned example, the system has been mapped as southern White Sea type, irrespective of whether it is comprised of a single type or a mixture of the two types. For some types, for example the aapa type (string fen type), the systems can be shown only by using distinctive outlines on the small-scale maps, since individual mire massifs of this type are very small.

3.3 MIRE MASSIFS OF DIFFERENT TYPES

Mire systems of this group require another approach when they are being mapped. The massifs forming these systems differ so greatly in vegetation cover, structure, hydrology, peat stratigraphy, etc. that they cannot be conjoined into a single type. The complexity of such systems can be demonstrated by citing a group of mire systems distributed in northern Karelia and formed from raised bog massifs of the northern Karelian type and aapa mire (string fen) massifs of the Karelian type.

The mire system near Lake Ashtakhma, for example, consists of 5 raised bog and 7 string fen (aapa mire) massifs, the latter being dominant in terms of areal extent. Oligotrophic communities, dominated by *Chamaedaphne calyculata*, *Sphagnum fuscum* on ridges, and *Eriophorum vaginatum - Sphagnum balticum* and *Scheuchzeria palustris - Sphagnum majus* in hollows, prevail on the raised bogs, whereas eutrophic and mesotrophic communities predominate on the aapa mires: *Carex lasiocarpa*, *Molinia caerulea*, *Sphagnum papillosum* on strings and *Carex limosa*, *Carex livida*, *Menyanthes trifoliata*, *Equisetum fluviatile* and *Scorpidium scorpioides* in flarks.

I have made a detailed study of a complicated system belonging to this group (Sebboloto) in the Archangel district (Fig. 3). This huge system occupies part of the watershed and slopes on the right bank of the River Pinega (a tributary of the Northern Dvina River).

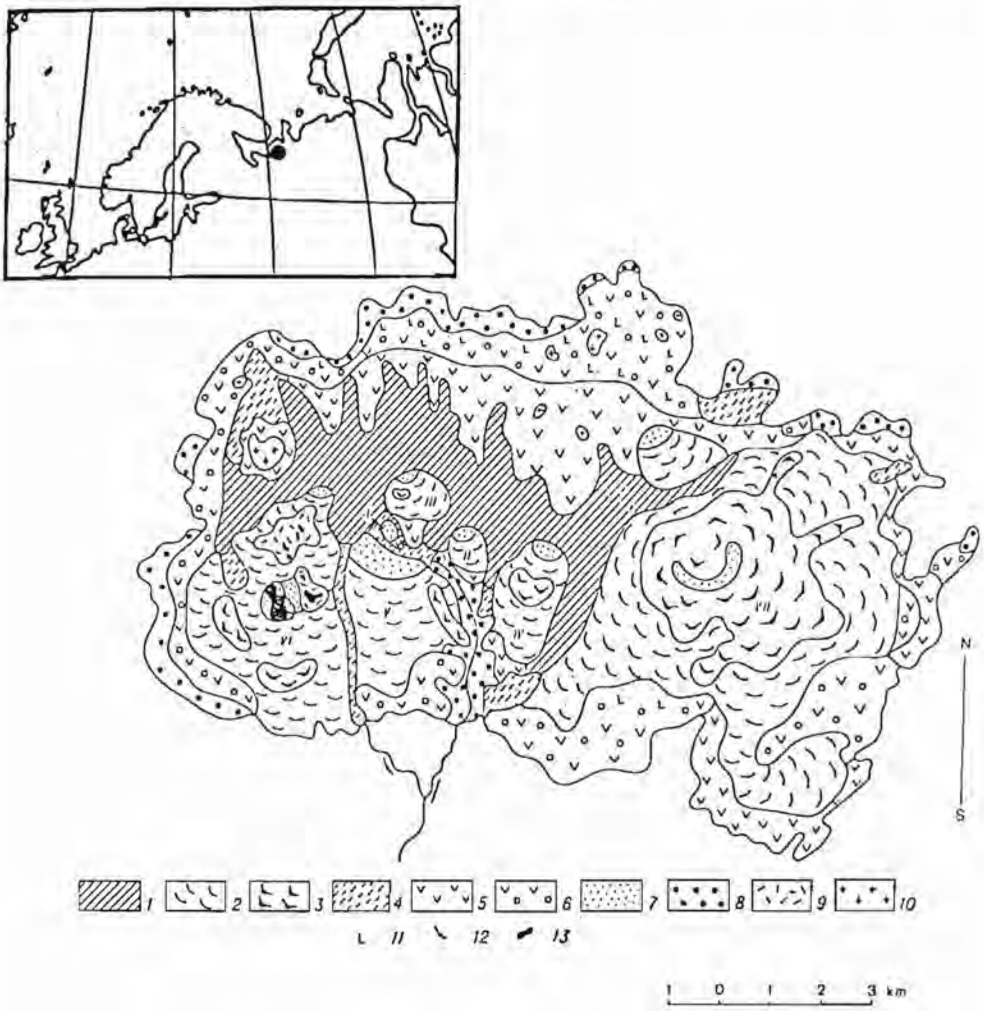

Fig. 3. Schematic map of the central and southeastern parts of the Sebboloto mire system (Archangel district). 1 - heterotrophic string-flark-pool aapa complexes; 2 - ridge-hollow *Sphagnum* oligotrophic complexes; 3 - regressive dystrophic complexes; 4 - herb and herb-*Hypnum* fens; 5 herb-*Sphagnum* mesotrophic communities; 6 - pine-herb-*Sphagnum* and pine-dwarf shrub-herb-*Sphagnum* mesotrophic and meso-oligotrophic communities; 7 - shallow hollow, oligotrophic complexes with a dwarf pine cover; 8 - pine and spruce-pine bog forest, 9 - herb-*Sphagnum* poor fens near the lakes; 10 - islands of mineral soil; 11 - dead wood; 12 - direction of stream flow; 13 - lakes.

The main part of the system is formed by aapa massifs which occupy the northern and western portions and penetrate to the south between separate raised bog massifs. In the central and southeastern parts, raised bogs of Pechora-Onegian type are found, which are at different stages of development. The raised bog massifs forming the system are highly distinctive in the structure of their vegetation and in their set of communities. The smallest raised bog massif (5.4 ha) is covered by a homogeneous pine-dwarf shrub-*Sphagnum* community *(Pinus sylvestris f. litwinowii, Chamaedaphne calyculata, Ledum palustre, Sphagnum fuscum).* The second raised bog massif (24 ha) is also heavily wooded, but its centre is occupied by a ridge-hollow complex, with *Pinus sylvestris f. litwinowii, Chamaedaphne calyculata, Rubus chamaemorus, Sphagnum fuscum* on ridges, and *Scheuchzeria palustris* and *Sphagnum balticum* in hollows. The third massif (32.5 ha) is at a much more advanced stage of development. Almost the entire area is occupied by a ridge-hollow complex. *Eriophorum vaginatum* alternates with *Scheuchzeria palustris* in the plant cover of the hollows, and in the moss cover *Sphagnum majus* alternates with *S. balticum* and *S. lindbergii*. The first signs of degradation and denudation of the *Sphagnum* cover can be seen in some hollows.

The fourth massif (88 ha) is regressive with denudated hollows stretching for 300 m along the profile. On central parts of ridges, *Sphagnum fuscum* is replaced by lichens. *Trichophorum cespitosus* appears on the ridges and in the hollows.

The fifth massif (140 ha) is larger than the others, is more strongly drained by streams flowing along the margins and is heavily forested. The regressive site is located in a small area where the peat is eroded and *Eriophorum russeolum* is abundant.

West of the central part of the system, there is a very peculiar plano-concave sixth mire massif (340 ha) with pools. Regressive sites are limited to areas in the lower part of the mire flanks.

The seventh massif (638 ha) occupies the entire southeastern part of the system, where regressive sites dominate. Communities with *Pinus sylvestris, Empetrum nigrum, Rubus chamaemorus, Cladina* spp. and *Sphagnum fuscum* are spread throughout the ridges, whereas *Eriophorum vaginatum, Scheuchzeria palustris* and *Trichophorum cespitosus* occur in the hollows, with bare peat. In the aapa massifs, string-fens predominate with a dominance of *Sphagnum papillosum, S. magellanicum, Carex lasiocarpa, Trichophorum cespitosus* and *Betula nana* on the strings; the flarks being covered by herb and herb-*Sphagnum* communities *(Sphagnum jensenii, Scheuchzeria palustris, Eriophorum russeolum).*

4 CONCLUSIONS

The principles of vegetation mapping of mire systems are determined by the degree of heterogeneity in the vegetation in the mire massifs which constitute any particular system. The vegetation of mire systems of the first and second groups should be mapped as vegetation of individual, simple, mire massifs. When mire systems of the third group are being mapped, the degree of heterogeneity in the vegetation should be indicated, even on small-scale maps. Various methods may be used to depict such heterogeneity. If the scale permits, the types of mire massifs forming each heterogeneous system should be distinctively outlined. For example, on the Mestchera lowlands, where enormous mire systems are formed by raised bog massifs with *Sphagnum magellanicum*, herb-sedge or birch-wooded meso-eutrophic and herb-*Sphagnum* mesotrophic massifs, each of these types has been shown with a separate distinctive outline on the maps. The most common way of depicting the mire systems of the third group, however, is to use a distinctive outline for the dominant types of massifs and symbols for smaller ones.

These principles and methods of representing the vegetation of mire systems have been tested on small-scale geobotanical maps that have been compiled for the past 15 years at the Department of Geography and Cartography of Vegetation in the Komarov Botanical Institute.

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Applying groundwater mound theory to bog management on Puergschachenmoos in Austria

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ABSTRACT

Bragg, O. & Steiner G.M. 1995. Applying groundwater mound theory to bog management on Puergschachenmoos in Austria. *Gunneria 70*: 83-96.

Puergschachenmoos is the largest remaining valley bog in the Alps. Because of its outstanding value, it was declared a Ramsar site in 1992. The central part of the mire is rented by the WWF to prevent peat extraction. Drainage and afforestation continue in the marginal parts, especially the lagg zone.

Comparison of the results of a preliminary vegetation survey with historical data indicated two significant changes between 1947 and 1992. First, hollows at the centre of the site were significantly reduced; and second, mountain pines at the mire margin had become taller and denser. These changes are consistent with lowering of the water table throughout the mire dome. Groundwater mound modelling indicates that this lowering is the result of reclamation and drainage of land at the edges of the system. Thus, to stabilise the current situation, management of the artificial drainage network is required. Amelioration of the hydrology of the site might be achieved by additional management of the surrounding peaty pastureland.

Theoretical models for both options have been constructed as a preliminary basis for costing, but their calibration requires longer-term monitoring of the water table and on-site measurement of hydraulic conductivity. A further project to obtain these data is now being planned.

1 INTRODUCTION

Puergschachenmoos is the largest valley bog in the Austrian Alps. It occupies the site of a late-glacial lake in the valley of the River Enns south of the village of Puergschachen, Styria. It is underlain by late-glacial deposits which include layers of clay. This is the last remnant of a series of 15 bogs which once virtually covered a 50 km stretch of the valley floor. Most disappeared at the time of land reclamation projects during the 19th century so that the site is now surrounded by farmland, used mostly for hay production and grazing. The centre of the site is owned by the Admont Monastery, whilst its margin is divided into a number of parcels which are owned or rented by different farmers.

The bog was declared a Ramsar site in 1992, and is rented by the WWF to prevent peat cutting in the central area. This paper reports some results of an investigation (Bragg et al. 1993) commissioned by the WWF and refunded by the Styrian government and the Ministry for Environment, Youth and Family Affairs. The work was carried out by a group comprising a vegetation ecologist, a hydrologist, a GIS specialist and experts on agriculture and tourism. The remit was to define a practical/financial basis for negotiations with landowners with the intention of securing control of an area capable of containing a sustainable ecological unit, and to suggest management options for the future.

2 METHODS

The initial site survey was based on air photographs (ortho-photo 1:10 000) and maps (1:25 000). Vegetation types, land uses and other features visible on the photographs were verified during a site visit in December 1992. The vegetation of the mire expanse was sampled in 1 m^2 relevés.

Information on the previous vegetation of the site was obtained from a vegetation map of the general area drawn in 1947 by Wagner & Lauber.

Soil sampling was carried out in February 1993, using augers, and a map showing soil types within the Ramsar boundary and in surrounding fields was compiled.

In February 1993, two transects crossing the site in approximately north-south and east-west directions were surveyed. Survey points were spaced at intervals of 50 m along each transect. At each survey point, peat depth was measured using a Russian peat borer. From these data, profiles of the surface of the mire and of the mineral substratum were constructed.

3 RESULTS

3.1 GENERAL FEATURES

The area investigated is shown in Figure 1b. It is bounded to the south by the River Enns, to the west and east by two tributaries of the river, and to the north by a road. The present Ramsar site is surrounded by drains which discharge into the river. Some of the marginal plots have been used for peat extraction in the past, and all are now afforested or covered by self-sown birch. At the southeastern side, one section of the natural marginal forest survives (Fig. 1c).

The soil map (Fig. 1a) shows that peat extends well beyond the Ramsar boundary. The summit of the bog lies approximately 4 m above the floors of boundary ditches, and the depth of peat beneath ditches is 7-8 m. The fields surrounding the bog are crossed by numerous open drains, 2-3 m deep, which in some places penetrate the underlying clay, and there is evidence of additional buried field drains.

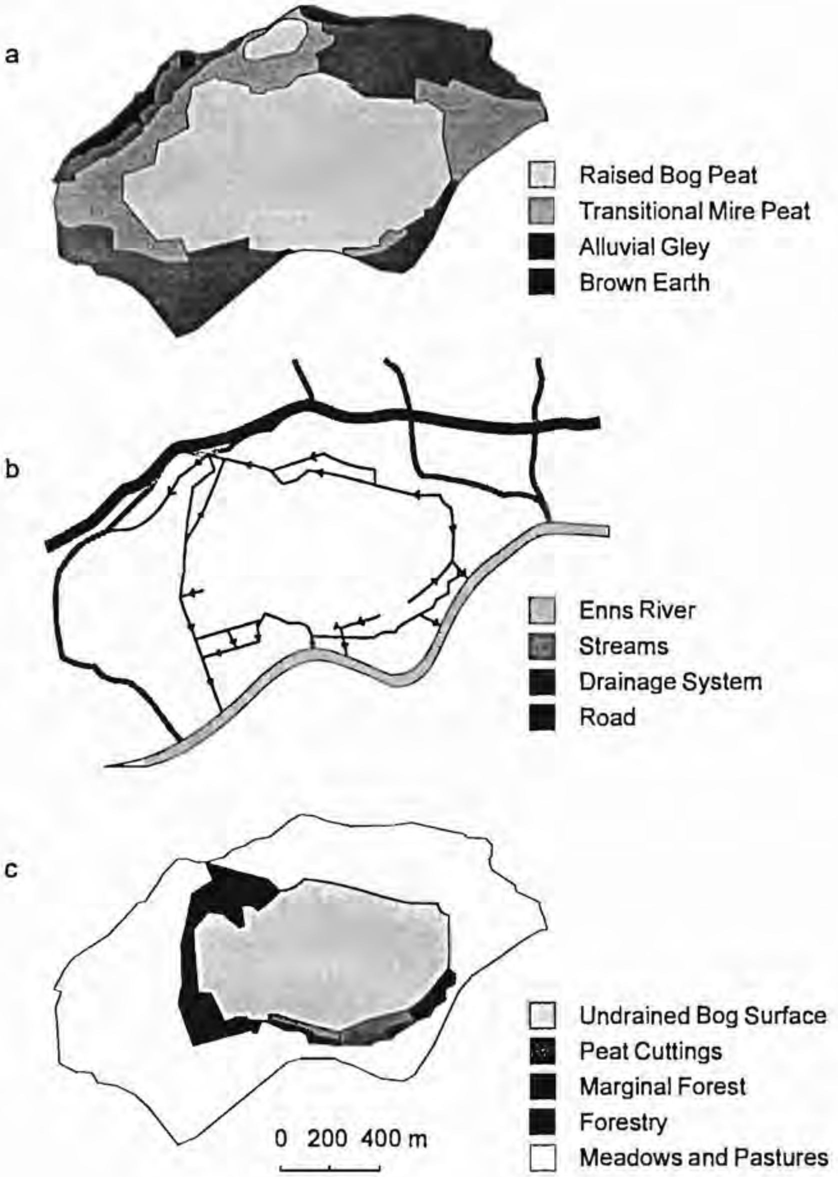


Fig. 1. Puergschachenmoos; a: soil map; b: drainage and stream system; c: present situation.

3.2 VEGETATION CHANGES

The vegetation communities identified in 1992 are shown in Table 1. A simplified version of the 1993 vegetation map appears in Figure 2a. In 1992, most of the mire expanse was covered by *Pino mugo - Sphagnetum*, which included an area with dense *Calluna vulgaris*. *Pinus mugo* formed marginal thickets adjacent to the drains to the north and west, and isolated birch (*Betula pubescens*) trees occurred up to 100 m from the inner edge of the marginal woodland. Two small areas of the mire expanse lacked *Pinus mugo* (*Sphagnetum magellanici*), and a third had hollow communities with *Sphagnum cuspidatum*, *Scheuchzeria palustris* and *Carex limosa* (*Caricetum limosae*).

The distribution of equivalent communities mapped by Wagner & Lauber is shown in Figure 2b.

Comparison of Figures 2a and 2b indicates that there were significant changes in the vegetation of the mire expanse during the 46 years between the two surveys. The area of hollows declined dramatically and *Pinus mugo* invaded most of the area within this time interval. Dense *Calluna vulgaris*, not recorded in 1947, dominated a substantial part of the site by 1993, and birch invasion also occurred within this period.

Thus, the vegetation shows trends towards communities which are atypical of raised mires, indicating a requirement for some form of management to retain the present interest of the site. However, since there has been no direct disturbance to the central area, it is not obvious how ameliorative procedures such as drain blocking might be applied here. Therefore, a study of the hydrophysics of the whole system was undertaken in search of both an explanation for the changes and an indication of how they might be reversed.

4 GROUNDWATER MOUND MODELLING

Groundwater mound theory offers a conceptual basis for understanding the ecology of raised mire systems which can also be interpreted in quantitative terms. The groundwater mound is maintained by a dynamic equilibrium between the maximum steady water supply sustainable by climate and lateral seepage through the sparingly permeable subsurface peat. A hydrological limit to the shape of the system is set by the requirement that peat can accumulate only if it is perennially waterlogged. Thus, an undisturbed mire may continue to grow until its surface lies no more than a few decimetres above the groundwater mound which it contains (Ingram 1982).

Table 1. The plant communities of Puergschachenmoos.

assoziations		A	B							C				
geographical races			I				II							
subassoziations			a	b		c	a	b	c	a		b	c	d
facies and variants				1	2					1	2			
		111	1	0001	00121	1	100010	11100	1	1	100	0101	0121	10
sample codes		000	0	2796	78700	0	876305	23041	1	6	776	7190	8019	79
		079	8	0411	52105	1	031030	00400	2	2	212	2126	1200	33
Char. spec. of ass. 1														
Scheuchzeria palustris	4	131	+	....	.....	.	......	.....	.	.	...	....	....	..
Diff. spec. of ass. 2+3														
Sphagnum magellanicum	25	.13	5	1553	25425	.	53.1..	.1.+.	.	5	...	.154	3.23	.1
Sphagnum capillifolium	29	.11	2	..12	4134.	5	2342..	112..	5	.	.13	.322	4524	13
Sphagnum angustifolium	19	...	1	41.3	3....	.	133..5	2....	1	.	544	3422	....	.3
Diff. spec. of ass. 3														
Pinus mugo TURRA s.str.	18	...	.	...+	...11	.	1	.....	.	3	455	4534	4555	35
Diff. spec. of geogr. races in ass. 2														
Vaccinium uliginosum	13	...	.	....	.....	.	3..4..	32.3.	1	.	.1.	31.1	..4.	42
Vaccinium vitis-idaea	16	...	.	....	.....	.	.12.43	2223.	1	.	233	22..	..3.	2.
Vaccinium myrtillus	8	...	.	....	.....	.	....3.	.4423	.	.	...	...+	...4	.4
Diff. spec. of the subass.														
Sphagnum cuspidatum	8	553	1	4112	.....	.	......	.....	.	.	...	....	....	..
Rhynchospora alba	4	23+	1	....	.....	.	......	.....	.	.	...	....	....	..
Sphagnum fuscum	5	...	.	....	.....	.	......	.....	.	.	...	1212	...1	..
Pleurozium schreberi	13	...	.	....	.....	1	......	431+3	1	.	...	....	1122	33
Cladonia	4	...	.	....	.....	.	......	.....	3	.	...	....	.333	..
Cladonia rangiferina	1	...	.	....	.....	.	......	.....	.	.	...	....	3...	..
Sphagnetalia magellanici species														
Vaccinium oxycoccos	26	.2+	1	.2..	33233	1	1221..	.....	3	1	331	2223	33.1	..
Andromeda polifolia	19	.2+	2	.322	213.3	.	222..+	.....	2	2	...	.13.	1...	..
Eriophorum vaginatum	28	221	3	3333	33445	.	543..2	.....	4	1	..1	.143	2111	.1
Polytrichum strictum	5	...	.	....	.....	3	......	.....	.	4	2..	....	11..	..
Dicranum undulatum	5	...	.	....	.....	.	......	.....	.	.	..+	.2..	1..2	.1
Aulacomium palustre	5	...	.	....	.....	.	......	...1.	1	.	..2	3...	..3.	..
Sphagnum tenellum	1	...	.	....	...2.	.	......	.....	.	.	...	....	....	..
Sphagnum papillosum	1	...	.	...2	.....	.	......	.....	.	.	...	....	....	..
Scheuzerietalia species														
Drosera anglica	4	+1+	1	....	.....	.	......	.....	.	.	...	....	....	..
Carex limosa	2	3.2	.	....	.....	.	......	.....	.	.	...	....	....	..
Vaccinio-Piceetea species														
Pinus sylvestris	6	...	.	....	.....	.	...1.3	..132	.	.	..+	....	....	..
Betula pubescens	9	...	.	....	.....	.	....-+	13.33	.	.	..1	.+..	....	3.
Picea abies	3	...	.	....	.....	.	......	++1..	.	.	...	....	....	..
Dicranum scoparium	5	...	.	....	.....	.	......	32.+3	.	.	...	....	....	3.
Hylocomium splendens	2	...	.	....	.....	.	......	11...	.	.	...	....	....	..
Companions														
Calluna vulgaris	29	...	.	3221	23231	3	2342.3	4..3.	3	3	3.3	2223	23..	22
Molinia caerulea	15	...	.	1...	.....	.	..1313	14413	.	.	+++	+...	....	+.
Cladonia sp.	2	...	.	....	.....	.	......	.....	1	.	...	....	...+	..
Sphagnum palustre L.	1	...	.	....	.....	.	......	2	.	.	...	....	....	..
Polytrichum juniperinum	1	...	.	....	.....	.	......	...+.	.	.	...	....	....	..
number of species per sample		001	1	0000	00000	0	000000	11010	1	0	001	0101	1001	01
		690	0	6769	76676	5	888749	11727	2	7	772	9390	1891	90

Legend

A: Caricetum limosae
- a: Sphagnetosum cuspidati

B: Sphagnetum magellanici
- I: oceanic race (without dwarfshrubs)
  - a: Rhynchosporetosum albae
  - b: typicum
    - 1: wet facies with Sphagnum cuspidatum
    - 2: typical facies
  - c: Pleurozietosum schreberi
- II: continental race (with dwarfshrubs)
  - a: typium
  - b: Pleurozietosum schreberi
  - c: Cladonietosum arbusculae

C: Pino mugo-Sphagnetum magellanici
- a: typicm
  - 1: oligotrophic variant
  - 2: minerotrophic variant
- b: Sphagnetosum fusci
- c: Cladonietosum arbusculae
- d: Pleurozietosum schreberi

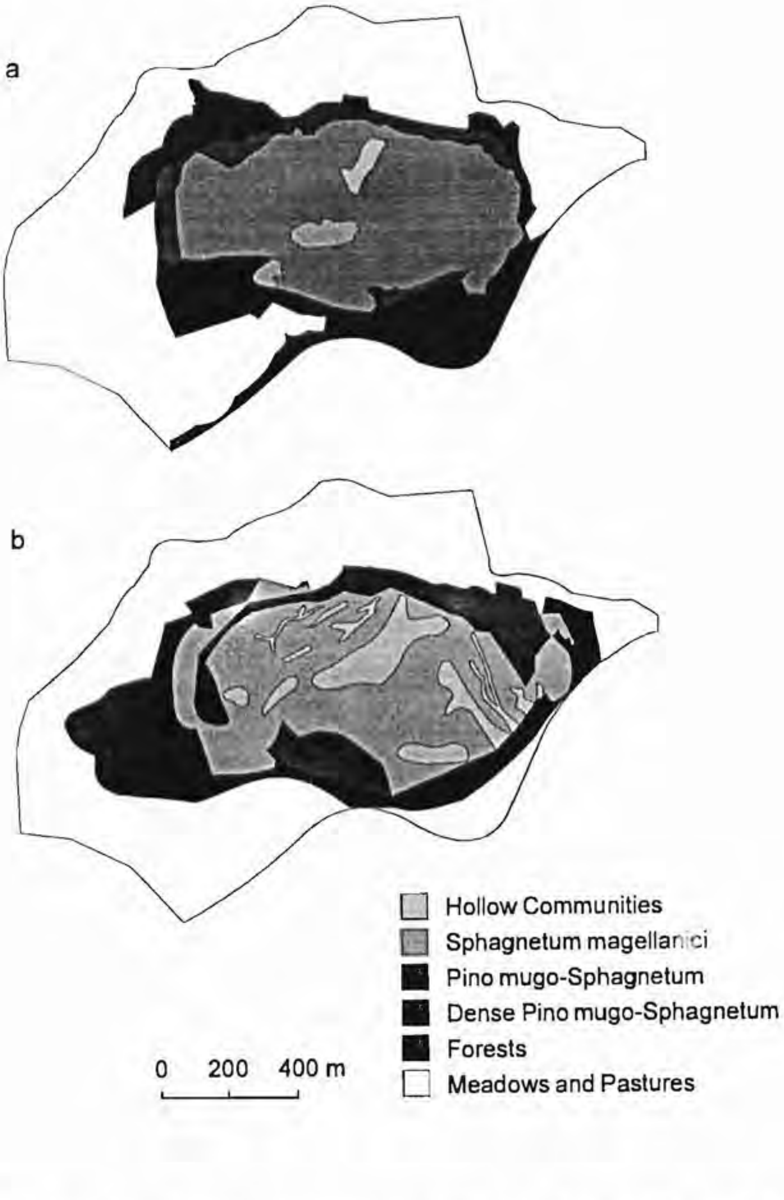


Fig. 2. Vegetation of Puergschachenmoos. a: 1993, b: 1947 (after Wagner & Lauber).

In essence, the theory indicates that the height of the water table at any point within the mire is a function of:

1. climatic water supply
2. peat permeability
3. plan shape and dimensions of the mire dome
4. level of the (regional) water table at the edges of the dome.

If any of these four factors should change, the shape of the groundwater mound will be altered, disrupting the close relationship between water table and surface upon which the character of the vegetation depends.

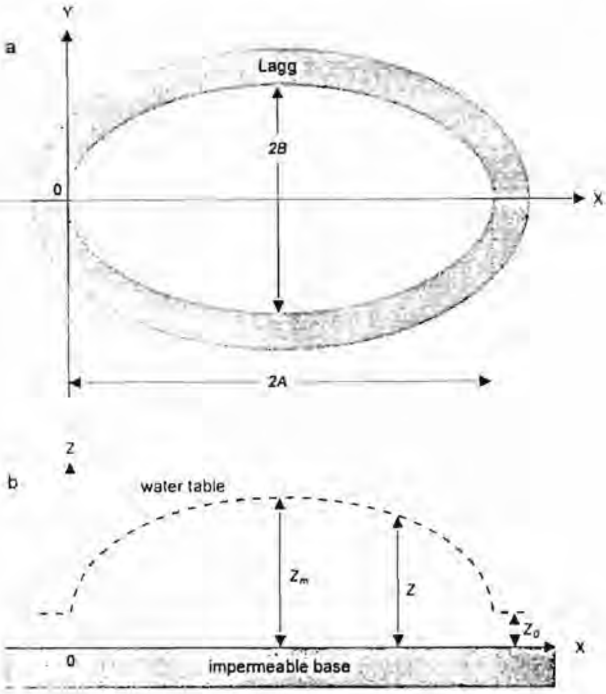
The evidence collected at Puergschachenmoos indicates that the bog once occupied a larger area than that defined by the present boundary drains. Thus, we may anticipate that drainage at the edges of the mire dome has disturbed the equilibrium of the groundwater mound by altering its hydrological boundaries (factors 3 and 4 above).

Groundwater mound modelling was employed to investigate implications of these changes for the future conservation value of the site, and to indicate options for ameliorative management. The approach adopted was to construct models to represent the equilibrium of the groundwater mound under existing and hypothetical boundary regimes.

4.1 A GROUNDWATER MOUND MODEL FOR PUERGSCHACHENMOOS

A solution to the general groundwater mound expression (Childs 1969, Bragg et al. 1991) for a raised mire developed on an elliptic base is shown in Figure 3. The following notation is used:

- Z : the height of the water table above the (horizontal, impermeable) mineral base
- Z_m : the height of the (central) summit of the groundwater mound relative to the base
- Z_0 : the height of the regional water table at the edges of the mire dome
- A, B: the respective lengths of major and minor axes of the elliptic base
- γ : a constant whose value depends upon the hydrodynamics of the system.



$$Z^2 - Z_0^2 = \gamma^2 \frac{A^2B^2}{A^2+B^2}\left[\frac{2X}{A} - \frac{X^2}{A^2} - \frac{Y^2}{B^2}\right]$$

$$Z_m^2 - Z_0^2 = \gamma^2 \frac{A^2B^2}{A^2+B^2}$$

Fig. 3. Dimensions of the groundwater mound model on an elliptic base; a: plan view, b: profile along major axis.

4.2 APPLICATION OF THE MODEL AT PUERGSCHACHENMOOS

4.2.1 Scenarios

The edge of the mire dome in 1992, defined by its junction with pastureland, approximates to an ellipse with A = 550 m and B = 300 m. The survey of surface altitudes and peat depths indicated that the current values of Z_m and Z_0 are approximately 11 m and 7 m respectively. If we assume that these measurements represent the current equilibrium of the groundwater mound, the equations which appear below Figure 3 can be used to derive a preliminary (morphometric) estimate for γ. Changes in summit height which might be achieved by changing the position of the boundary can then be predicted. Values of Z_m generated for the various scenarios envisaged are shown in Table 2.

Table 2. Dimensions of elliptic groundwater mound models employed to represent various management scenarios for Puergschachenmoos. See text for further details.

Case	A (m)	B (m)	Z_0 (m)	Z_m (m)	Lowering of water table summit (m)
current situation	550	300	7.0	11.0	0.7
original raised mire	850	400	0.0	11.7	0.0
unmanaged	525	290	0.0	8.2	3.5
Ramsar boundary	550	300	0.0	8.5	3.2
managed to raise edge water level by :					
0.5 m	550	300	7.5	11.3	0.4
1.0 m	550	300	8.0	11.7	0.0
1.5 m	550	300	8.5	12.0	-0.3
largest practical area	700	400	0.0	11.2	0.5

The hypothetical scenarios considered are as follows:

1. A raised mire occupying the area available between the Enns and its tributaries, which corresponds approximately to the area of peat shown in Figure 1a. This model represents the bog in its undisturbed state (Fig. 4a).

2. An "unmanaged" scenario in which forestry and tree growth continue at the site margins, but trees are allowed to encroach no further onto the mire expanse. Ultimately, we may expect that all peat peripheral to the present open centre will disappear by wastage so that the raised mire dome occupies only the area of the present open centre (Fig. 4a).

3. The area of the present mire dome is maintained. Trees are removed and forestry discontinued within this boundary, but the current drainage and use of surrounding pastureland continues, resulting in eventual wastage of all peat outside the present Ramsar boundary (Fig. 4b).

4. Boundaries and modification of land uses as in scenario 3, but the boundary drains are dammed and kept permanently full of water. Surveying indicated that Z_0 might thus be increased by up to 1.5 m; three 0.5 m increments of boundary water level are considered in Table 2.

5. A raised mire covering the largest area now, in practice, available for groundwater management, in view of the presence of a new road to the west of the site (Fig. 4c). It is assumed that drainage at the edges of this area would be at the level of the clay base ($Z_0 = 0$).

Profiles along the major axes of the various models are compared in Figure 5.

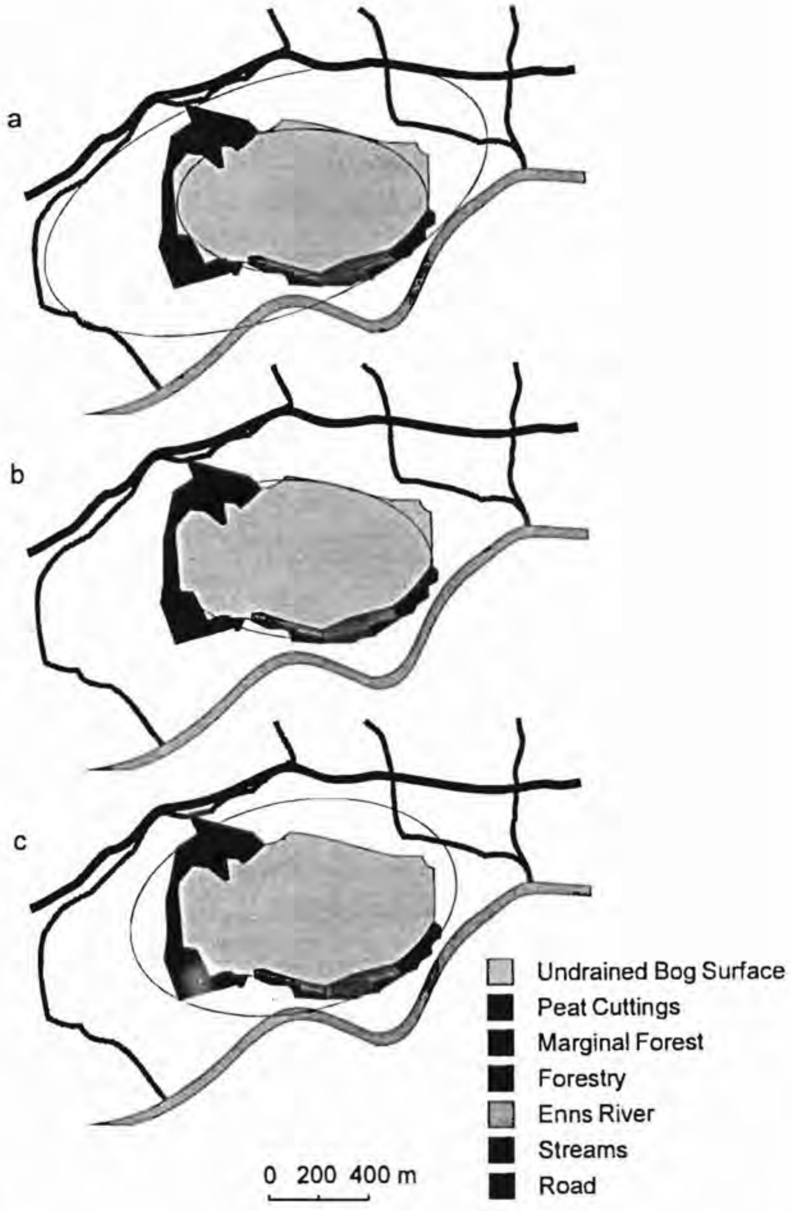


Fig. 4. Bases of groundwater mound models for a: original mire and unmanaged site, b: current boundary of site, c: largest practical area.

4.2.2 Indications of groundwater mound modelling

The model adopted for the original mire covers the greatest area available for peat formation (Fig. 4a). Particularly since the soil map (Fig. 1a) indicates that there was a smaller dome to the north of the main mire area, the size of the original site is likely to be over- rather than under-estimated.

Thus, the 0.7 m lowering of the summit of the groundwater mound attributed to imposition of the current boundaries is regarded as a maximum estimate. The model shows drawdown increasing towards the present boundary (Fig. 5a), where the predicted lowering is 1.9 m and the most marked changes in vegetation have occurred.

Without management, the prognosis (scenarios 2, 3) is that the groundwater mound will continue to decline as peat wastes from the surrounding pastureland, with eventual drawdown of around 3 m at the summit. Vegetation changes greater than those already evident at the margins are thus implied for the whole mire expanse.

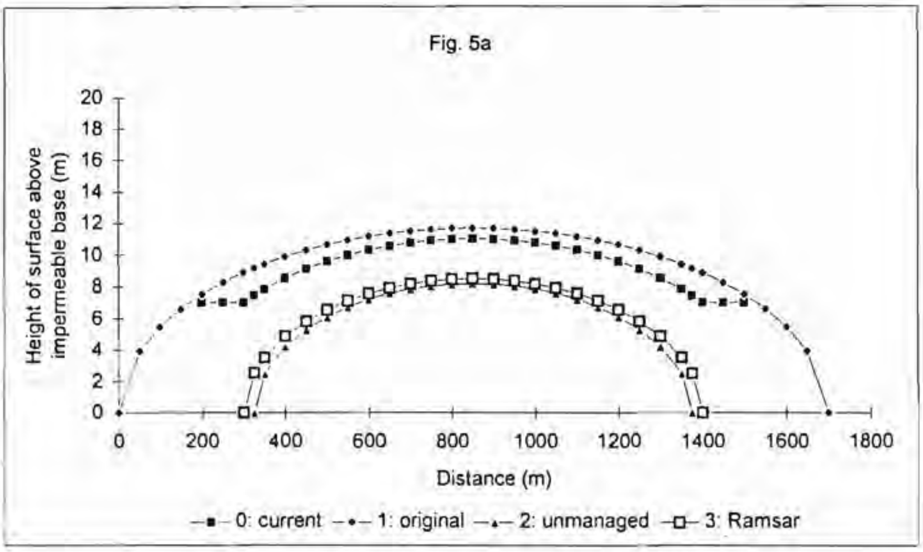
Figure 5b shows the profiles for the original mire, and for a groundwater mound covering the area now practically available for peat formation, lying within the envelope of profiles generated for scenarios in which the water level at the present boundary is stabilised and raised by up to 1.5 m. The implication is that the present degenerative trend might effectively be arrested by controlling the water level at the site margins.

Water level control will be most expediently achieved by management of the boundary drains. The highest water level which might be achieved here will depend upon the amount of peat remaining on the surrounding pastureland to form the outer walls of the drains. Thus, action to arrest wastage of peat from the fields is identified as a management requirement for conservation of the raised mire system. In practice, this would involve blocking agricultural drains, with associated implications for land use.

The indications for conservation management are, therefore, significant; in order to secure the future interest of the present Ramsar site, it will be necessary to control the hydrology of a peripheral zone at least 100-150 m wide.

5 DISCUSSION

For Puergschachenmoos, the predictions of groundwater mound modelling are consistent with observed degenerative trends which cannot be explained in terms of direct damage to its surface. Moreover, the quantitative potential of the method has been successfully exploited to arrive at practical management recommendations within a relatively short time scale.



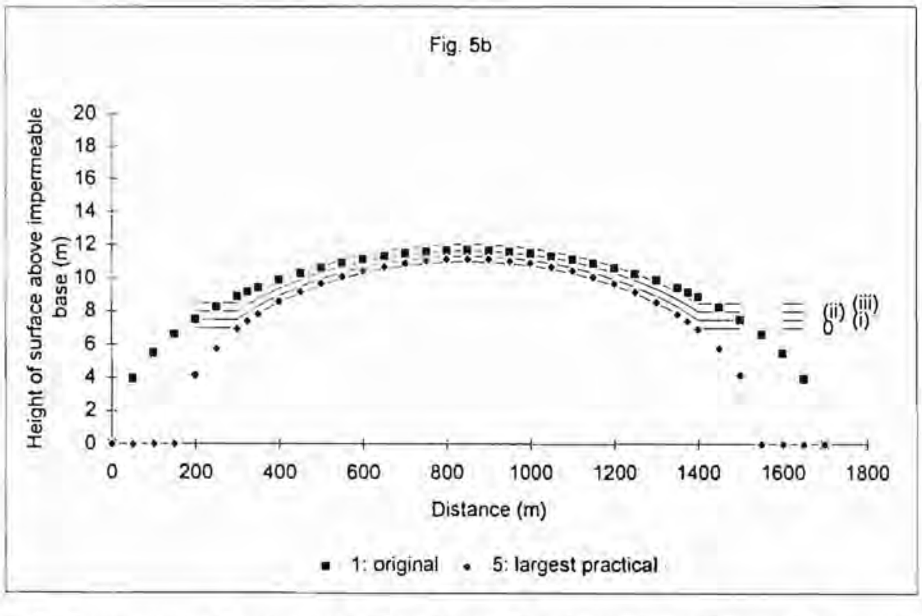


Fig. 5. Comparison of major-axis (Y = 0; see Fig. 3) profiles of groundwater mound models representing existing and hypothetical management scenarios for Puergschachenmoos. (a) supposed original mire, current situation and unmanaged scenarios 2 and 3. (b) points: supposed original mire and scenario 5; lines: current situation (0) and scenarios with management to raise marginal water levels by (i) 0.5 m, (ii) 1 m and (iii) 1.5 m. See text for further details of scenarios.

The predictions made here are helpful when used comparatively, but must be regarded as quantitatively approximate. This results not from limitations of the general groundwater mound model, but from practical difficulties in its solution. First, accurate calibration requires location of the water table (morphometric approach) or measurement of hydrological variables (hydrodynamic approach) during the driest conditions occurring over a series of years; thus, the time required to obtain these data directly is determined by weather. Second, the shape of the site deviates to some extent, in base topography and in plan shape, from that of the elliptic model employed to represent it. Whilst such analytical solutions of the groundwater mound problem are extremely useful for comparative work, and in the initial stages of the study of individual sites, it may be necessary to forego their mathematical tractability in favour of numerical techniques should very close correspondence between model and reality be required (Bragg et al. 1991, Bromley & Robinson 1993).

A practical solution to apparently conflicting requirements for expedient action for site conservation on the one hand and high-accuracy hydrological modelling on the other is, nevertheless, achievable. This approach involves construction of a preliminary analytical model to indicate requirements for both management and model calibration data, followed by data collection proceeding in tandem with progressive refinement of the model as different weather conditions arise. The hydrological data required for such an exercise are precisely those which should be collected to monitor the success of site management. For both purposes, the longest possible run of baseline data should be obtained before management commences.

At Puergschachenmoos, a follow-up hydrological study is now in progress. In addition to measurement of rainfall, evapotranspiration and peat permeability, a grid of dipwells has been established on the mire expanse and water levels are being measured regularly. Implementation of the management recommendations has yet to be approved.

ACKNOWLEDGEMENTS

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The influence of surface slope, acrotelm depth and drainage on groundwater level fluctuations at Raheenmore Bog, Ireland

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ABSTRACT

Van der Schaaf, S. 1995. The influence of surface slope, acrotelm depth and drainage on groundwater level fluctuations at Raheenmore Bog, Ireland. *Gunneria 70*: 97-116.

The fluctuation patterns of groundwater levels and their relationships with drainage, acrotelm depth and surface slope, based on field research on Raheenmore Bog, Co. Offaly, Ireland, over the period 1990-1992, are discussed. The mire area is 162 ha. It is typically dome shaped. The central part is in a good condition; other parts have been affected by drainage and some peat cutting. Both have led to subsidence, resulting in increased surface slopes in the vicinity. The groundwater regime has been influenced by the changed morphology of the mire surface. The temporal fluctuation of the groundwater levels was greater and the mean levels deeper in the affected than in the relatively unaffected parts. The fluctuation amplitudes in the former were generally less than 0.20 m, in the latter they could fluctuate by up to 0.50 m. Groundwater depth, fluctuation amplitude and surface slope were clearly correlated. The acrotelm depth was also surveyed. Where the slope was about 0.5-1%, or steeper, the top 5-10 cm of the peat could still have a degree of humification below 4, but often the value was 5-7, though in such cases it normally overlay a less decomposed layer. This sequence probably indicates a recent change in hydrological conditions, related to human activities.

1 INTRODUCTION

The temporal pattern of the fluctuation of groundwater levels is a dominating factor for growth conditions of mire vegetation which, in addition to climatic conditions, are influenced by the surface slope and the hydrophysical properties of the peat in the fluctuation zone. In contrast to mineral soils, changes in the hydrological regime can easily alter these properties, in part irreversibly.

Much literature is available on the effects of draining mires for agriculture or peat mining, and studies on hydrological effects of regeneration of mire relicts have recently appeared in literature on peatlands. Systematic studies on effects of human interference, such as peat cutting and shallow drainage, on the hydrology of partially intact mires are, however, very scarce. Such studies are relevant to the conservation of existing mires.

In raised mires, changes are usually brought about by turf cutting along the margins and drainage on the surface. The most important effects are

- increase of the surface slope towards the margin, which causes faster precipitation runoff and consequently a quicker and greater fall in the water table following precipitation than in a pristine mire
- reduction of the storage co-efficient and the thickness of the acrotelm.

Both lead to an increase of groundwater fluctuations with an inevitable impact on vegetation.

This paper deals with the temporal variability of groundwater levels along two transects across a small mire, Raheenmore Bog, in County Offaly, Ireland (Fig. 1), in relation to depth, surface slope, acrotelm conditions and drainage effects. The hydrology of this mire was surveyed as part of an Irish-Dutch research programme. It was chosen because it is a typical raised mire in the Irish Midlands, developed as a single dome in a single basin.

Fig. 1. Position of Raheenmore Bog (dot marked by 'R').

2 RAHEENMORE BOG

Raheenmore Bog has formed in a deep, glacial basin of Weichselian age. The mire was once connected to a larger mire complex in the northeast by a narrow valley. The former has been cut for peat and no longer exists. On Raheenmore Bog, peat cutting has been restricted to the margins. According to Cross (1989), its present size is 162 ha. It has a well-developed dome shape. In the centre, the peat is about 15 m deep. Figure 2 shows the surface contours and the groundwater monitoring network. The contours show that the mire is slightly eccentric.

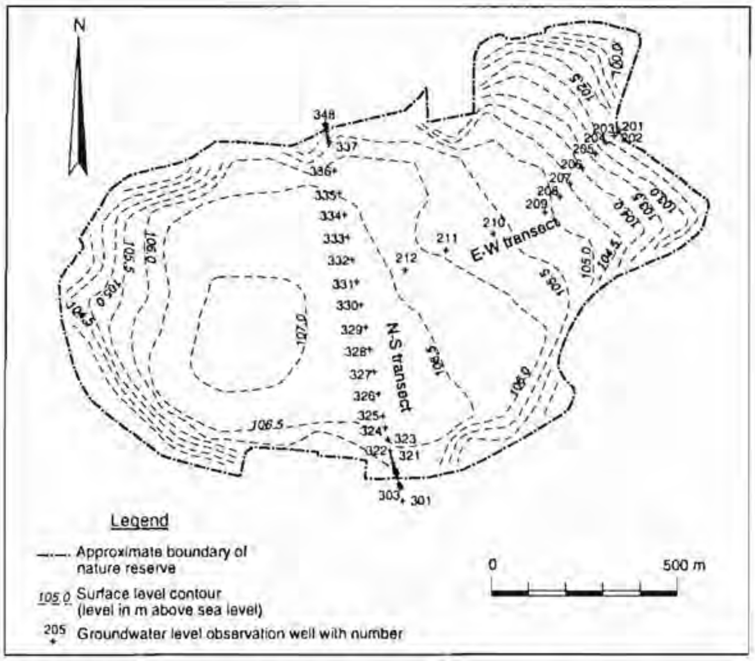

Fig. 2. Surface contours and transects on Raheenmore Bog.

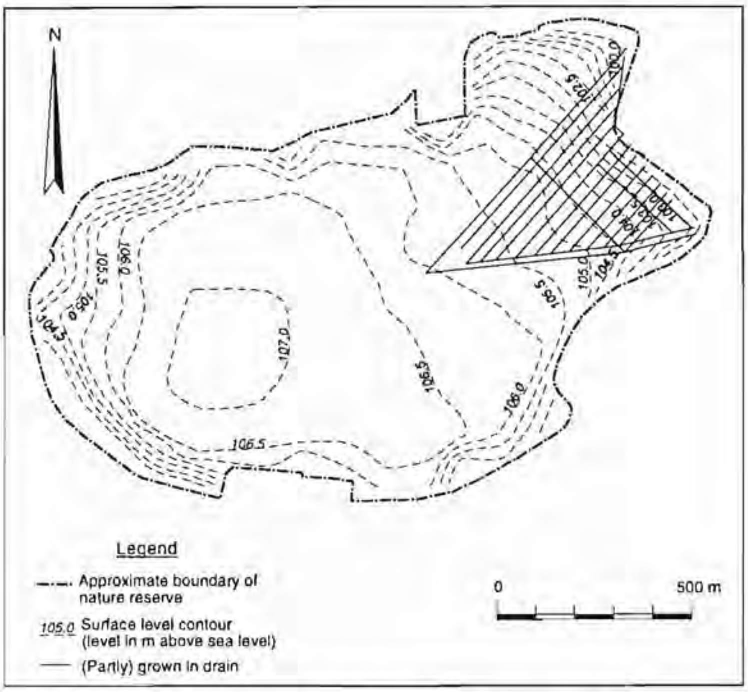

Fig. 3. Position of the system of old, ingrown drains on Raheenmore Bog.

A shallow system of drains occurs over about 13 ha in the east (Fig. 3). These drains are possibly some 100 years old and have now mostly become occluded. They have led to surface subsidence and the drained area now forms a shallow, sloping valley in the mire. Surface contour analysis (Lensen 1991) showed that this valley diverts the discharge of 30 ha of mire towards a small part of the eastern margin. This was confirmed by a water balance study made by Veldkamp & Westein (1993).

3 AVAILABLE DATA AND MEASURING METHODS

3.1 GROUNDWATER LEVELS

Groundwater levels were monitored at intervals of about two weeks from October/November 1989 until March 1992 along two transects across the mire, which, despite diverging somewhat from these directions, for convenience are denoted N-S and E-W, respectively (Fig. 2). Most of the E-W transect lies in the area of the drains. Although the observation period covered more than two years, for seasonal effects to be represented equally the statistical analyses have been restricted to two full years (see section 4). The analysed period began on 21 January 1990 and ended on 13 January 1992, and comprised 51 observed values from the N-S transect and 52 from the E-W transect. The observation tubes were perforated 5 cm diam. PVC drain tubes and a 1" (2.54 cm) diam. installation tube, perforated over its length.

The groundwater levels will be given relative to surface level. If the tube was placed on a hummock, the surface level is defined as the level of the surface in the direct vicinity of the hummock. The fluctuations in the surface level have not been taken into account, because they have little or no direct relevance to growing conditions. The fluctuations, measured at three sites, did not exceed 8 cm (difference between highest and lowest recorded levels). The amplitude of the fluctuation is indicated by the standard deviation around the mean level. This is a single value, which facilitates comparison between sites. The difference between the highest and the lowest recorded levels is 3 to 4 times the standard deviation.

3.2 SURFACE LEVELS

Surface levels were surveyed by the Irish Office of Public Works in the autumn of 1990, based on a 100 x 100 m grid. The surface level contours, measured relative to mean sea level (O.D.), shown in Figures 2 and 3 are based on these results.

3.3 ACROTELM DEFINITION AND DEPTH

The acrotelm is an essential concept in mire hydrology because of two hydrophysical properties:

- its large storage co-efficient, considerably over 25% in most cases
- its large hydraulic conductivity, often over 1000 m/d near the surface in the centre of an undisturbed mire.

The hydrological importance of the acrotelm was recognised long ago by mire hydrologists in the former Soviet Union. It was brought to general attention again by Ingram & Bragg (1984). Usage of the term "acrotelm" was proposed by Ingram (1978). Ingram & Bragg (1984) defined the acrotelm as the "...peat forming layer, in which organic matter, alive at the surface, is undergoing conversion to peat".

In quantitative hydrological studies dealing with the acrotelm, a quantitative, or at least reproducible and hydrologically functional, definition of the term is essential. Because the above definition leaves the term "peat" undefined, it lacks reproducibility. If the underlying catotelm is defined as the "permanently waterlogged part of the peat body", then the acrotelm is almost automatically defined as the "zone in which the groundwater level fluctuates". The latter definition probably does not contradict the first providing that the mire is undisturbed, but once again it does not define the material concerned. This limits its usefulness in hydrology.

A (rather arbitrary) definition we have found useful is "the top layer of the peat with a degree of humification of 4 or less on the Von Post scale". This defines the material, and its hydrological functionality is supported by the results of Baden & Eggelsmann (1963). For mires in northern Germany, they found a strong decrease in the hydraulic conductivity of *Sphagnum* peat with increasing humification, up to a humification degree of 2-4, with a smaller change towards higher values. Verry (1984) proposed the above as an addition to existing definitions of the acrotelm.

3.4 ACROTELM SURVEY METHOD

The acrotelm depth survey of Raheenmore Bog, made in the spring of 1991, was based on the above definition. The depth of the acrotelm was measured over the 100 x 100 m grid that was also used in the surface level survey. Where hollows with *Sphagnum* spp. occurred in the relatively dry parts of the bog, the depth was measured in the hollows, as described by Van 't Hullenaar & Ten Kate (1991).

4 RESULTS

4.1 GROUNDWATER LEVELS AND THEIR FLUCTUATION PATTERNS

4.1.1 E-W transect

Figure 4 shows the fluctuation pattern of the groundwater level at the eastern end of the transect (site 201) in the centre of the area containing the old, occluded drains (site 206), and upslope of the drained part (site 212), over the entire observation period. The relatively large differences in level between successive observation dates indicate a low storage co-efficient in the zone in which the water table fluctuates.

Site 201 shows the typical pattern of the disturbed margin: a large amplitude and a relatively deep average level. The fluctuation patterns at sites 206 and 212 differed little during the winter, at which time the differences between successive observation dates rarely exceeded 2-3 cm. During the summer, the water table at site 206 fell to a considerably deeper level than at site 212, indicating a relatively low storage co-efficient, beginning some 5 cm below the surface. Near site 206, the acrotelm is between 0 and 10 cm thick. This is in agreement with the fluctuation pattern of the groundwater level just described; the pattern must be related to the existence of a reduced storage co-efficient below the acrotelm. Boelter (1964) showed that the storage co-efficients of moss peat do indeed decrease sharply with increasing degree of decomposition. At site 212, the average depth of the acrotelm was approximately 10-20 cm, i.e. the water table did not fall below it during the observation period. The similarity between the winter patterns indicates that the old drains now have little or no direct effect on the fluctuation pattern.

Figures 5 and 6 show a cross section along the E-W transect, with surface level, mean groundwater level and standard deviation. The drain system ends just above site 211. The mean groundwater level remained below the surface up to this site. The standard deviation fell from about 0.12 m near the mire margin to 0.06 m at site 203, and then varied between 0.06 and 0.09 m up to site 211 whereafter it fell to about 0.04 m at a point where the transect lies outside the drained area. The lower values at sites 203 and 204 may be caused by runoff collected from higher parts of the mire. These sites are situated in the lowest part of the drained area.

The rather sudden decline in the standard deviation upslope of site 211 suggests that the drains influence the amplitude of fluctuation. Because of the similarity between the winter fluctuation patterns inside and outside the drained area, this can only be caused indirectly by decreased storage co-efficients in the drained area.

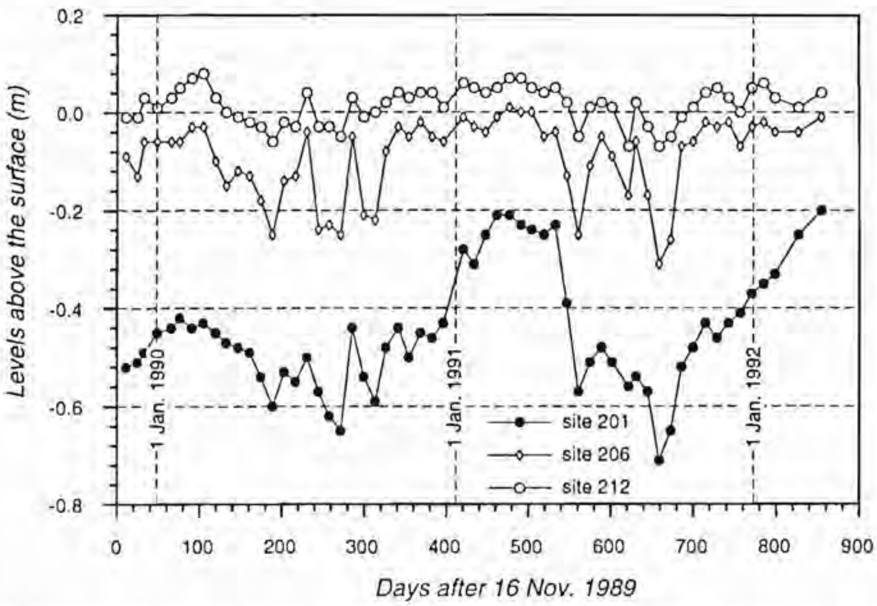

Fig. 4. Fluctuation pattern of the groundwater level at sites 201, 206 and 212 on the E-W transect.

The amplitudes gradually decreased upslope of site 206. The summer features of the pattern became less pronounced and disappeared upslope of site 211, as demonstrated in Figure 7 which shows the fluctuation patterns at sites 207, 209, 211 and 330 (212 is already included in Figure 4).

4.1.2 N-S transect

Apart from some peat cutting along the southern mire margin and a deep marginal drain at both ends, this transect has not been affected by drainage. Figure 8 shows some of the fluctuation patterns observed at the southern end. The pattern at site 315 is typical for the margin; even more extreme than that at site 201 on the E-W transect. Site 320 shows a transitional pattern that still reflects low storage co-efficients. Site 328 shows the typical pattern for the central mire area. A cross section, with surface levels, mean groundwater levels and their standard deviations, is shown in Figures 9-11. The fluctuation pattern of the central mire, with standard deviations of less than about 6 cm, occurs between site 323, some 170 m from the southern margin, and site 336, about 100 m from the northern margin. It therefore covers about 75% of the 950 m of the transect that lies in the uncut mire.

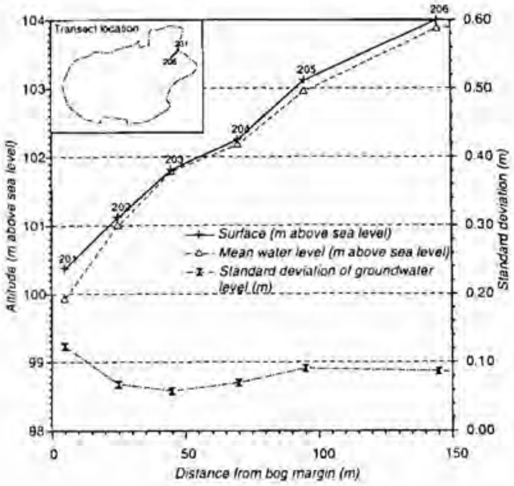

Fig. 5. Surface levels and mean and standard deviation of groundwater level vs. distance to mire margin along the eastern part of the E-W transect.

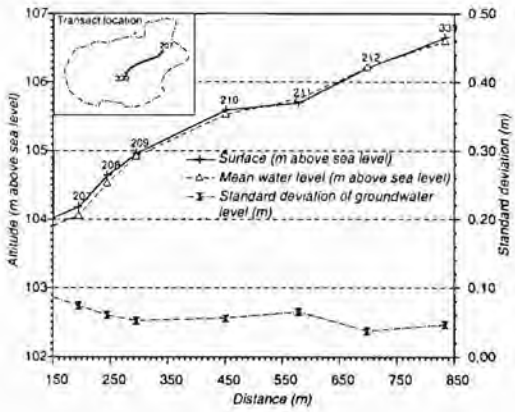

Fig. 6. Surface levels and mean and standard deviation of groundwater level vs. distance to mire margin along the western part of the E-W transect.

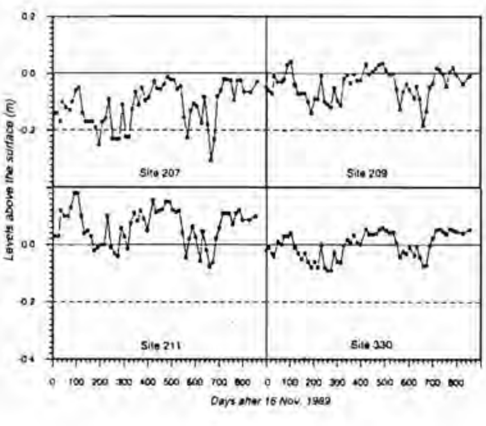

Fig. 7. Fluctuation patterns of the groundwater level from site 207 upwards on the E-W transect.

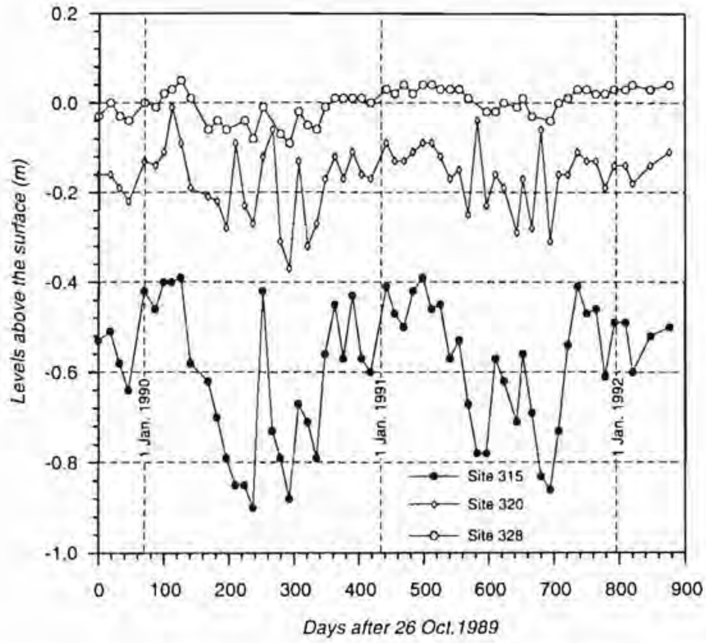

Fig. 8. Fluctuation patterns of the groundwater level at sites 315, 320 and 328 on the N-S transect.

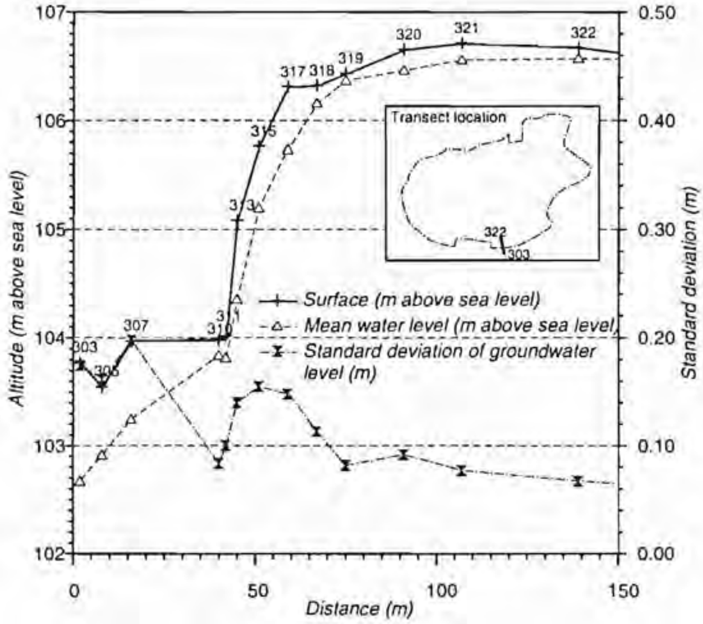

Fig. 9. Surface levels and mean and standard deviation of groundwater level vs. distance along the southern part of the N-S transect.

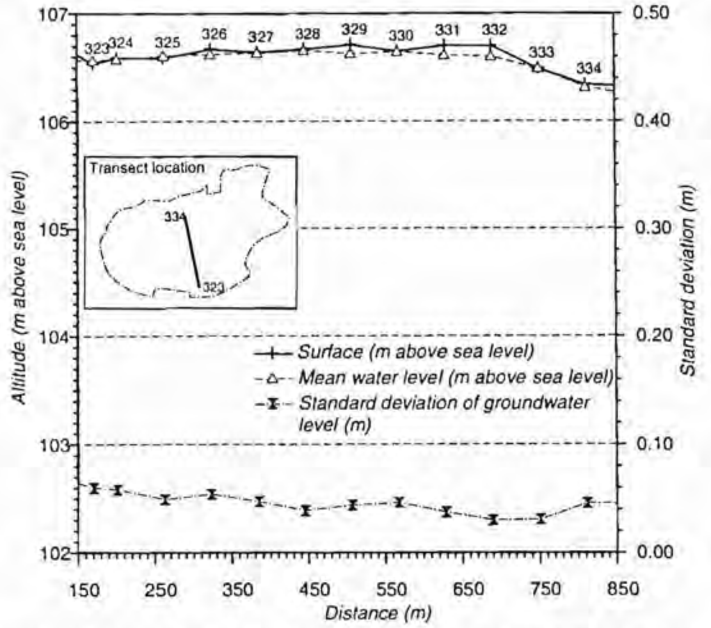

Fig. 10. Fluctuation patterns of the groundwater level along the central part of the N-S transect.

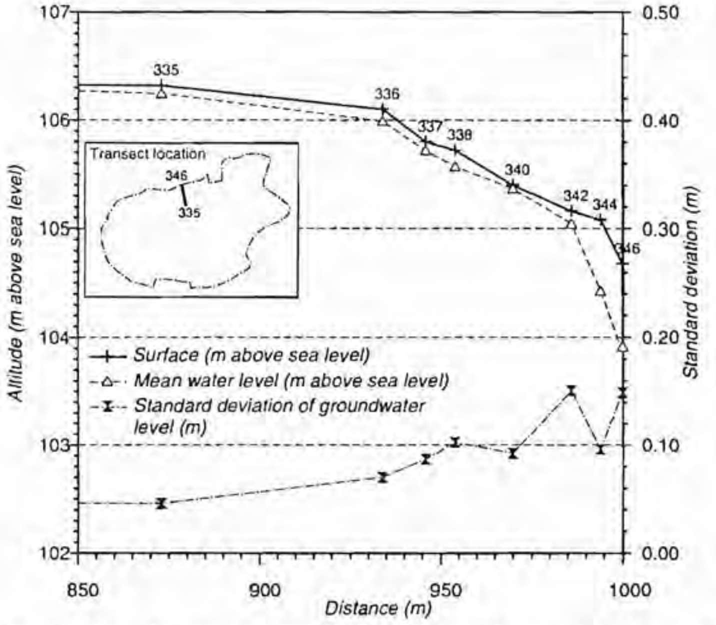

Fig. 11. Surface levels and mean and standard deviation of groundwater level vs. distance along the northern part of the N-S transect.

Between these points, the vegetation is dominated by *Sphagna,* particularly *S. magellanicum;* elsewhere *Sphagna* are less dominant and are almost absent at the margins.

The levels fell and the amplitudes increased towards the peat face in the south, but at its base the amplitude decreased sharply, probably because discharge of runoff from the mire to the south is impeded by the flat area below the peat face.

The levels also fell and the amplitudes increased towards the mire margin in the north, but over a shorter distance and more irregularly. This irregularity is almost certainly due to the positioning of the observation tube at site 344, which stood in a large hollow.

4.2 RELATIONSHIP BETWEEN DEPTH AND AMPLITUDE OF GROUNDWATER LEVELS

The cross sections suggest that a relationship exists between the mean depth of the groundwater level and the fluctuation amplitude. Figure 12 is a plot of the standard deviations versus depth, with two fitted lines, one for all points and one for points with a mean level of 0.20 m or less below the surface. The last ones represent the interior part of the mire since points with deeper levels reflect the situation in the marginal zone.

The fitted models are

$$s = 0.050 l_u + 0.235 z_m \qquad z < 0.25\text{ m} \qquad (1a)$$

and

$$s = 0.058 l_u + 0.130 z_m \qquad \text{all } z \qquad (1b)$$

where

l_u unit length (1 m)

s standard deviation around the mean of the groundwater level (m)

z_m mean depth of the groundwater level below the surface (m; levels above the surface are negative)

Table 1 shows the results of an analysis of variance (ANOVA) for both relationships.

The two fitted models indicate that a difference exists between areas with deep and those with shallow groundwater levels. The shallow levels yield a steeper line than that for all levels taken together, which may mean that the fluctuation amplitude approaches a limit as the mean levels become deeper. The ANOVA analysis shows a good level of significance for both models (significant at the $p < 0.001$ level).

Table 1. ANOVA of linear regression of standard deviation vs. groundwater level (Eqs. 1). *r* is the correlation coefficient, *F* is the variance ratio and *p* is the probability that the two tested quantities are independent (based on the value of *F*).

	Sum of squares	Degrees of freedom	Mean square
Values (z<0.25)	0.021372	34	
Mean		1	
Model	0.006775	1	0.006775
Residual	0.014598	32	0.000456
	$r = 0.563$	$F_{32}^{1} = 14.85$	$p \approx 0.05\%$
Values (all z)	0.043486	40	
Mean		1	
Model	0.026151	1	0.026151
Residual	0.017335	38	0.000456
	$r = 0.775$	$F_{38}^{1} = 57.33$	$p < 0.001\%$

In Figure 12, the points of the N-S and E-W transects are shown with different markers, the black dots representing the E-W transect. There is no clear difference in position between the two. This means that the relationship is not influenced to a detectable extent by the drains in the east.

4.3 RELATIONSHIP BETWEEN MEAN AND AMPLITUDE OF THE GROUNDWATER LEVELS AND SURFACE SLOPE

4.3.1 Level and surface slope

Surface slopes have been determined from the 100 x 100 m levelled grid made by the Office of Public Works. They are therefore estimates of averages over relatively long distances. Both slopes and mean groundwater levels and slopes and standard deviations showed correlations with fairly low degrees of significance. The significance improved when the logarithm of the slope was used, instead of the value of the slope itself.

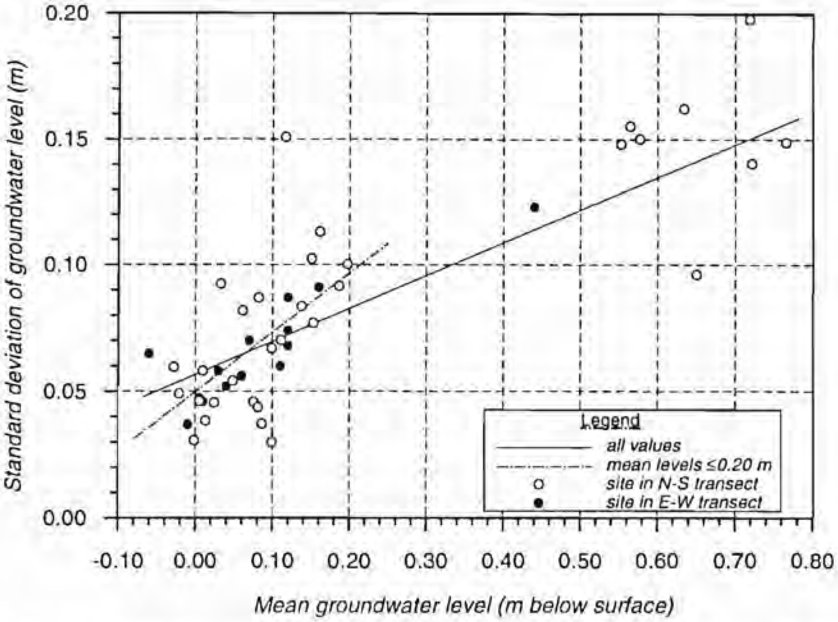

Fig. 12. Standard deviation vs. mean depth of the groundwater level; fitted lines for all levels (continuous line) and mean levels less than 0.25 m below the ground surface (dash and dot line).

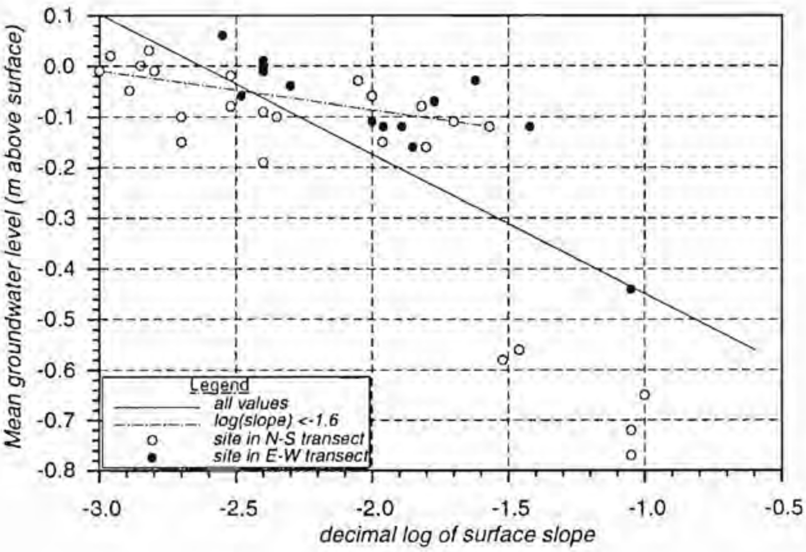

Fig. 13. Mean groundwater level vs. $^{10}\log(slope)$; fitted lines for all slopes (continuous line) and slopes less than 2.5% (dash and dot line).

Figure 13 shows the fitted lines, with data points, for the mean groundwater level compared to $^{10}\log(slope)$. As in Figure 12, there are two distinct groups of data points with respect to groundwater level: those from slopes of less than 2.5% (log 0.025=-1.6) and those from steeper slopes. The relationships were therefore calculated for both the first group and all points.

The fitted models are

$$z_m = -0.239 l_u - 0.076 l_u \, ^{10}\log(slope) \qquad slope < 0.025 \qquad (2a)$$

and

$$z_m = -0.725 l_u - 0.276 l_u \, ^{10}\log(slope) \qquad \text{all } slope \text{ values} \qquad (2b)$$

Table 2 shows the ANOVA results of equations (2a) and (2b).

Table 2. ANOVA of linear regression of mean groundwater level vs. $^{10}\log(\text{slope})$ (Eqs. 2). Explanation of symbols in Table 1.

	Sum of squares	Degrees of freedom	Mean square
Values (slope<0.025)	0.112570	32	
Mean		1	
Model	0.029743	1	0.029743
Residual	0.082827	30	0.002761
	$r = 0.514$	$F^1_{30} = 10.77$	$p \approx 0.3\%$
Values (all z)	1.708517	40	
Mean		1	
Model	0.992107	1	0.992107
Residual	0.716409	38	0.018853
	$r = 0.762$	$F^1_{38} = 52.62$	$p < 0.001\%$

The estimated regression co-efficients differ considerably between the models. The result implies that surface slope has only a slight effect on the mean groundwater level so long as its value lies below about 2.5%. The significance of both levels is good. The change in the estimated depth of the groundwater level over the slope interval of 0.1% to 2.5% is only about 10 cm.

4.3.2 Amplitude and surface slope

Figure 14 shows the points and the fitted lines for the standard deviation compared to $^{10}\log(slope)$. The points form a more homogeneous group than those in the two previous analyses. However, for the sake of comparison with the results of section 4.3.1, relationships for slope values of <2.5% and for all values have been derived. As might be expected, there is less difference between the two regression co-efficients than was the case for equations 2a and b. The fitted models are

$$s = 0.146 l_u + 0.035 l_u \, ^{10}\log(slope) \qquad slope < 0.025 \qquad (3a)$$

and

$$s = 0.174 l_u + 0.047 l_u \, ^{10}\log(slope) \quad \text{all } slope \text{ values} \qquad (3b)$$

The ANOVA results are shown in Table 3. The amplitude doubles from a slope of 0.1% to one of 2.5%.

In Figures 13 and 14, the points along the E-W transect and those along the N-S transect are differently positioned. In Figure 13, most points along the E-W transect fall above, and in Figure 14 below, the fitted line for all points. This means that a surface slope value on the E-W transect has the same effect as a less steep slope along the N-S transect. This can only be explained by the somewhat convergent flow towards the subsided, drained area, which partly compensates for the slope effect.

4.4 RELATIONSHIP BETWEEN ACROTELM DEPTH AND SURFACE SLOPE

As mentioned in section 2.3, the acrotelm depth was surveyed over the area covered by the 100 x 100 m grid. At the same points, the mean slope was estimated using the surface levels at the four neighbouring points. Data from 125 points were available. Cutaways were not included. Because the logarithm of the surface slope correlated better with the other data than with the slope values themselves, a logarithmic relation has been derived here. The data points and the fitted curve are plotted in Figure 15. The fitted equation based on all values is

Table 3. ANOVA of linear regression of standard deviation of groundwater levels vs. $^{10}\log(slope)$ (Eqs. 3). Explanation of symbols in Table 1.

	Sum of squares	Degrees of freedom	Mean square
Values (slope<0.025)	0.021346	33	
Mean		1	
Model	0.006332	1	0.006332
Residual	0.015014	31	0.000484
	$r = 0.545$	$F^1_{31} = 13.07$	$p \approx 0.1\%$
Values (all points)	0.048167	40	
Mean		1	
Model	0.027508	1	0.027508
Residual	0.020659	38	0.000544
	$r = 0.756$	$F^1_{38} = 50.60$	$p < 0.001\%$

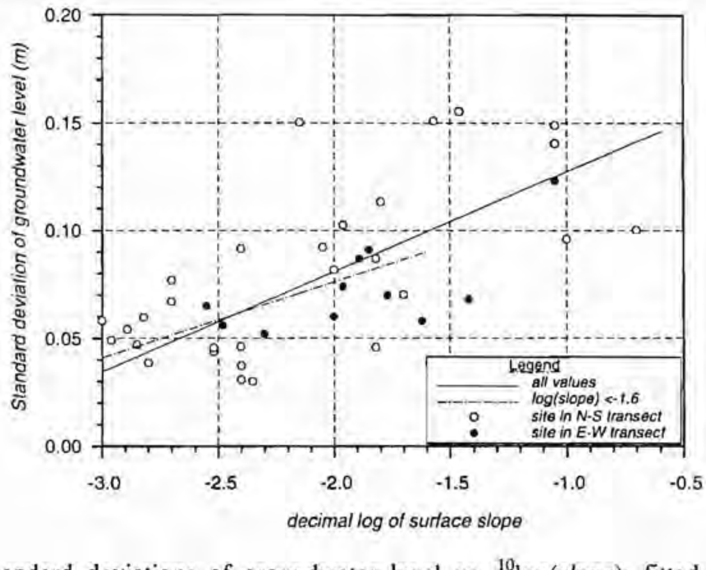

Fig. 14. Standard deviations of groundwater level vs. $^{10}\log(slope)$; fitted lines for all slopes (continuous line) and slopes less than 2.5% (dash and dot line).

$$D_a = -0.296 l_u - 0.174 l_u *^{10}\log(slope) \qquad (4)$$

where

D_a acrotelm depth (m)

Table 4 shows the ANOVA results for the fit of equation 4.

Table 4. ANOVA of non-linear regression of acrotelm depth vs. slope (Eq. 4). Explanation of symbols in Table 1.

	Sum of squares	Degrees of freedom	Mean square
Values	1.570852	125	
Mean		1	
Model	0.558055	2	0.279028
Residual	1.012796	122	0.008302
	$r = 0.596$	$F^2_{122} = 33.61$	$p < 0.001\%$

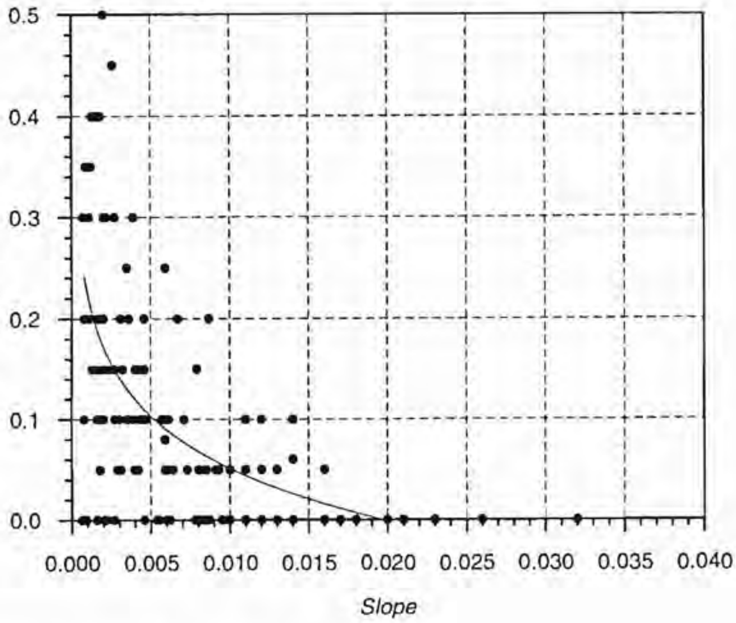

Fig. 15. Acrotelm depth vs. slope. All data points.

The drainage effect of the surface slope increases with the steepness of the slope. Increased drainage causes increased aeration of the top layer and thus an increase in the speed of decay, resulting in humification of the organic matter, a thinner acrotelm and consequently a decreased transmission and slower discharge of excess water. Eq. (4) reflects this process.

Although the derived equations suggest that on slopes steeper than 0.5-1%, good, though shallow, acrotelms may occur, in many such situations a top layer of 5-10 cm with a degree of humification of 5-7 occurred, overlying less humified material. This probably indicates relatively recent deterioration in the hydrological conditions, probably as a result of human activities.

5 DISCUSSION AND CONCLUSIONS

A deeper groundwater level was correlated with an increased fluctuation amplitude. This must be due to a decrease in the water storage co-efficient at greater depths. This decrease is in part caused by differences in the properties of the little humified material at the surface and the more strongly humified material at greater depths, but also by the storage of water in hollows on the mire, which have a limited depth. In this study, the surface has been defined as the surface level of the lower parts around the tubes, i.e. the hollows. Little difference was found in the fluctuation patterns above and just below this "surface" level, but as soon as the water levels fell below the acrotelm, as defined in section 3.3, the amplitudes increased. At greater depths, the amplitudes tended to become stabilised at a new, much higher, level. The superficial drainage in the western part of the mire seemed to have had no influence on the mechanism of this process.

Slopes of less than 2.5% had only a small effect on the average groundwater level, but their influence on amplitudes was considerable. It is likely that this difference is caused by the effects of the slope on the depth of the acrotelm, because on slopes of over 0.5-1% only poorly developed acrotelms occurred. The effect of the latter is twofold:

- the decreased hydraulic conductivity impedes a rapid discharge of water
- the decreased storage co-efficient leads to an increase in the fluctuation amplitude.

The condition of the top layer at locations with slopes over 0.5-1% indicates that relatively recent changes in hydrological conditions have led to a deterioration of the acrotelm. The significance of the correlation found between the surface slope and the groundwater regime may have been affected by the scale on which the slopes had to be measured.

The occluded drains now seem to have little or no direct effect on the groundwater levels, but there are indirect effects, via the subsidence they have caused in the past:

- decreased storage co-efficients cause larger amplitudes
- convergent flow influences the relationship between the slope and level regime in that slopes in the drained area had a similar effect as less steep slopes in the undrained parts of the mire.

ACKNOWLEDGEMENTS

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Estonian mires - past, present and future alternatives

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ABSTRACT

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About 60-70% of the mire areas in Estonia have been drained or significantly affected by reclamation. Some 10% of minerotrophic fen sites and about 65% of ombrotrophic bog sites are still in a virgin state. 94 mires, covering 172,600 ha, have been preserved in national parks, reserves, etc., i.e. 17% of the original mire area. More than 75% of the protected mires are ombrotrophic bogs and, in the future, greater emphasis must be placed on protecting the full spectrum of mire types in Estonia. There is an urgent need to map Estonian mire sites. The destiny of the mires largely depends on legislation being introduced to provide effective conservation to reduce the potential destruction of sites through land privatisation and the rapidly increasing interest for exploiting peat resources.

1 INTRODUCTION

Peatlands cover about 1,010,000 ha of Estonia, representing 22.5% of the land surface (Orru et al. 1992).

In 1955, a map showing the plant cover of Estonia was completed (Laasimer 1965) which also served as a good map of the distribution of mires for the time prior to the onset of intensive exploitation. Following this, two peat resource inventories were carried out (Truu et al. 1964, Orru et al. 1992), but unfortunately no comparison can be made between these and the plant cover map.

Several workers have proposed mire typologies. This paper uses the landscape typology of Masing (1975, 1988) (Table 1). In this, the mire site, characterised by homogeneity in physiographical conditions, peat and plant cover, is the smallest classification unit in the mire landscape.

2 GEOGRAPHY

The maximum elevation in Estonia is 318 m. As in other lowland countries, the nature of the surface and the climate favours the formation and expansion of mires. Estonia has a rather dense network of rivers and a high proportion of lakes. Per 100 km^2, there are about 22.8 km of rivers, about 50 km of streams and channels and 3 lakes with a mean area of 1.1 km^2. The climate varies from submaritime (in the western coastal region) to subcontinental (in the easternmost region) with an annual precipitation of 500-700 mm. The

Table 1. Types of mire in Estonia (after Masing 1975, 1988), their extent in 1955 (after Laasimer 1965) and in 1993 (after Ilomets 1994) and the main factors causing their decline.

Mire type	Appr. area in ha 1955	1990	Manner of exploitation
1 MINEROTROPHIC MIRE SITES	**650,000**	**58 000**	
1.1 Soligenous mire sitess	***1500***	***400***	surrounding areas drained
1.1.1 Woodless spring fens		*350*	
1. Moss, 2. Juncus, 3. Schoenus, 4. Low sedge			
1.1.2 Wooded spring swamps		*50*	
1.2 Topogenous mire sites	***334,200***	***40,000***	
1.2.1 Rich fens	*74,900*	*7000*	*mostly agri-*
1. Cladium, 2. Myrica-Schoenus, 3. Rich low sedge (Carex hostiana-C. davalliana association), 4. Sesleria		*200*	*culture*
1.2.2 Poor fens	*152,300*	*30,000*	*ca 50% agri-*
1. Tall sedge, 2. Low sedge, 3. Calamagrostis			*culture*
1.2.3 Wooded swamps	*10,700*	*3000*	*mostly forestry*
1. Alder, 2. Birch			
1.3 Limnogenous mire sites	***84,300***	***2500***	
1.3.1 Floating fens (quagmires)	*1300*	*1300*	
1. Schoenus, 2. Carex			
1.3.2 Flood-plain fens	*83,000*	*1000*	*mostly agri-*
1. Equisetum, 2. Flooded tall sedge, 3. Flooded low sedge			*culture*
1.3.3 Wooded swamps on mobile groundwater sites	*500*	*50*	*forestry*
1. Filipendula, 2. Alder, 3. Birch-reed			
1.4 Transitional (topo-ombrogenous and limno-ombrogenous mire sites	***230,000***	***18,000***	
1.4.1 Transitional fen	*76,200*	*10,000*	*partly agri-*
1. Carex-Sphagnum mire, 2. Trichophorum alpinum-Sphagnum mire, 3. Myrica-Schoenus fen with Sphagnum patches, 4. Eriophorum vaginatum-Sphagnum mire			*culture*
1.4.2 Wooded transitional bog	*151,800*	*8000*	*mostly forestry*
1. Pine-birch bog (mesotrophic), 2. Cottongrass-pine bog (meso-oligotrophic), 3. Bilberry-pine bog (meso-oligotrophic)			
2 OMBROTROPHIC MIRES	*383,000*	*250,000*	
2.1 Moor sites	***3000***	***1500***	*mostly forestry*
2.1.1 Heath moors			
2.2 Bog sites (ombrogenous sites on ± thick peat	***380,000***	***250,000***	
2.2.1 Bog margin sites	*80,000*	*60,000*	*forestry, industry*
1. Trichophorum bog, 2. Eriophorum bog, 3. Chamaedaphne bog, 4. Dwarf shrub bog			
2.2.2 Bog centre sites	*170,000*	*125,000*	*industry*
1. Calluna bog with small hollows, 2. Calluna-Cladina bog with Rhynchospora hollows (regressive stage), 3. Calluna-pine bog with Scheuchzeria (Rhynchospora) hollows, 4. Ledum (Chamaedaphne)-pine bog with pools			
2.2.3 Bog forest sites	*130,000*	*65,000*	*forestry*
1. Ledum-pine, 2. Myrtillus-pine			
TOTAL	**1,033,800**	**310,000**	

mean temperature in July is 16.5° to 17.5° C, with a February range of -4.0° to -7.5° C.

The main phytogeographical boundary (Fig. 1) crossing Estonia in a NNE-SSW direction (Laasimer 1965) corresponds well with the geomorphological differences that follow the maximum transgression limits of the Baltic Sea during the Holocene. The western part, Lower Estonia, was covered by the Baltic Glacial Lake and local glacial lakes; the eastern part, or Upper Estonia, lay beyond the glacial lakes. The 50 m contour corresponds to this boundary line. Floristic peculiarities in mire plant cover, described first by Thomson (1922), are related to the distribution of *Trichophorum cespitosum, Cladium mariscus, Myrica gale* and some other species in Lower Estonia and the occurrence of *Chamaedaphne calyculata* and *Saxifraga hirculus* in Upper Estonia. Following the system of Botch & Masing (1983), the first region belongs to the Baltic coastal bog province, while the Upper Estonian mires belong to the East Baltic bog province.

Based on differences in landscape features, mire area and mire frequency, as well as peculiarities in the development of the mires, Allikvee & Masing (1988) divided Estonian mires into 8 mire districts and several subdistricts.

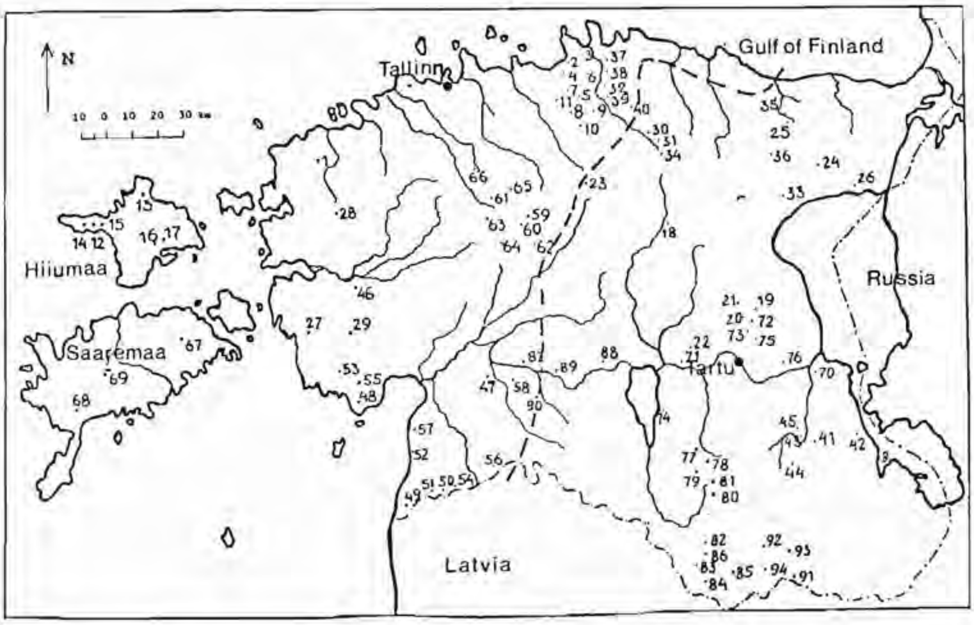

Fig. 1. Location of protected mires in Estonia. For numbers 1-94, refer to Table 2. The broken NNE-SSW line marks the boundary between the distribution of eastern Estonian domed bogs and western Estonian plateau bogs (after Lassimer 1965).

3 MIRE TYPES AND THEIR DISTRIBUTION

Mires in Estonia can be divided into two hydrological types, minerotrophic and ombrotrophic mires. Among the minerotrophic type there are soligenous, topogenous, limnogenous and transitional mires (Table 1). The waters of rare soligenous or spring fens are commonly calcium rich, sometimes with a very high Ca content. *Schoenus nigricans* and *Juncus subnodulosus* communities are found on such calcium-rich spring fens (the island of Saaremaa). In many cases, however, the spring fens are affected by a lowering of the water table due to drainage in surrounding areas.

Rich fens are predominantly found in western Estonia where they occur on carbonate-rich substrates. *Myrica gale, Schoenus ferrugineus* and *Cladium mariscus* fens occur on the western part of the island of Saaremaa and in some places on the west coast of the mainland. Poor fens are more common in the eastern part of the country where tall sedge *(Carex acuta - C. elata* association) or low sedge fens *(Carex nigra - C. panicea* association) occur.

All these fen types, except *Cladium mariscus* fens, are extensively affected by man and are used for agricultural purposes, such as meadows for mowing, grazing, or arable land. This is particularly true for rich fens occurring on a thin peat deposit.

Flood-plain fens originally occurred alongside every river, especially in southern Estonia where flood water played an important role. They still exist in some areas, but have mostly been destroyed by man. However, several floating fens are still in a pristine condition.

In Estonia, transitional mires are divided into transitional fens and wooded transitional bogs. Four different categories of this type of fen are distinguished. Sedge-moss fen *(Carex lasiocarpa* and *C. lasiocarpa - C. rostrata - C. limosa* association) is found in western and central Estonia. It is distributed rather sparingly, except on flood plains around lakes where it is common. This type of fen has frequently been affected by mowing or grazing. *Myrica-Schoenus* fen with *Sphagnum* patches on calcium-rich substrates occurs in western Estonia. Such sites, characterised by a thin peat layer and therefore easily damaged by exploitation, are rarely found in a natural state, most having been turned into pasture.

The wooded transitional bogs often form a belt around large ombrotrophic bogs, especially in northern Estonia. These mires are usually seriously affected by drainage associated with forestry.

Ombrotrophic mires are divided into moor and bogs. The moor heaths (on thin peat and underlying pure sand) occur in depressions between sand dunes on the west coast of the mainland and on islands in western Estonia (especially on Hiiumaa).

Depending on the density of the tree canopy on the bogs, wooded and open types are distinguished. The bog margin is usually covered by bog forests. In certain cases where the bog is still in its early developmental stage, the entire bog area may be covered by pine forests. In the 1950s and 1960s, many Estonian bogs were affected by drainage on their margins, for example in the lagg zone. The drainage effect has, however, decreased with time as the ditches have become infilled.

Unpatterned, open or wooded bogs dominate western Estonia, whereas patterned bogs with strings, hummocks and pools are more characteristic of the eastern part of the country.

Regionally, Estonian bogs are divided between eastern Estonian convex and western Estonian plateau bogs which possess certain differences in vegetation types and mire complex types (Masing 1982).

4 EXPLOITATION HISTORY

Exploitation of Estonian mires started in the 17th century. At the beginning of the 19th century, drainage and burning of mires was widely practised for agricultural purposes (Valk 1988). The Estonian Agricultural Society was founded in 1839. One of its aims was to drain mires. The first drainage system made of burnt clay pipes was in place in an Estonian mire as early as the 1850's. Cultivation of mires was expanding by the end of the 19th century.

In 1908, the Baltic Peatland Improvement Society was founded in Tartu and in 1910 the Tooma Experimental Peatland Station was opened, specialising in the development of mire cultivation, but mire hydrometeorology began to be studied in 1951.

After 1947 there was a significant increase in mire drainage as powerful machinery became available. During the 1980s, more than 130,000 ha (compared with about 10,000 ha for the entire period before) of peatland were drained and brought into agricultural production as cultivated grassland, pasture and arable land.

Although the drainage of mires for forestry started at the beginning of the 19th century, most work has taken place in the last 40 years. In 1987, about 180,000 ha of peaty soils and 238,000 ha of paludified mineral soils have been drained for forestry (Valk 1988). At the end of the 1960s, it was concluded that the afforestation of ombrotrophic bogs was clearly uneconomic and such areas were excluded from potential grant funding for such activities.

Peat began to be cut for fuel in the 17th century. This increased during the next century due to lack of other fuel (large forested areas had been felled). Peat was also, among other things, used for alcohol distilleries. Small amounts of hand-cut peat were used for domestic heating up to the 1960s. The first peat briquette factory was established in 1938 and this was followed by others in 1964 and 1976. Peat extraction reached a maximum of 753,000 tonnes in 1988. During the last few years, peat sods have been cut for fuel in some areas, a trend which is increasing.

For several decades, milled peat has been widely used as bedding material for livestock - up to 2 million tonnes per year being excavated for this purpose. This is now decreasing (in 1991 ca 1 million tonnes) and will reach a level of about 0.5 million tonnes per year.

At the same time as the domestic use of milled peat is declining, its excavation for export (to the Netherlands, Germany, the United Kingdom, Sweden, Finland, etc.) is increasing. This trend is likely to increase as the price of Estonian peat is lower than the average world price. Hence, milled peat exports increased from 110,000 tonnes in 1988 to 394,000 tonnes in 1991. Extraction is taking place in some 108 milled peat fields with a total area of about 14,800 ha. The overall area of cut-away bogs is 38,400 ha.

5 CURRENT THREATS

Until 1987, the most important threat to mires in Estonia came from drainage. Now, due to the political changes, the economic situation has altered significantly. The need for peatland improvement is diminishing, and the excavation of fuel peat is now the greatest threat to mires.

Recently, the Estonian government borrowed 64.5 million USD from the World Bank to re-establish a number of municipal heating schemes to be based on local peat and wood instead of heavy oil and natural gas imported from Russia. This is part of the new national energy programme and means that the role of peat in the total energy budget is likely to increase from 2.6% to a minimum of 5-6% annually. Approximately 5 million tons of peat will eventually be used in energy production each year. The World Bank Environmental Assessment report has advised that peat extraction for this purpose should be concentrated on peatlands that have already been partially drained or used for milled-peat production.

However, the Estonian government and regional authorities are under pressure from developers to permit new peat extracting plants on virgin peatlands. These developments are being urged forward by the world demand for moss peat and the relatively low price of Estonian peat A recent joint venture between a Swedish power company and an Estonian peat-briquetting company will see 100,000 tons of peat briquettes being exported annually for ten years to heat homes in Stockholm.

Important mires have also been destroyed through excavation of oil shale in opencast mines in northeastern Estonia. About 2000 ha of mire have already been destroyed, and a further 100 ha are being destroyed annually.

The emission of calcium-rich alkaline compounds from power plants that use oil shale (kukersite) as a fuel has significantly affected the *Sphagnum* carpet of ombrotrophic bogs. Some 200,000 ha of land in a radius of 30 km around some power plants have been affected. It has been estimated that 30,000 tonnes of Ca are deposited in dust falling on this area, resulting in the disappearance of the *Sphagnum* carpet, which in turn has halted the peat forming process and increased the decomposition of organic matter in the bogs within 10-15 km of the pollution source. The only way of preventing such pollution, which in addition to a high Ca content, also contains several heavy and rare metals such as As, Zn, Th, Hf, V, etc. is to install special filters in factory chimneys.

According to official statistics, about 30% of Estonian mires have been drained - 15% for forestry, 12% for agriculture and 1% for peat extraction (Valk 1988). The results obtained in the course of a pilot inventory of the state of Estonian mires (Ilomets 1993) indicate that about 60-70% of Estonian mires may be affected by human activities (Table 1). The most endangered are minerotrophic fens, especially rich-fen sites of which up to 90% have been damaged for agricultural and forestry purposes. About 35% of ombrotrophic bog sites, mostly bog forests have been drained.

94 mires covering in all 172,600 ha, which is approximately 17% of the total mire area in Estonia, have been given protected status (Fig. 1, Table 2). Estonia has four national parks, three of which consist partly of mires. The Karula National Park (10,318 ha) has 7 mires totalling 1479 ha and the Lahemaa National Park (112,011 ha) has 9 mires totalling 6048 ha. The Soomaa (Mireland in English) National Park (36,700 ha) was established to protect large raised bogs. It has 5 bogs covering an area of 25,332 ha which is about 70% of the overall area of the park. The West Estonian Archipelago Biosphere Reserve has 8 mires, but the four largest ones are considerably affected by human activities.

Table 2. Protected mires in Estonia; their total area is 172,582 ha and the total peat resource on them is 651,427 t x 10^3.

No. Name	No. on Fig. 2	Area ha	Peat res. t x 10^3	No. Name	No. on Fig. 2	Area ha	Peat res. t x 10^3
Karula National Park							
1. Palu	83	10	10	5. Lauksilla	86	249	435
2. Köstrejärve	82	56	83	6. Kaugjärve*	92	835	970
3. Koobassaare	84	76	202	7. Ubajärve	94	168	261
4. Väike-Apja	85	85	324				
Lahemaa National Park							
8. Aabla	2	356	840	13. Tuksmani	37	485	1589
9. Hara	3	747	2130	14. Udriku	38	1169	3190
10. Kahala	4	353	1011	15. Uuemõisa	39	864	539
11. Viru	6	253	634	16. Vohnja	40	431	824
12. Laukasoo	32	139	1858				
Soomaa National Park							
17. Kikepera	47	3025	18138	20. Valgeraba	89	3379	9840
18. Ojasaare	58	932	1082	21. Öördi	90	7154	23424
19. Kuresoo	87	10842	37659				
West Estonian Archipelago Biosphere Reserve							
22. Eiste	12	26	22	26. Pihla*	16	2587	5160
23. Kodeste	13	77	48	27. Määvli*	17	5951	863
24. Kõivasoo	14	39	37	28. Koigi*	67	2575	4630
25. Kõrigu	15	35	23	29. Pelisoo*	69	348	1000
Alam-Pedja Nature Reserve							
30. Umbusi*	22	8696	32092	31. Emajõe-Pedja (Laeva)	71	10290	34015
Nature Reserves							
32. Endla*	18	4214	17860	34. Viidumäe (Lümanda)*	68	8	45
33. Nigula	49	2320	10105				
Mire Reserves							
35. Suursoo*	1	5793	24216	54. Tolkuse	52	5503	14695
36. Muraka	24	12793	44384	55. Tõhela	53	1709	5584
37. Sirtsi	25	2457	10939	56. Tõrga	54	1291	3036
38. Agusalu	26	2711	10666	57. Võlla	55	9511	64077
39. Nehatu	27	222	30	58. Kodesma	56	1293	1362
40. Marimetsa	28	3700	22989	59. Soometsa	57	1631	3768
41. Tuhu	29	2531	10991	60. Aela-Viirika	59	904	4724
42. Luusaare				61. Loosalu	60	816	3890
(Venevere)	33	669	1981	62. Mahtra*	61	804	3023
43. Sämi-Kuristiku	35	807	2757	63. Piiumetsa (Rumbi)	62	548	1373
44. Tudu-Järvesoo	36	1418	4816	64. Keava	63	1311	4750
45. Meenikonna	41	471	2072	65. Palasi	64	437	1791
46. Meelva*	42	1827	6855	66. Kodila-Linnuraba	65	3160	5525
47. Valgeraba	43	329	385	67. Hagudi	66	46	9143
48. Ahijärve	44	358	877	68. Emajõe-Suursoo	70	15098	81442
49. Jõe	45	319	468	69. Laukasoo*	76	500	914
50. Avaste	46	5086	19528	70. Parika*	88	821	6531
51. Lindi	48	539	1510	71. Kellamäe			
52. Rongu	50	1348	4506	(Vanamõisa)	91	1546	664
53. Ruuna	51	249	594				

Table continued.

No. Name	No. on Fig. 2	Area ha	Peat res. t x 10^3	No. Name	No. on Fig. 2	Area ha	Peat res. t x 10^3
Haanja Landscape Reserve				**Kôrvemaa Landscape Reserve**			
72. Murati	93	69	145	73. Epu-Kakerdi*	23	4245	22583
Mustjärve Landscape Reserve							
74. Valguta*	74	78	360				
Neeruti Landscape Reserve							
75. Kiku	30	135	188	77. Neeruti	34	45	82
76. Kôrbse	31	154	197				
Otepää Landscape Reserve							
78. Nuustaku	77	51	136	81. Vidrike	80	90	56
79. Pori	78	29	52	82. Pühajärve	81	185	235
80. Rebaste	79	148	118				
83. Suru	5	2566	5601	86. Muki*	9	1798	3191
84. Koitjärve*	7	1800	5586	87. Lille*	10	640	1480
85. Salu	8	379	333	88. Salgu*	11	80	200
Vooremaa Landscape Reserve							
89. Kaiavere	19	650	2477	92. Punnasjärve	72	1735	4103
90. Lava	20	167	502	93. Simuvere	73	936	1578
91. Ulpe	21	268	637	94. Vasula	75	135	736

* - partly protected mire

Of the five nature reserves listed, mire conservation is a priority on the Alam-Pedja, Endla and Nigula Nature Reserves where 16,800 ha of mire occur.

Estonia has 23 state and 14 local mire reserves with total areas of about 72,598 ha and 20,558 ha, respectively. These are chiefly large ombrotrophic bogs, but the Avaste mire (no. 46 on Fig. 1) is a fen, and mesotrophic conditions prevail on Emajôe-Suursoo (no. 70 on Fig. 1).

6 MANAGEMENT PROBLEMS

Over 3/4 of Estonia's protected mires are ombrotrophic bogs. For a long time, mire conservation policy in Estonia was essentially designed to protect large ombrotrophic mire systems. It was difficult to preserve fens due to their usefulness as agricultural land, despite their high value from a nature viewpoint and the significant threats facing this habitat type.

In the last few years, anthropogenic pressures have increased significantly due to basic changes in Estonia's political and economic systems. The rapid changes in these systems make it essential that a national mire protection programme is evolved and implemented.

Several levels of government have a role to play in such a programme. The State Energy Programme attaches significant weight to the use of peat as an energy source. The Department of Energy has listed some 100 mires with an area of 122,500 ha which contain a total fuel peat resource of some 245 x 10^6 tonnes. However, these sites were selected on the basis of their energy value and their environmental value was not taken into account.

Another factor affecting mire protection relates to government reforms designed to return land to its previous owner. Before this happens, it is essential that a system of regulation is introduced to ensure the correct management of such areas.

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Mires of Ukraine

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ABSTRACT

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The southern limit for the common occurrence of mires in Europe crosses central Ukraine, and the eastern limit for calcareous mires is also located here. Three principal vegetational zones, the mixed forest zone, the forest-steppe zone and the steppe zone, are recognised, in addition to two mountainous regions, the Carpathians and the Crimea. Mires are most widespread in the first of these zones, in Ukrainian Polissia furthest northwest. The steppe zone, covering most of the southern half of the country, has very few mires. The most common types of mire and their most characteristic plant communities are described.

Nearly half the area of mire recognised in the 1950s still remains undrained, amounting to about 500,000 ha. Measures were introduced in the early-1980s aimed at bringing an end to the large-scale destruction of mires. Alternative ways of using them are being sought, and some previously drained mires are being restored, partly by planting berry communities. Some mires are protected in reserves and national parks. Programmes to make inventories of the mires and wetlands of Ukraine, and to study and restore them, are about to start in collaboration with Dutch and German groups.

1 MIRE TYPES AND THEIR DISTRIBUTION

Because of the physical geography of Ukraine, the vegetation and flora of its mires and wetlands is characterised by strong diversity. Three vegetational zones, the mixed forest zone (Polissia), the forest-steppe zone and the steppe zone, and two mountainous regions, the Crimea and the Ukrainian Carpathians, are recognised. Due to its geographical position, the natural conditions for mire development in Ukraine are either little favourable or quite unfavourable. There is a general tendency for a north-south decrease in mire areas and for a dominance of minerotrophic mires over ombrotrophic ones. The southern limit in Europe for the common occurrence of mires passes through Ukraine. South of this limit, mires are found only rarely in Ukraine and cover small areas, but sedge-reed mires become more widespread. The eastern limit of calcareous mires, with dominant *Carex davalliana*, *Cladium mariscus* and *Schoenus ferrugineus* (Balashov et al. 1982), is also located within Ukraine.

According to data obtained in 1959 (Peat Fund of Ukraine), about 1,146,298 ha, or approximately 2% of Ukraine, were then mire covered,. the area of peatland with a peat depth of more than 0.5 m being 801,491 ha, or 1.33%. However, Bradis et al. (1973) showed that the mire-covered area had decreased to 1.68% and the peatlands to 1.15%. By 1973, the total mire area was 1,008,100 ha, including 693,700 ha of undrained peatlands. However, by 1978 the last figure had decreased considerably, by more than 100,000 ha according to estimates.

The most widespread mires are found in northern and northwestern parts of Ukraine, in the area called Ukrainian Polissia (Fig. 1). In 1973, 6.2% and 4.3%, respectively, of that region (the mixed-forest zone) was swamp and peat covered. In the forest-steppe zone, the corresponding figures are much lower (1.5% and 1%), and mires are a real rarity in the steppe zone where swamp and peat-covered areas account for only 0.3% and 0.2% of the zone, respectively.

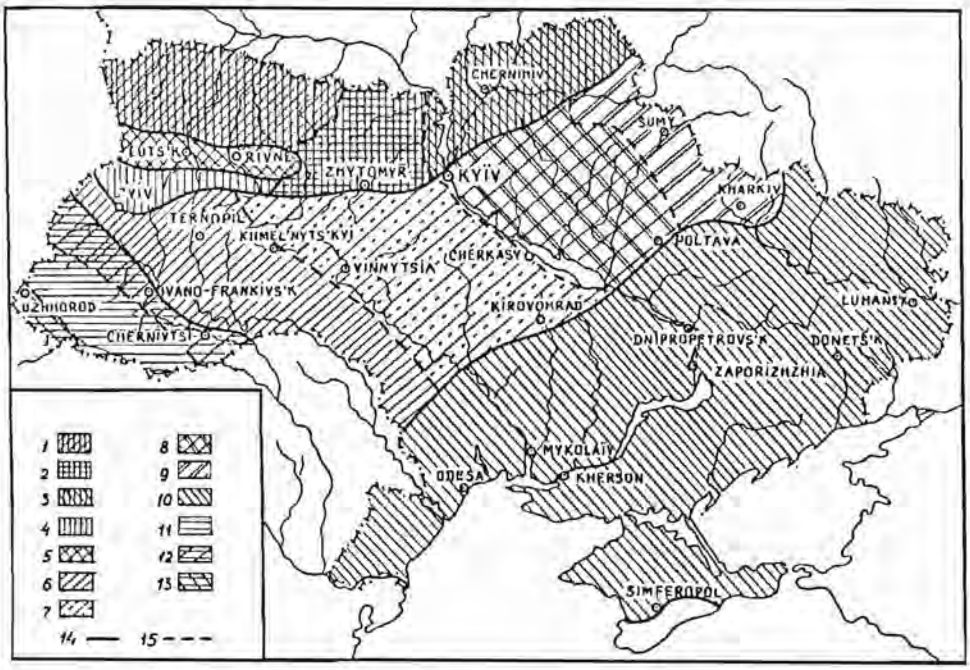

Fig. 1. Schematic map of the mire regions of Ukraine (after Bradis 1973): **mixed forest zone**: 1. western Polissia, 2. central Polissia, 3. eastern Polissia, 4. Little Polissia; **forest steppe zone**: 5. Volyn, 6. Podillia, 7. Right bank (of the River Dnieper), 8. Left bank (of the River Dnieper), 9. Eastern part; 10. **steppe zone; Carpathian mountain region:** 11. Carpathian mountains, 12. Precarpathians, 13. Transcarpathians; 14. borders of vegetational zones; 15. borders of mire regions.

Because of the geomorphological conditions, there is little mire (about 0.05%) in the Carpathian mountains, even though climatic conditions favour mire development (the annual precipitation is 700-1000 mm). In the adjacent mountains, mires cover somewhat larger areas (1.22%). The Crimea has no mires at all.

In Ukraine, mires are mainly located in concave relief forms. They usually occupy the valleys of former and present-day rivers, karstic and eolic landforms, and various local depressions. Eutrophic mires related to glacial overflow valleys, and former and present-day rivers, are the most widespread. Their main water supplies derive from lakes and rivers (Bradis & Bachurina 1969).

Oligotrophic and mesotrophic (ombrotrophic, ombro-minerotrophic) mires are associated with peat formation in depressions of varying origin on the upper flood plain terraces, watersheds and slopes. Their source of water is mainly precipitation. They are widespread only in the mixed forest zone.

Sloping mires are developed on hillsides where springs occur in the Carpathian mountains and locally on the Donetsk range and the slopes of the Azov crystalline platform. These mires are characterised by a eutrophic graminoid vegetation, and peat deposits are thin or absent.

2 EUTROPHIC MIRES

The vegetation of eutrophic mires, the most characteristic type of mire in the Ukrainian lowlands, is characterised by great diversity. Grass and grass-moss mires are most widespread, wooded and shrub-covered ones being less common.

2.1 WOODLESS EUTROPHIC MIRES

In the mixed forest zone, the largest areas are occupied by sedge and sedge-moss coenoses. They often cover the entire surface of large mires situated in valleys, on flood plains and land adjoining terraces. In the forest-steppe zone, these coenoses are somewhat less widespread. Plant communities in which *Carex acuta*, *C. appropinquata* and *C. elata* ssp. *omskiana* are dominant, are most common on sedge mires, whereas those with *C. acutiformis* and *C. rostrata* are less widespread, and mires with a predominance of *C. juncella, C. riparia*, *C. rostrata* and *C. vesicaria* are very rare.

Carex elata ssp. *omskiana* coenosis not only occurs in the mixed forest and forest-steppe zones, but even in the steppe zone, particularly on the Kardashyn mire. These coenoses attain their optimal development where there is sufficient water. The field layer is differentiated there with *Calama-*

grostis canescens, *Caltha palustris*, *Festuca rubra*, *Lycopus europaeus*, *Mentha arvensis*, *Poa palustris* and other species occupying the hummocks, and *Carex rostrata*, *Glyceria maxima*, *Hottonia palustris*, *Menyanthes trifoliata*, *Phragmites australis* and other species growing in the hollows. *Calliergonella cuspidata* and *Drepanocladus aduncus* are the dominant mosses.

Where less moisture is present, the plant cover becomes thicker and the number of species increases, including such sedges as *Carex acutiformis*, *C. appropinquata*, *C. davalliana* and *C. lasiocarpa*. In the moss cover, *Campylium polygamum*, *Fissidens adianthoides*, and even such a rare species as *Scorpidium scorpioides*, are present in addition to those mentioned above. *Sphagnum obtusum* and *S. platyphyllum* occur sporadically.

Sedge-reed mires are mainly found in the forest-steppe zone. Apart from *Phragmites australis*, which covers some 55-90% of these mire areas, *Carex acutiformis*, *C. elata* ssp. *omskiana*, *C. riparia* with *C. appropinquata* and *C. diandra*, as well as *Cicuta virosa*, *Euphorbia palustris*, *Lythrum salicaria*, *Scirpus maritimus* and *Stachys palustris* also grow there. Under really wet conditions, a great deal of *Lemna trisulca*, *Salvinia natans* and *Spirodela polyrhiza* can be found, and the rare species *Aldrovanda vesiculosa* has been noted.

Reed mires are found in all the vegetational zones of Ukraine, but they predominate in the forest-steppe zone. In the mixed forest zone and the northern part of the forest-steppe zone they form peat deposits, sometimes quite extensively, but in the southern part of the forest-steppe zone and in the steppe zone, peat is thinner or absent.

Grass-moss coenoses are mainly found in the mixed forest zone, but also occur in the forest-steppe zone. As Zerov (1938) showed, these coenoses are formed where there is stagnant water containing a high concentration of minerals; under natural conditions in the forest-steppe zone the peat of such mires contains a great deal of carbonate. The mires are swampy because they are well supplied with water. *Betula pubescens* and *Salix pentandra* are predominant with sporadic occurrences of *S. aurita*, *S. cinerea* and *S. rosmarinifolia*. *Carex chordorrhiza*, *C. diandra*, *C. limosa*, *C. nigra* and *C. rostrata*, as well as *C. cespitosa*, *C. davalliana* and *C. elata* ssp. *omskiana* in the western part of Ukraine, dominate the vegetation. Apart from these sedges, *Epilobium palustre*, *Eriophorum angustifolium*, *E. gracile*, *E. latifolium*, *Lycopus europaeus*, *Lysimachia vulgaris*, *Lythrum salicaria*, *Menyanthes trifoliata*, *Pedicularis palustris*, *Peucedanum palus-*

tre, Potentilla palustris, Stachys palustris, Thelypteris palustris and others occur with great constancy.

Such species as *Liparis loeselii, Pinguicula vulgaris, Saxifraga hirculus, Schoenus ferrugineus, Tofieldia calyculata* Wahlenb., which are rare in Ukraine, grow on the sedge-moss mires.

Aulacomnium palustre, Calliergon cordifolium, C. giganteum, Calliergonella cuspidata, Climacium dendroides, Drepanocladus aduneus and *D. vernicosus* are predominant among the mosses. Where the carbonate content is higher, *Campylium stellatum, Drepanocladus revolvens* and *D. sendtneri* dominate in the moss cover. *Calliergon trifarium, Helodium blandowii, Meesia triquetra, Paludella squarrosa* and *Scorpidium scorpioides*, which are rare in Ukraine, have been noted in the mixed forest zone.

2.2 WOODED EUTROPHIC MIRES

Plant communities in which *Alnus glutinosa* is predominant are the most widespread in this group. They are found all over the lowlands of Ukraine, on mires situated on flood plains, in old river beds and on land adjoining river terraces. Sometimes they occupy the whole area of a mire, but they are mostly concentrated on the margins of grass or grass-moss mires. Their water supply derives from mineral-rich groundwater, springs or floods. The peat thickness generally varies from a few centimetres up to 4 m, but peat is sometimes absent.

An interesting peculiarity of the alder swamp forests is considerable variation in their microrelief, leading to a mosaic structure in the vegetation cover. Plants requiring relatively little moisture, such as *Athyrium filix-femina, Carex norvegica, Dryopteris carthusiana, D. filix-mas, Majanthemum bifolium, Oxalis acetosella, Trientalis europaea*, grow on humps associated with tree trunks (so-called "pedestals"), which can attain 1 m in height, and on prostrate tree trunks and sedge hummocks. *Carex appropinquata, C. cespitosa, Filipendula ulmaria, Lysimachia vulgaris* and *Peucedanum palustre* grow on the margins of such "pedestals". Such hydrophilous species as *Alisma plantago-aquatica, Calla palustris, Carex acutiformis, C. riparia, C. vesicaria, Hottonia palustris, Iris pseudacorus, Menyanthes trifoliata, Lysimachia thyrsiflora* and *Phragmites australis* grow in the wettest parts.

The moss cover is only poorly developed, but it is also differentiated. *Dicranum bergeri, Hylocomium splendens, Pleurozium schreberi* and *Polytrichum longisetum* grow near the tree trunks; *Sphagnum girgensohnii, S.*

plathyphyllum, *S. squarrosum*, *S. subsecundum* and *S. teres* occur sporadically. *Calliergon cordifolium*, *Calliergonella cuspidata*, *Drepanocladus aduncus* and *D. vernicosus* have been noted in the hollows between hummocks and in the swamps.

Eutrophic associations with pine and birch occur rarely in Ukraine (and only in the mixed forest zone). They can be found on mires situated on old river beds and watersheds, and a considerable thickness of peat forms on the mire margins.

Grygora (1956) described a typical valley mire at Kryvukha in the Rivne region. The peat was 3.9 m thick and the moisture supply was moderate. The tree stand was *Pinus sylvestris*, 12 m tall and with a trunk diameter of 12-20 cm. Shrub species were represented by *Sorbus aucuparia* and *Salix cinerea*. *Vaccinium myrtillus*, *V. oxycoccos*, *V. vitis-idea*, *Rubus saxatilis*, *Pyrola rotundifolia* and *Menyanthes trifoliata* occurred locally with cover values up to 15%. *Hylocomium splendens* and *Pleurozium schreberi* dominated in the moss cover, and *Sphagnum recurvum*, *S. squarrosum* and *S. teres* grew between the hummocks.

Shrub-mire communities have developed widely in recent decades, but do not occupy large areas. Continuous shrub communities of *Salix cinerea*, *S. lapponum*, *S. pentandra*, *S. rosmarinifolia* and *S. triandra* are formed in places where fires or felling of swamp forests have taken place as well as on the eutrophic, grass and grass-moss mires following drainage. Bradis (1969) noted that a large number of the moderately wet sedge and sedge-moss mires have been preserved in their natural state only because of mowing which has prevented scrub development.

3 OLIGOTROPHIC MIRES (BOGS)

Oligotrophic and mesotrophic *Sphagnum* mires are only widespread in the mixed forest zone, where they account for 16% of all mires, 12% of mire-covered areas and 15% of the peat reserves. The greater part (some 10-11%) is mesotrophic (see next section) and some 4-5% is oligotrophic. Oligotrophic mires are situated in depressions on watersheds, or on parts of the flood plains of small rivers which are never subject to flooding. They are formed in areas that are poor in mineral nutrition. The largest areas of mesotrophic and oligotrophic mires are located between the Styr and Ubort' rivers (Kreminne mire), the Lva and Stvyga rivers (Ozerianske mire), the Ubort' and Perga rivers (Morochno mire 1), and the Stubl' and Goryn' rivers (Morochno mire 2) (Bradis & Bachurina 1969).

The *Sphagnum* mires of the mixed forest zone are situated at their southernmost European limit and consequently show some peculiarities. Raised bogs with pools and ridges, which are characteristic for northern regions, are absent; only small fragments of hummock-pool bogs occur locally. The mires are either slightly domed, or the domes are almost imperceptible. *Sphagnum angustifolium*, *S. flexuosum* and *S. magellanicum* dominate in the moss layer.

The southern limits of some mire species are found in this zone, namely *Andromeda polifolia*, *Carex chordorrhiza*, *C. dioica*, *C. pauciflora*, *Chamaedaphne calyculata*, *Rhynchospora alba*, *Salix lapponum*, *S. myrtilloides*, *Scheuchzeria palustris* and *Vaccinium microcarpum*.

The oligotrophic mires of Ukraine are characterised by a very poor floristic composition. Bradis (1973) noted that only 26 species of vascular plants are known to be present there. The plant communities are very similar in their species composition, but nevertheless differ markedly with aspect.

Wooded oligotrophic mires are generally found on the margins of large oligotrophic mires or cover small mires which are only moderately wet. The water table stands at 5-10 dm and only drops during droughts. The tree cover of the wooded oligotrophic mires is formed by *Pinus sylvestris*, sometimes with *Betula pubescens*. *Eriophorum vaginatum* is predominant in the grass-shrub cover, sometimes with *Ledum palustre*. *Vaccinium oxycoccos* and *V. uliginosum* occur frequently. *Andromeda polifolia*, *Calluna vulgaris*, *Carex pauciflora*, *Chamaedaphne calyculata*, *Drosera rotundifolia*, *Rhynchospora alba* and *Scheuchzeria palustris* are locally present.

The moss cover of the oligotrophic mires may form a continuous blanket, or isolated patches. It consists of *Sphagnum angustifolium*, *S. flexuosum* and *S. magellanicum*, sometimes with *S. cuspidatum*, *S. fuscum*, *S. recurvum* and *S. rubellum*. Green mosses, such as *Aulacomnium palustre*, *Dicranum bonjeanii*, *D. bergeri*, *Pleurozium schreberi* and *Polytrichum strictum*, grow on hummocks and tree trunks.

Grass-shrub oligotrophic coenoses are very rare in Ukraine. Almost the only place where they occupy a large area is on the Kreminne mire, described by Bradis (1969). *Sphagnum* coenoses are continuous for tens of kilometres, the mire being almost treeless. The central part of the mire is almost flat, with a slight formation of *Sphagnum* cushions. Large, flattened hummocks, up to 3 m in length and 0.4 m in width, occur sporadically all over the mire surface. Open water is absent and the whole surface is moist. Poorly-growing pine trees are widely separated. The grass-shrub vegetation cover is 30-40% on the expanses and 50-60% on the hummocks. *Eriopho-*

rum vaginatum (on the expanses) and *Ledum palustre* (on the hummocks) dominate. *Carex limosa*, *Rhynchospora alba* and *Scheuchzeria palustris* occur locally in the lowest places. The moss cover is continuous; in the hollows it consists of *Sphagnum cuspidatum* and *S. recurvum*, with *S. angustifolium*, *S. magellanicum* and *S. rubellum* on the hummocks, although *S. fuscum* dominates.

4 MESOTROPHIC MIRES

Mesotrophic mires in Ukraine are mainly found in the northwestern part of the mixed forest zone, but small mires occur sporadically in the more southern zones; some being found on the sandy terraces of the Dnieper, Samara and Siversky Donets rivers in the forest-steppe zone, and even in the steppe zone. They form in elongated depressions on flat watersheds and where sandy river terraces have never been flooded by running water. The mineral supply is poorer than that of the eutrophic plant associations, but is richer than in the oligotrophic ones.

In the mixed forest zone, forested mires with well-developed stands of *Pinus sylvestris* and *Betula pubescens*, and a continuous *Sphagnum* cover, dominate. Mesotrophic grass-*Sphagnum* mires, or poorly-wooded mires occur sporadically. In the forest-steppe and steppe zones there are only small, treeless sedge-*Sphagnum* mires.

The floristic composition of the mesotrophic plant communities is much poorer than that of the eutrophic ones. The same species as are found on the oligotrophic mires grow there, except for *Sphagnum fuscum*, *S. rubellum* and *Vaccinium microcarpum* and some species typical for the eutrophic mires (*Calamagrostis canescens*, *Carex flava* coll., *C. nigra*, *Lysimachia thyrsiflora*, *Menyanthes trifoliata*, *Peucedanum palustre*, *Potentilla palustris* and *Thelypteris palustris*).

5 HISTORY OF MIRE DESTRUCTION IN UKRAINE

In Ukraine, mire drainage began more than 100 years ago, especially in 1873-1898 in the Volyn', Rivne and Zhytomyr regions. More than 4700 km of drainage channels were constructed. The drained land was transformed into pastures and hay meadows.

By the turn of the century, most of the wetlands (about 15,000 ha) had already been pipe-drained. A further 5265 km of drainage channels were constructed from 1909 to 1914 (Balashev et al. 1982) and by 1917 about 430,000 ha of mires had been drained. This land was used as natural pasture.

In the ensuing period, the drainage rate varied for various reasons, but the total area of drained land increased. During the post-War period, the mire systems were heavily attacked and natural ecosystems were destroyed, the rate of this process becoming ever faster. At the beginning of 1966, 1,370,300 ha of wetlands in Ukraine had been drained, and this figure increased to 2,061,000 ha by 1976. In 1978, the total area of drained wetland amounted to 2.25 million ha, including 613,900 ha of former peatlands (about 51.2% of the original area) of Ukraine. In the various regions, the figure varies from 3.8% to 86.8%.

6 PRESENT-DAY STATE OF MIRES IN UKRAINE

There are now about 500,000 ha of undrained mires in Ukraine. The different mire regions are shown in Figure 1.

6.1 MIXED FOREST ZONE

This zone is divided into the following four regions (Fig. 1, 1-4).

6.1.1 Western Polissia

This is the western part of the mixed forest zone and is the region of Ukraine that has most mires, with 10.9% paludification in the past, and 7.3% of peat cover. Raised and transitional *Sphagnum* bogs occupy 15% of the total mire area, fens 85%. By 1977, 45% of the peat bogs of this region had been drained. Under natural conditions, the mires were mainly used for haymaking. Nowadays, parts of the drained mires are used for growing crops, or as sown pastures. A few large mire massifs have been preserved almost intact. These are the Kreminne mire (35,000 ha) and the mire massifs of Perebrody (6000 ha) and Chemeryshche (5600 ha), which adjoins the first one. Morochno 1 and Morochno 2 mires have been partly drained and are now used for peat extraction.

6.1.2 Central Polissia

This is the least boggy part of the mixed forest zone with only 1.2% paludification and 0.8% peat cover. Eutrophic mires dominate, but there are a few small mesotrophic and oligotrophic mires. Almost 42.9% of the mire area in this region has been drained, including 27% of the oligotrophic and 47.1% of the eutrophic mire areas. Before being drained, the mires were used as natural grassland of high quality and for the gathering of berries (*Vaccinium oxycoccos* and *Vaccinium uliginosum*). Parts of the mires are now wooded and about 75% is ploughed up. Some mires that are still in their natural state are preserved in the Polissia Reserve.

6.1.3 Eastern Polissia

Paludification is 4.1% and the peat cover is 2.9%. Minerotrophic mire complexes dominate. Almost all the large mires have been drained, only small parts of some mires having been preserved in their natural state.

Intensive peat extraction has taken place in the past and still continues, 20,000 ha of peat bogs having been allocated for this. Some mires were flooded when Lake Kyiv (Kiev) was created by the regulation of several small rivers.

6.1.4 Little Polissia

Paludification is 5.3% and the peat cover is 4.4%. 98.8% of the peatlands have now been drained and are used for peat and agriculture. In many places, there are abandoned pits where peat extraction once took place.

6.2 FOREST-STEPPE ZONE

Regions 5-9 (Fig. 1) make up this zone. The paludification and peat cover vary from, respectively, 3.2% and 2.8% (in region 8) to 0.48% and 0.33% (in region 9). More than half the mire areas of the zone have now been drained. Prior to the drainage, sedge and tall-grass mires with some admixture of wooded mires with *Alnus glutinosa* dominated. Following drainage, they are used as natural grassland and for peat extraction.

6.3 STEPPE ZONE

This zone, region 10 in Figure 1, has few mires.

6. 4 AREA ADJOINING THE CARPATHIANS

This is regions 11-13 in Figure 1. The paludification here is 1.2% and the peat cover is 1%. The largest area of mire used to be on the flood plain of the River Dnieper, but this mire complex has now been drained and the mire vegetation has been replaced by meadow land. Only the Turova Dacha complex and a few small mires are preserved in their natural state.

7 POSSIBILITIES FOR USING MIRES WITHOUT DRAINING THEM

Undrained mires were traditionally used for haymaking. The hay yield amounted to 5000 kg per ha on some mires in western Polissia. Another traditional use was berry harvesting. The yields here amounted to 1000 kg per ha for *Vaccinium oxycoccos* and 300-400 kg per ha for *Vaccinium uliginosum*. Some berry communities are now being restored, partly by planting. In addition, more than 20 species of medicinal plants grow there and may be gathered in limited quantities. The mires are also very important for hunting and recreation.

8 PERSPECTIVES FOR MIRE CONSERVATION

Fortunately, mire destruction stopped at the beginning of the 1980s when it was decided to preserve a considerable proportion of the mires in their natural, undrained state. Measures were introduced to use the mires without damaging them further.

The first list of mires requiring protection was compiled by E. Bradis and A. Bachurina in 1969. It included 14 mire massifs. In 1982, a new list of Ukrainian mires which were in need of protection was published. It included 42 typical mires that are rare or unique in Ukraine.

At present, mire massifs and their elements are preserved in the Polissia Reserve (20,104 ha), the Shatsky, Carpathian and Synevir National Parks, and a number of other areas. The creation of a regional landscape park, "Prypiat-Stokhod", with many natural monuments, as well as the extension of existing reserves is foreseen. The programme of investigations, inventorisation and restoration of the biome complex of Polissia (in collaboration with similar agencies in the Netherlands and Germany), as well as a programme for compiling an inventory of the mires and wetlands of Ukraine in collaboration with the Netherlands Government and the IWRB, are due to begin.

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Hydrological mire types in the Polish lowlands and their vegetation

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ABSTRACT

Kloss, M. & Sienkiewicz, J. 1995. Hydrological mire types in the Polish lowlands and their vegetation. *Gunneria 70*: 139-148.

Based on the type of water supply, the following four principal mire types have been distinguished: ombrogenous (fed solely by precipitation), topogenous (fed by a slightly inclined water table with a low flow rate and surface runoff), soligenous (fed by groundwater, apparently with an inclined water table) and fluviogenous (on seasonally flooded river plains).

Abundant carpets of the *Sphagnetum magellanici*, *Ledo-Sphagnetum magellanici* communities and/or pine bog forests (*Vaccinio uliginosi-Pinetum*) develop on ombrogenous mires. Alder forests (*Carici elongatae-Alnetum*), willow scrub (*Salicetum pentandro-cinerae*) or reed beds and tall sedge communities (e.g. *Caricetum elatae*) grow on seasonally inundated topogenous mires. Poor birch-alder woods (*Thelypteridi-Betuletum*), spruce bog forest (*Sphagno girgensohnii-Piceetum*) and spruce-birch woods (*Betulo pubescentis-Piceetum*) are typical of topogenous mires with a capillary water supply. Sedge-moss communities belonging to the alliances *Caricion lasiocarpae* and *Caricion nigrae* (*fuscae*) are typical of soligenous mires, which may also be covered by a large group of forest communities. Fluviogenous mires are covered by communities typical of flooded areas, such as the *Phragmitetum*, *Typhetum*, *Scirpetum*, *Glycerietum* and tall sedge associations, including *Caricetum elatae*, *C. acutiformis*, *C. rostratae*, *C. ripariae* and *C. acutae*.

1 INTRODUCTION

The variety of mires found in the Polish lowlands is mainly a result of differences in hydrological conditions, i.e. water supply and outflow. The chemical composition of the water is another major factor. Depending upon the type of water inflow, the following four major types of mire can be distinguished: ombrogenous, topogenous, soligenous and fluviogenous (Sjörs 1948, 1983, Gore 1983, Okruszko 1983).

Ombrogenous mires are fed exclusively by precipitation and develop on terrain with no extraneous groundwater. They seldom occur in the Polish lowlands and account for only about 5-7% of the total mire area. Topogenous mires are formed in situations where the land relief favours the accumulation of drainage water and represent a kind of underground "water body". Depending upon the hydrological situation, two types of topogenous mire can be distinguished: seasonally inundated ones (flood plain) and those supplied by capillary water rise. Soligenous mires are fed by a mobile source of groundwater, such as springs, and are often encountered on sloping terrain, mostly on the sides of river valleys. Fluviogenous mires are formed where water is dammed up and occur on river valley floors. These types of water supply conditions frequently intergrade and are not truly separable. This results in a complex of mire types.

Analyses of mire vegetation in the Polish lowlands show that the above-mentioned hydrological variation of major types of mire is generally reflected in the differentiation of the mire plant communities. However, even though certain types of vegetation show a particular association with one or other of these basic types, the classification of mire vegetation is more complicated and does not closely follow the above hydrological division of peatlands.

2 HYDROLOGICAL MIRE TYPES

Ombrogenous mires (Fig. 1) are restricted to those parts of watersheds that are subject to neither inflow nor outflow, and are typically produced by precipitation. They are associated with the moraine landscape formed by glaciers from the youngest glaciation period in northern Poland. The peat deposits are predominantly raised bog formed by *Sphagnum* species and have a low pH, low ash content and low decomposition rate. They are sometimes underlain by thin layers of moss peat, sedge-moss peat, or transitional peat types. Lacustrine sediments occur below the peat deposits in most of the mires and are usually detrital gyttjas. Ombrogenous mires have small catchments, lateral inflow being limited to the mesotrophic lagg (Kloss 1993).

Topogenous mires (Figs. 2 and 3) usually occur on the margins of watersheds, in areas situated between river basins. Mire development is confined to situations in which groundwater accumulates in concave landforms, or where lakes are fed by lateral inflow. The water table in the mire and its surroundings is usually slightly inclined and the groundwater has a low rate of flow. Such mires are also frequently formed in enclosed basins of variable size, or hollows with only a slight outflow of water. The peat deposits are mostly of the alder- or willow-carr type, sedge-moss peats or, less frequently, tall sedge or sedge-reed peats. The peat stratification is generally horizontal and the mire surface is flat. When peat is forming in topogenous mires with a capillary groundwater supply (Fig. 2), its upward growth eventually raises the mire surface above the influence of groundwater, bringing about a

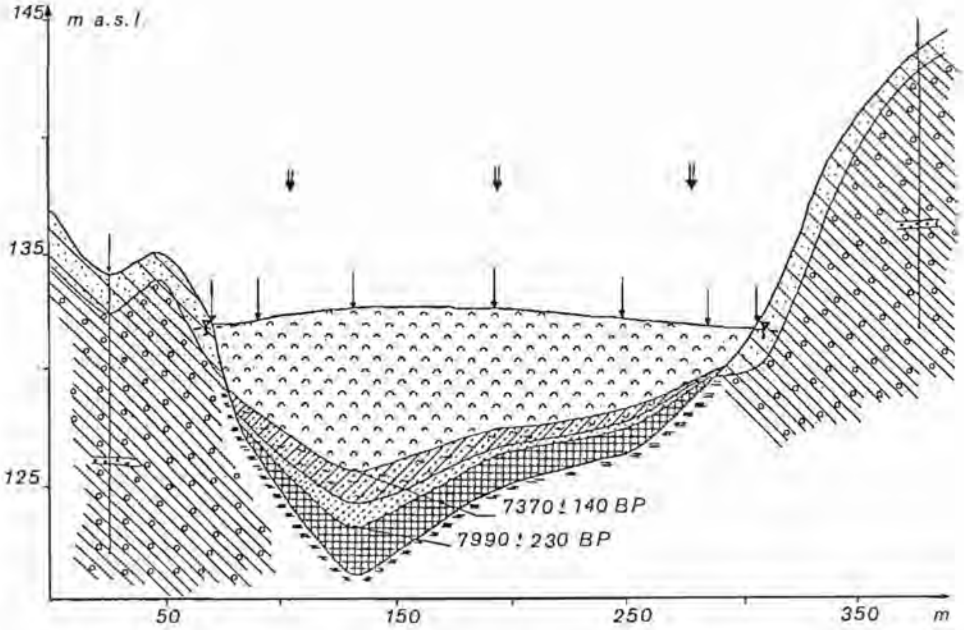
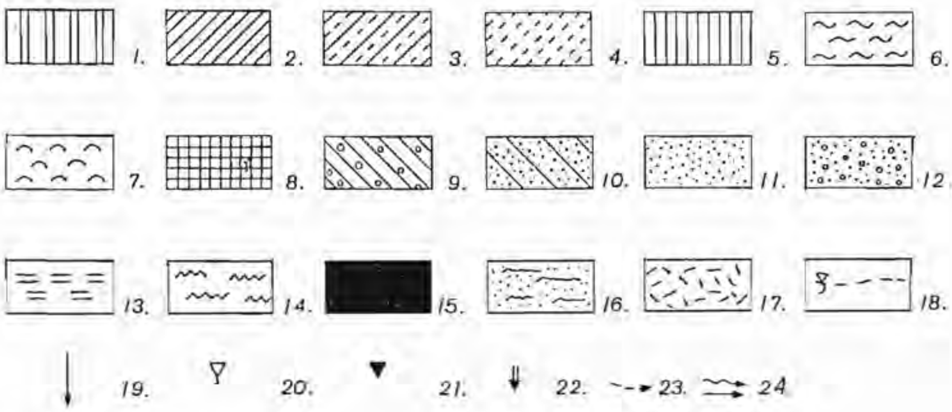


Fig. 1. Stratigraphical and hydrological situation in an ombrogenous mire (near Mikołajki, Masurian Lakeland). Stratigraphical symbols used in Figures 1-5: 1. reed peat, 2. tall-sedge peat, 3. sedge-moss peat, 4. moss peat, 5. alder-osier peat, 6. *Sphagnum*-sedge peat, 7. raised *Sphagnum* peat, 8. gyttja, 9. boulder clay, 10. loamy sand, 11. sand, 12. sand with gravel, 13. clay, 14. silt, 15. mud, 16. diluvial deposit, 17. alluvial deposit, 18. water level, 19. bore-core sampling point, 20. bored water level in a core, 21. stabilised water level, 22. precipitation, 23. groundwater, 24. runoff or flooding.



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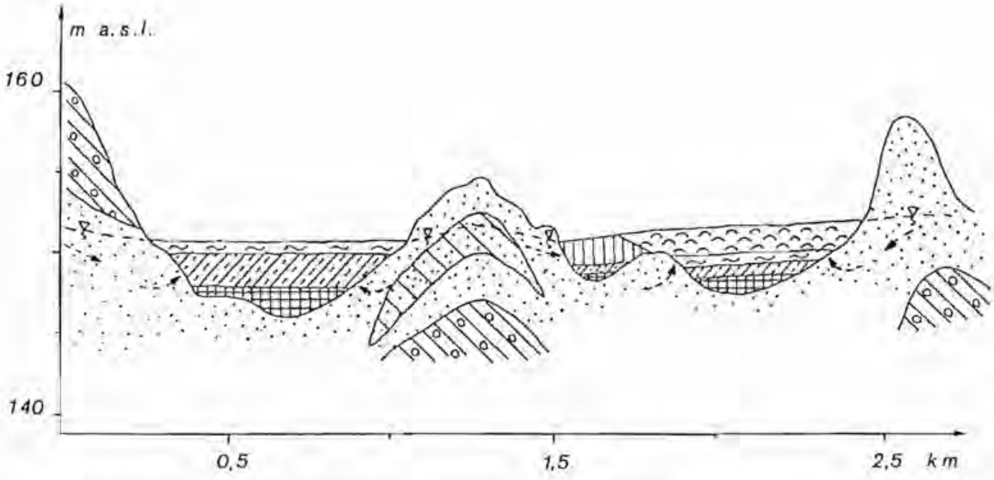

Fig. 2. Stratigraphical and hydrological situation in a topogenous mire with capillary water supply (Machnacz, Knyszyn Forest). See Figure 1 for explanation of symbols.

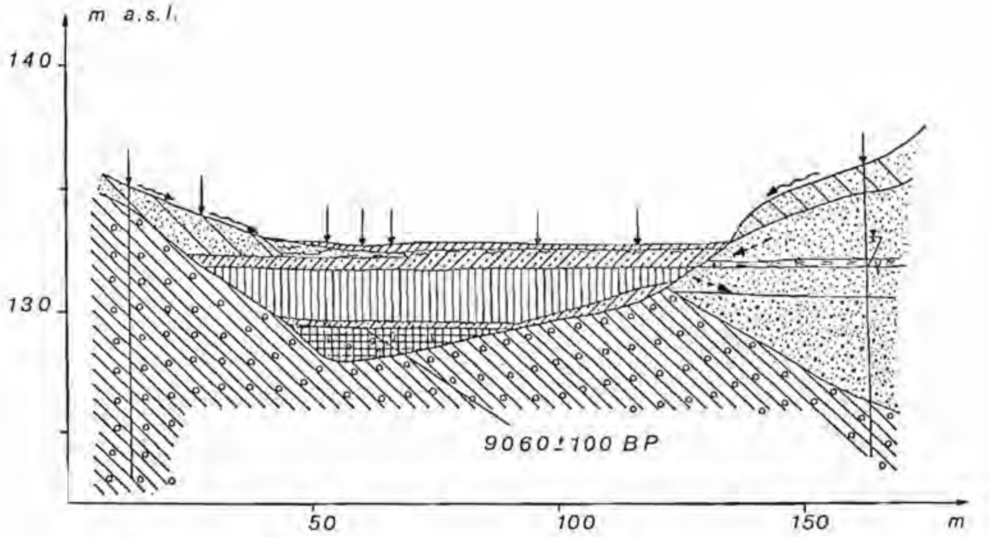

Fig. 3. Stratigraphical and hydrological situation in a topogenous inundated mire (near Mikołajki, Masurian Lakeland). See Figure 1 for explanation of symbols.

decline in the nutrient status. The moisture content of the surface layers of the mire then depends upon supply of precipitation. Ultimately in the mire development, an oligotrophic stage is initiated, marked by the accumulation of *Sphagnum*-sedge peats of transitional character, or raised bog *Sphagnum* peats.

Topogenous inundated mires (Fig. 3) develop in depressions and are fed by either periodic spillage from surface runoff (rainfall or melting snow), or seasonally high groundwater. Accumulation of diluvial sediment sometimes occurs in the marginal parts of such mire basins (Żurek 1990, 1992, Kloss 1993).

Soligenous mires (Fig. 4) develop in areas where aquifers reach the surface on valley sides. They are confined to sites influenced by springs or seepage. The mire water level is apparently inclined. A regular and abundant supply of groundwater favours the development of moss-sedge communities such as *Caricetum lasiocarpae* and *Caricetum diandrae*, as well as the accumulation of little humified moss-sedge peats. A less intensive supply of groundwater is marked by a domination of alder-forest peats in the mire stratigraphy. The mire surface is either inclined along the slope, or is uplifted to form walls or cupolas surrounding springs (Dembek 1993).

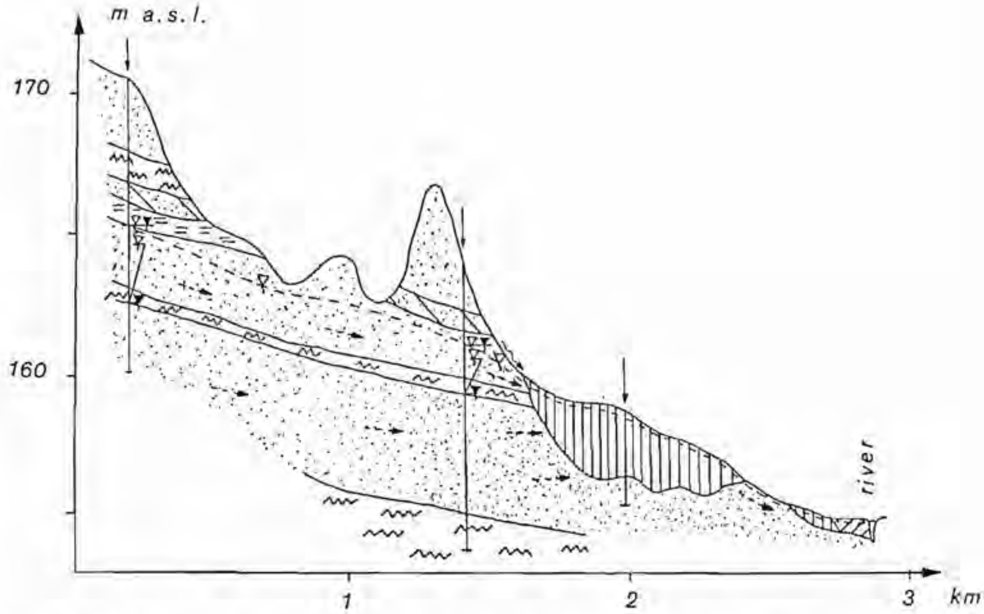

Fig. 4. Stratigraphical and hydrological situation in a soligenous mire (Białowieża Forest). See Figure 1 for explanation of symbols.

Fluviogenous mires (Fig. 5) become established in channelled depressions in inundated valleys where the river bed is more or less level and abundantly overgrown by rushes. The peat stratigraphy shows that alluvial sediments underlie well-decomposed alder-forest peats, followed above by moderately decayed reed-sedge and sedge peats. The surface layers of such mires are heavily silted and the mire surface is flat (Oświt & Dembek 1989).

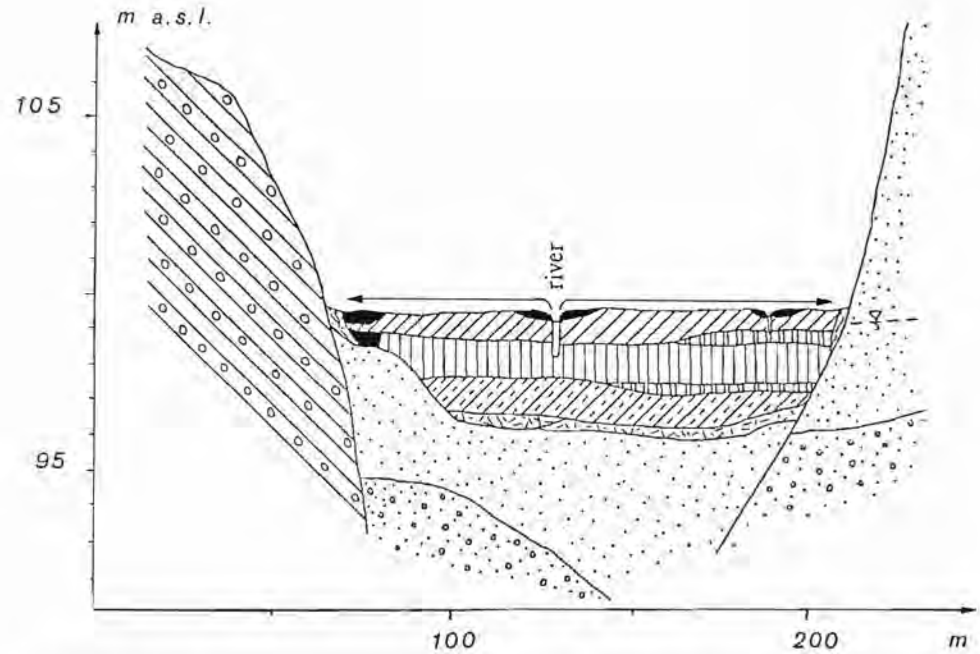

Fig. 5. Stratigraphical and hydrological situation in a fluviogenous mire (Bzura river valley). See Figure 1 for explanation of symbols.

3 SYNTAXONOMY OF MAJOR PLANT COMMUNITIES OCCURRING ON MIRES OF THE POLISH LOWLANDS

The syntaxonomical classification of mire plant communities (after Matuszkiewicz (1981)) is shown in Table 1 and is based on the principles of the central European phytosociological approach introduced by Braun-Blanquet (1964).

The relationships between the mire types distinguished and the relevant vegetation units are shown in Table 2.

Table 1. Syntaxonomical classification of major mire plant communities (after Matuszkiewicz (1981)

COMMUNITIES CLASS	ORDER	ALLIANCE	ASSOCIATIONS
Reed beds & tall sedge			
Phragmitetea R.Tx. et Preisg.1942	Phragmitetalia Koch 1926	Phragmition Koch 1926	1 Phragmitetum australis (Gams 1927) Schmale 1939 2 Equisetetum fluviatilis (limosi) Steffen 1931 3 Typhetum angustifoliae So 1927 4 Typhetum latifoliae So 1927 5 Glycerietum aquaticae Hueck 1931 6 Scirpetum lacustris Chouard 1924
		Magnocaricion Koch 1926	7 Caricetum elatae Koch 1926 8 Caricetum acutiformis Sauer 1926 9 Caricetum vesicariae Br.-Bl. et Denis 1926 10 Caricetum rostratae Rubel 1912 11 Caricetum appropinquatae (paradoxae) (Koch 1926) So 1938 12 Caricetum ripariae So 1928 13 Caricetum acutae (gracilis) R.Tx. 1937 14 Thelypteridi-Phragmitetum Kuiper 1957
Sphagnum-sedge, sedge-moss & moss			
Scheuchzerio-Caricetea nigrae (fuscae) R.Tx. 1937	Scheuchzerietalia palustris Nordh. 1936	Rhynchosporion albae Koch 1926	15 Caricetum limosae Br.-Bl. 1921 16 Rhynchosporetum albae Koch 1926
		Caricion lasiocarpae Van den Berghen ap. Lebr. 1949	17 Caricetum lasiocarpae Koch 1926 18 Caricetum diandrae Jon. 1932 em. Oberd. 1957 19 Sphagno-Caricetum rostratae Steffen 1931
	Caricetalia nigrae-(fuscae) Koch 1926 em. Nordh.1937	Caricion fuscae Koch 1926 em. Klika 1934	20 Carici canescentis - Agrostietum caninae R.Tx.1937 (Caricetum nigrae (fuscae))
Sphagnum bog			
Oxycocco-Sphagnetea Br.-Bl. et R.Tx. 1943	Sphagnetalia magellanici (Pawl. 1928) Moore 1968	Sphagnion magellanici Kästn. et Flösn. 1933 em.Dierss. 1975	21 Sphagnetum magellanici Kästn. et Flösn. 1933 22 Ledo-Sphagnetum magellanici Sukopp 1959 em. Neuhäusl 1969
Alder, birch & willow swamp woodland			
Alnetea glutinosae Br.-Bl. et R.Tx. 1943	Alnetalia glutinosae R.Tx. 1937	Alnion glutinosae: Meijer Drees 1936	23 Carici elongatae-Alnetum Koch 1926 24 Thelypteridi-Betuletum pubescentis Czerwiński 1972 (Sphagno squarrosi-Alnetum Sol.-Górn. 1975) 25 Salicetum pentandro-cinereae (Almq. 1929) Pass. 1961 (Salici-Franguletum Malc. 1929) 26 Betulo-Salicetum repentis Oberd. 1926
Pine bog, spruce & birch-spruce bog forest			
Vaccinio-Piceetea Br.-Bl. 1939	Vaccinio-Piceetalia Br.-Bl. 1939	Dicrano-Pinion Libb. 1933	27 Vaccinio uliginosi-Pinetum Kleist 1929
		Vaccinio-Piceion Br.-Bl. 1938	28 Sphagno girgensohnii-Piceetum Polakowski 1962 29 Betulo pubescentis-Piceetum Sokołowski 1980

Table 2. Hydrological types of mires and related vegetation

HYDROLOGICAL TYPES OF MIRES	PHYTOSOCIOLOGICAL UNITS
	Sphagnetum magellanici
	Ledo-Sphagnetum magellanici
Ombrogenous mires	Vaccinio uliginosi-Pinetum
	Caricetum limosae
	Rhynchosporetum albae
	Sphagno-Caricetum rostratae
	Caricetum lasiocarpae
	Caricetum diandrae
Topogenous mires with capillary water supply	Caricici anescentis-Agrostietum caninae
	Sphagno girgensohnii-Piceetum
	Betulo pubescentis-Piceetum
	Thelypteridi-Betuletum pubescentis
Soligenous mires	Betulo-Salicetum repentis
	Carici elongatae-Alnetum
	Salicetum pentandro-cinereae
	Caricetum elatae
Topogenous mires inundated	Caricetum acutiformis
	Caricetum vesicariae
	Caricetum rostratae
	Caricetum appropinquatae (paradoxae)
	Caricetum ripariae
	Caricetum acutae (gracilis)
	Thelypteridi-Phragmitetum
Fluviogenous mires	Phragmitetum australis
	Equisetetum fluviatilis (limosi)
	Typhetum latifoliae
	Typhetum angustifoliae
	Scirpetum lacustris
	Glycerietum aquaticae

4 CONCLUSIONS

Ombrogenous mires are characteristically covered by a dense carpet of *Sphagnum* formed by *Sphagnion magellanici* or pine bog forest communities (*Vaccinio uliginosi-Pinetum*).

Topogenous mires with a capillary groundwater supply are typically associated with forest vegetation, including poor alder-birch swamp and spruce-birch bog, or spruce bog, communities. Inundated topogenous mires are frequently covered by alder woods or willow scrub, or tall sedge communities such as *Caricetum elatae*.

On soligenous mires with a permanently waterlogged substrate, sedge-moss communities, such as *Caricion lasiocarpae* and *Caricion nigrae (fuscae)*, develop. Under conditions of mineral-rich lateral seepage, or surface runoff, the eutrophic communities characteristic of alder woods (*Carici elongatae-Alnetum*) develop.

On fluviogenous mires, the predominant type in the Polish lowlands, a flood plain vegetation with reed beds (*Phragmition*) and tall sedge communities (*Magnocaricion*) develops. However, in general, the type of plant association growing on a mire cannot be used as an indicator of a given hydrological type of wetland, since identical vegetation units may be found on several types of mires. For example, the tall sedge communities, such as *Caricetum elatae* or *Caricetum appropinquatae*, grow on both topogenous inundated mires and fluviogenous mires. The variety of phytocoenoses results primarily from differences in the degree of waterlogging and in nutrient status. The influence of the groundwater supply is consequently indirect, and is capable of being greatly modified by a wide range of factors. An adequate classification of mires can therefore only be made using inter-related criteria that combine the vegetation with other characteristics of mires, such as mire stratigraphy, hydrology, the nutrient status of the water, and the hypsometry and relief of the surrounding terrain.

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Distribution and conservation of mires in Poland

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ABSTRACT

Sienkiewicz, J. & Kloss M. 1995. Distribution and conservation of mires in Poland. *Gunneria 70*: 149-158.

The state of mires in Poland is reviewed, including the differentiation and distribution of natural mires and threats resulting largely from drainage and associated changes in catchment management. Poland has three distinct mire zones, marked by different frequencies of mires; the northernmost one has 80% of the peat-producing ecosystems. Much of the total mire area is given over to agriculture and forestry. About 200,000 ha of mires have been altered by past and present-day peat extraction. About 80% of mire ecosystems are subject to various forms of human intervention, and only some 18% of the mire area is in a natural or semi-natural state. Only some 8700 ha are in strictly protected mire reserves. Most of the original types of mire plant communities are protected in these reserves, but an average mire reserve measures less than 100 ha. Some fens are protected in national parks or Ramsar sites, the combined protected area being about 100,000 ha.

1 INTRODUCTION

Poland has a total land area of about 31,268,300 ha, the mire area amounting to some 1.3 million ha, or about 5% of the country. Much of this has been reclaimed for agriculture and forestry and only a few peat resources remain untouched after centuries of human intervention. Every kind of mire formation typically found in central Europe has been recognised in Poland, including a group of rheophilous mires that are distributed throughout the country. Ombrophilous mires are largely confined to two climatic zones, the Baltic coast and the mountains.

The rheophilous (lowland and transitional) fens in Poland are classified according to their topographical and hydrographical features into three hydrological types: topogenous, soligenous and fluviogenous. Together, these account for 95% of the peat-producing ecosystems, with fluviogenous mires dominating in the lowlands. The ombrophilous mires (raised bogs) are found mainly in the coastal region in the north and the mountains in the south. Together, they account for only about 5% of the total peatland area. The variety of biocenoses associated with all these mires is typically determined by hydro-ecological conditions, such as waterlogging of the soil and the presence or absence of surface flooding (Okruszko 1993).

It is estimated that there are 55,000 mires and that they have an average thickness of 1.5 m. They are an important factor influencing the hydrological balance of the natural drainage systems of the country.

2 MIRE TYPES AND THEIR DISTRIBUTION

In Poland, as in most central European countries, a zonal pattern of mire distribution follows the pattern of successive glaciations (Figs. 1 and 2). Three distinct zones relating to the percentage cover of peatlands have been distinguished. The northernmost one, whose southern boundary largely coincides with the southern boundary of the most recent glaciation, contains most of the country's wetlands (65%) and has a peat surface index of 7.7; the inter-

Fig. 1. Mires of Poland. - - - southern boundary of Baltic glaciation,
⊥⊥⊥ southern boundary of central Poland glaciation (after Żurek (1987)).

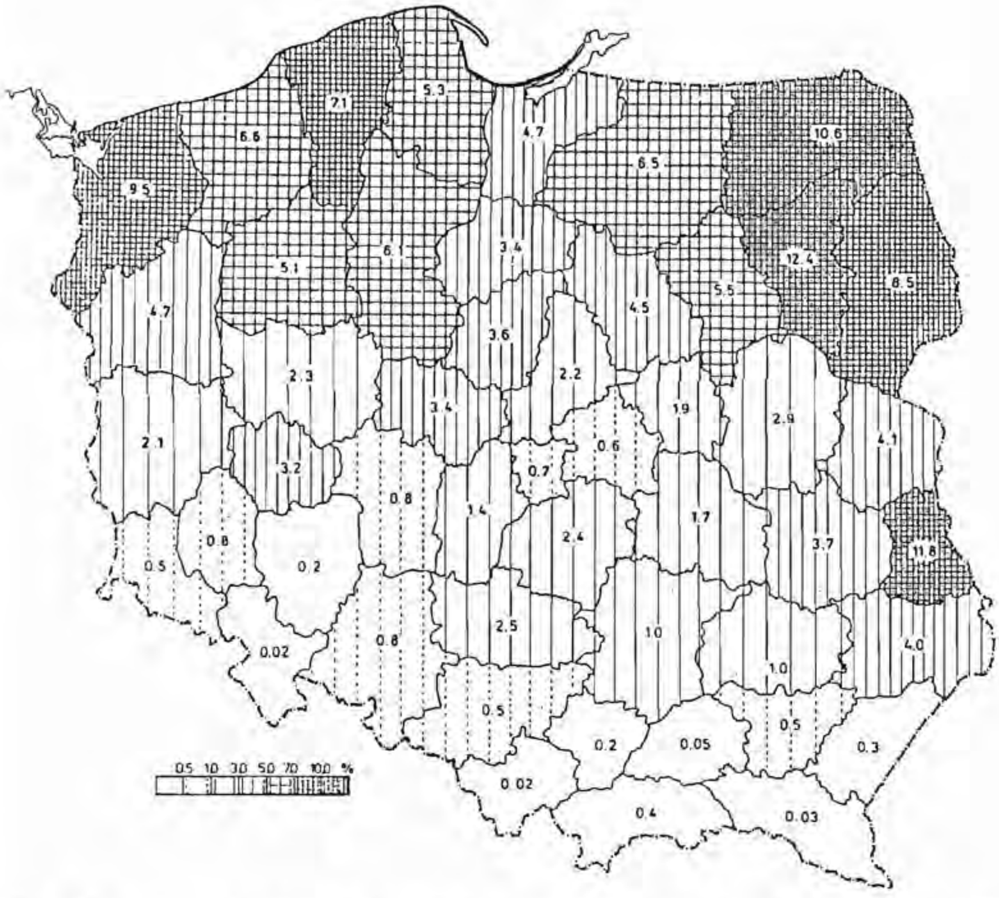

Fig. 2. Percentage distribution of mires in the various provinces of Poland (after Denisiuk et al. (1991)).

mediate zone of lowlands comprises 33% of the total mire area and has a peat surface index of 3.2; and the southern zone, the poorest in mires (2%), has a peat surface index of 0.4 (Jasnowski 1978).

Although the average size of mires in Poland is small, amounting to only a few hectares, there are numerous lowland, fluviogenous and soligenous mires which rank with the largest and best preserved in Europe, such as the 100,000 ha mire in the Biebrza valley, the 50,000 ha mire in the Noteć valley, and one of about 50,000 ha at the mouth of the River Odra. In addition, smaller mires, but none smaller than 10,000 ha, are situated in the valleys of the Łeba, Obra, Warta, Omulew, Szkwa, Pisa and Narew rivers (Krzemiński 1994).

Most peatlands (roughly 80%) in northern Poland have developed through infilling of lakes.

Of the soligenous peatlands, spring mires and ombrophilous mires (raised bogs) are mostly found in the northern zone. The latter are subdivided into four categories that differ in structure and peat quality, the Baltic (convex), the Subatlantic with cross-leaved heath (*Erica tetralix*), the continental and the subalpine raised bogs.

The Baltic and Subatlantic heath raised bogs, with *Sphagno-Ericetalia* vegetation, are confined to the Baltic coastal area which has a humid climate with an annual precipitation of 600-700 mm and a relatively low evaporation rate. The continental raised bogs, with *Vaccinio uliginosi-Pinetum* woodland, have their western European boundary in eastern Poland.

The upland plateau, subalpine mires in the Karkonosze mountains resemble the Scottish and Irish blanket bogs. The vegetation on these mires includes such rare glacial relicts as dwarf birch (*Betula nana*) and cloudberry (*Rubus chamaemorus*).

These mire ecosystems still support a rich flora and fauna, despite considerable damage resulting from peat cutting, drainage and eutrophication. Vast expanses of mires, for instance in the Biebrza valley, provide homes for 231 species of birds, including the rare white-tailed eagle (*Haliaetus albicilla*), the national emblem of Poland.

Phytosociological studies have shown that the mires in Poland host more than 50 different plant associations, including 40 non-forest communities and some 15 woodland types. Recent plant censuses estimate the entire mire flora at about 200 bryophyte and 700 vascular species, the latter constituting about one third of the total of 2200 vascular species found in Poland (Jasnowski 1980).

3 MAJOR THREATS TO MIRE ECOSYSTEMS

In general, the chief danger arises from the drainage and excessive drying-out of peat deposits, when permanent lack of waterlogging leads to decrease in organic matter and soil contraction (Okruszko 1981). Shrinkage of peat deposits due to accelerated mineralisation occurs at a rate of 1-1.5 cm per year in fen peats and about 3 cm per year in raised bog peats (Okruszko 1979).

Recent assessments indicate that an increase in the water deficit within an area of about 120,000 km^2 in the Polish lowlands is mostly due to wetland drainage and deforestation (Ryszkowski & Bałazy 1994). Large-scale drainage of riverside wetlands took place in the 18th century in the valleys of the

Odra, Warta and Noteć rivers and in the 1920s further areas of peatland were reclaimed in northern and eastern Poland. At present, 82% of the drained mire area is managed as meadow and pasture (IUCN 1991).

Another major threat has been peat cutting. About 200,000 ha of peatland have suffered damage due to peat exploitation, especially for fuel after World War II. Peat is now extracted largely for domestic, medicinal and horticultural purposes, although a certain amount is exported. Other threats are relatively new and result from raw sewage pollution, industrial discharges and waste dumping, all of which lead to eutrophication of mires and synanthropisation and simplification of the original vegetation, which changes into reed and cat-tail communities (*Phragmitto-Typhetum*). Tourism and recreation increasingly tend to affect some wetlands and threaten the wildlife of mires in many ways. Mire fires, which occur frequently in spring and summer, have posed a considerable threat recently.

Changes in the vegetation cover have been observed on more than 82% of the mire ecosystems where human influences are more or less conspicuous, and only 18% of mires have retained their natural or semi-natural status. Polish mires can therefore be increasingly regarded as a severely threatened resource.

In many cases, too, the abandonment of traditional agricultural practices, such as hay mowing, leads to an impoverishment of the local biodiversity of the mire vegetation. This kind of threat is also new on a countrywide scale and results from the major, ongoing, socio-economic developments.

Analysis of the magnitude and rate of change in mire vegetation up to the end of the 1970's has shown that about 172 vascular plants were already endangered then, i.e. almost 56% of the native mire flora (Jasnowski 1980). The recent Polish Plant Red Data Book (1993) lists 19 mire species as vulnerable or seriously endangered due to wetland drainage. One species *Cornus suecica* is now extinct, while others such as *Betula nana*, *Carex disperma*, *Chamaedaphne calyculata*, *Ligularia sibirica*, *Hammarbya paludosa*, *Ophioglossum azoricum*, *Rubus chamaemorus*, *Salix myrtilloides* and *Viola epipsila* are regarded as highly vulnerable. Some sedge (*Carex*) and rush species (*Juncus*, *Schoenus*) are also becoming increasingly vulnerable. These include *Carex magellanica*, *C. globularis*, *C. strigosa* and *C. vaginata*, as well as *Rhynchospora fusca*, *Schoenus nigricans*, *Trichophorum alpinum* and *T. cespitosum*. In addition, many still common mire and wet meadow species are also threatened. These include sedges such as *Carex elata*, *C. lasiocarpa*, *C. pseudocyperus* and herbs such as *Calla palustris*, *Epipactis palustris*, *Gentiana pneumonanthe*, *Iris sibirica*, *Menyanthes trifoliata*, *Pedicularis palustris*, *Ranunculus lingua*, *Trollius europaeus* and many orchids (Denisiuk et al. 1991).

4 MIRE CONSERVATION

Effective mire conservation includes all activities directed towards protecting and supporting the total biological diversity of sites and ecosystems and safeguarding the sustainability of mire ecosystems in all their complexity.

In general, the distribution of mire reserves in Poland corresponds to the natural distribution of mires. The majority of reserves are concentrated in the northern part of the country, beyond the reach of industrial pollution, but some individual mires, or clusters of peatland reserves, are scattered throughout the country in the lowlands. In southern Poland, where threats from air pollution and other anthropogenic activity are greatest, there are relatively few mire reserves.

Apart from strict protection in mire reserves, some large peat-producing ecosystems are protected in 10 of the 19 Polish national parks, which together cover 240,853 ha. Some of the parks were established expressly to preserve extensive peatland areas (e.g. the Poleski National Park (4913 ha), the Biebrzański National Park (59,223 ha), and part of the Słowiński National Park (18,247 ha)). Protected peatlands make up extensive tracts of the Ramsar sites, including Słońsk, Świdwie, Karaś Lake and Jezioro Siedmiu Wysp. It has been proposed to add a further three wetland sites to the Ramsar List. The total mire area accorded protected status is now roughly 100,000 ha.

From one reserve of about 3 ha in 1952, the area of strictly protected mires grew to 51 reserves covering 3100 ha in 1980 and to the current (1994) figures of 106 reserves and 8759 ha, giving an average size of about 84 ha. However, this constitutes only 0.67% of the total mire area. Despite only modest achievements as regards the area of strictly protected mires, Poland can boast of having a relatively effective mire biodiversity conservation, i.e. preservation of mire plant communities. Most of the associations identified on the Polish mires are protected in reserves, the most widespread ones being the raised bog communities of *Sphagnetum magellanici* and a dystrophic community of *Caricetum limosae*, both present in more than 30 reserves. Other mire communities that are frequently encountered in the reserves include moss-sedge associations of *Caricion lasiocarpae*. A variety of rush and reed-bed communities (*Phragmition*) are also protected, as well as meadows covered by *Molinietum caeruleae* and wet meadow of *Cirsio-Polygonetum* (Denisiuk et al. 1990).

5 FUTURE ACTIVITIES

A detailed countrywide evaluation and description of wetland resources remains to be done. This has greatly delayed a comprehensive national strategy for the wise use and restoration of wetland. A national inventory of mires, made between 1955 and 1970, comprised about 50,000 ha of peatlands, complete with an assessment of mire type, surface features, peat depth and stratigraphy, as well as a characterisation of the vegetation cover and type of substrate. However, these data have so far not been effectively utilised, although the data base exists at the Institute for Land Reclamation and Grassland Farming. In 1991, a new project was launched to supplement and revise the data bank. Entitled «Characterisation and evaluation of wetlands and grasslands in Poland in relation to natural environment protection», this project is designed to provide a basis for drawing up a strategy for wetland and grassland protection and for formulating guidelines for effective wetland conservation (Okruszko et al. 1994). The project has been completed in 1995. A Red Book of Biotopes is currently under preparation, which will help to identify threatened wetlands and promote their conservation.

Fens and fen reserves are in need of special protection at the moment, since they are most seriously endangered. Fen reserves, where appropriate, should have a less strict reserve status, since in many cases the maintenance of biodiversity in such reserves requires the retention of some agricultural practices, such as hay mowing. A minimum surface area for such mire reserves should exceed 0.5 ha (Denisiuk 1990).

New schemes involving the restoration of some degraded mire ecosystems by artificial paludification, or raising the water level in some way in order to restore the near-natural status of such mires, are becoming increasingly popular (Okruszko 1993).

The most important action is to introduce changes, both legislative and in the mentality of people through education on ecology, focusing on possibilities for the wise use of wetlands and their sustainable management. This is especially urgent in view of the emerging threat to mire ecosystems in Poland, associated, among other things, with increased peat cutting for export.

So far, there is an absence of legal restrictions on private landowners that could aid the effective conservation of wetlands. There is also a need for municipal planning departments to recognise the wise use of wetlands, and the education of the general public needs improving. In view of the ongoing socio-economic changes, the situation for nature conservation in Poland is particularly difficult.

6 SUMMARY

Poland has a total land area of 31,268,300 ha, 1.3 million ha of which consist of mire. The country lies within the zone of rheophilous mires which constitutes about 95% of the entire mire area, ombrophilous mires accounting for only 5%. The distribution of mires is highly irregular, with more than 80% being situated in northern Poland in a lakeland landscape dominated by glacial deposits from the last Ice Age. The major threats to peat-producing ecosystems are drainage, peat cutting, sewage pollution, waste dumping and fires. Over half the peat bogs in northern Poland have been transformed into wet meadows and pastures. Only 18% of the mires are considered to be in a natural or semi-natural state. The mires in the lowlands are especially vulnerable to various threats, mostly drainage and peat cutting, which result in excessive drying-out and shrinkage of the peat and accelerated mineralisation. The average annual rate of decrease in the thickness of peat deposits is about 1.5 cm in fens and 3 cm in raised bogs.

Over 50 plant communities have been identified among the mire vegetation types. This testifies to the considerable biodiversity of Polish mires. 40 have already been given strict protection in about 100 mire reserves. The raised bog vegetation is the main object of protection. Peat-producing ecosystems are also protected in national parks and Ramsar sites, so that the entire mire area that is accorded protected status is about 100,000 ha, 8759 ha being in strictly protected mire areas. However, the protection of mire ecosystems is becoming increasingly difficult in Poland under the pressures of a national economy that is undergoing transformation, contributory factors being the absence of a consistent national policy of wetland conservation and effective legal restrictions on private landowners.

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The Norwegian national plan for mire nature reserves: methods, criteria and results

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ABSTRACT

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The various steps employed when drawing up the Norwegian mire plan are described. Preliminary study of aerial photographs was the principal basis for selecting localities for subsequent field work. The main emphasis of the field work was on: a) hydromorphological mire types, b) vegetation, c) flora. Sixteen criteria were used to assess the conservation value of the mire localities. The criteria were grouped in three categories to indicate: 1) value as a natural feature, 2) scientific value, 3) assessment of the present state and vulnerability. Each mire locality was further assessed in relation to its conservation value as a type site (representative within its phytogeographical region) and as a site of special interest (mires of more unusual or extreme types). Each mire was classified in one of five conservation categories: 1) international value, 2) national value, 3) regional value, 4) local value, 5) no conservation value. Some 1000 mire localities have been investigated in Norway, and are described in 20 county reports. To date, 217 mire reserves have been established, together with mire localities conserved within national parks, wetland reserves, etc.

1 INTRODUCTION

In 1966, the Norwegian National Council for Nature Conservation proposed that work should commence on a national plan for mire nature reserves (Gjærevoll 1967), and surveys began in 1969. The worldwide mire conservation plan TELMA (in Norway, part of the International Biological Program) was amalgamated with the national plan (Moen 1973). The Norwegian Peat Society was responsible for the three northernmost counties of Norway (Hornburg 1973), and the Department of Botany at the Museum of the University of Trondheim was responsible for the rest of the country (Gjærevoll 1973, Moen 1973). Since 1969, more than 1000 localities, generally comprising more than one discrete mire, have been investigated.

Mire terminology, classification system, etc. used during the mapping followed those that had been in use in Fennoscandia for many years (e.g. Sjörs 1948, Malmer 1973). The methods employed are described in detail in Moen (1973, 1985) and in reports published for the various counties (e.g. Moen & Wischmann 1972, Flatberg 1976, Vorren 1979, Moen & Pedersen 1981, Moen 1983, Moen et al. 1983, Singsaas & Moen 1985). In mire reports and publications after 1980, the following set of geographical concepts (equivalent to Ivanov's (1981) microform, microtope, mesotope and macrotope) has been employed: mire feature (Norwegian - myrstruktur), mire site (- myrelement), mire synsite (- myrelementsamling), mire complex (- myrkompleks); see Moen & Singsaas (1994: 30 ff).

The present paper summarises:
1. the methods used in the national plan for mire nature reserves
2. the main criteria used for conservation purposes
3. the conservation status of mires in Norway.

2 INVENTORIES

The various steps in the procedure used to draw up the mire plan are shown in Figure 1.

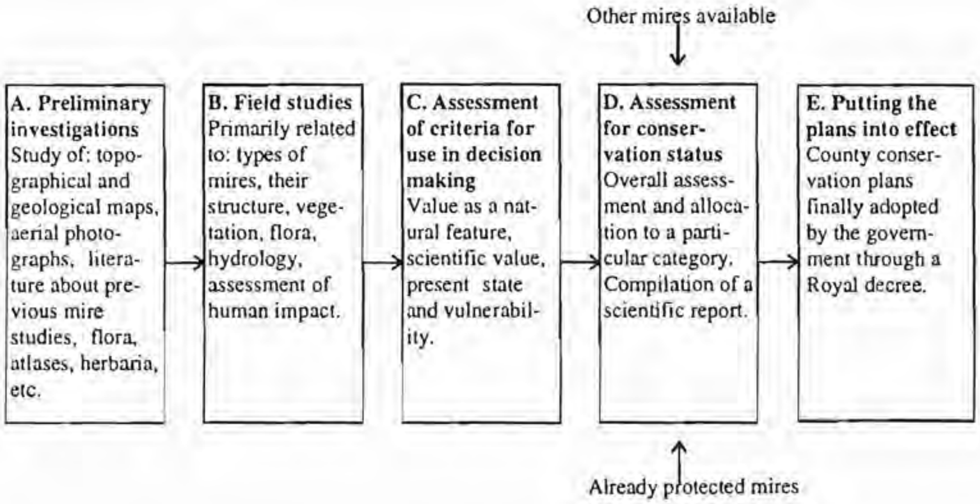

Fig. 1. Schematic presentation of the steps taken when drawing up the plans for mire conservation in Norway, i.e. designation as nature reserves. The Ministry of the Environment, the Directorate for Nature Management and the County Governors of the various counties are responsible for putting the plans into effect.

2.1 PRELIMINARY INVESTIGATIONS

2.1.1 Proposals received

In the 1960s and early 1970s, individuals, institutions and public authorities put forward proposals to protect certain mires. These were an important source of data for work at the commencement of the project. More proposals have been received since, in particular from nature conservation consultants in the county authorities. The agricultural authorities often proposed alternatives to controversial areas. Many interesting mires that merit protection have been proposed, but sometimes rather haphazardly and often without much documentation. All these suggestions have been followed up, either in the field or by examination of the areas on aerial photographs and topographical maps.

2.1.2 Literature and herbarium collections

Any references to previous botanical investigations of the mire in question were studied first, but these were very scarce. Floristic studies proved invaluable, both with regard to local floras and more extensive surveys. The Flora Atlas of Norway, which provides base maps for a large number of phytogeographically interesting species, was of key importance in this respect (Fægri 1960, Gjærevoll 1990). The herbaria at the various museums of natural history were useful in providing information about the presence and distribution of important mire plant species, as was advice provided by the staff in these institutions.

2.1.3 Map studies

Topographical maps on a scale of 1:50 000 (M 711 series), equipped with the UTM grid system, were used. These maps were constructed on the basis of aerial photographs and clearly show the extent of mires. When available, bedrock and drift maps were consulted as part of the preliminary investigations.

2.1.4 Aerial photographs

As far as possible, the most up-to-date high-altitude aerial photographs, on a scale of 1:30 000 to 1:40 000, were consulted. Stereoscopic examination of such aerial photographs provided good information on the form and structure of the mires, features of drainage and slope, variations in vegetation cover (assessed from different shades of grey on black-and-white photographs), degree of human impact, etc. These studies were decisive in choosing localities for subsequent field studies. Identification of drainage ditches, peat cutting or other forms of impact saved many pointless journeys. Study of the aerial photographs also enabled comparative assessment of localities within an area, allowing the selection of those that exhibited the best development of a particular mire type, or the greatest variety of types. The aerial photographic study stressed the importance of why such great emphasis has been placed on the morphology of a mire when considering its inclusion in the national plan. Other important criteria (e.g. the occurrence of rare species or vegetation types), which could not be determined from the study of aerial photographs, were attributed less importance in the selection process.

2.2 FIELD STUDIES

An itinerary was drawn up for each area, based on the preliminary investigations together with a scale of priority for all the localities concerned.

At each locality, the following information was sought in the field:

Morphology and structure - the shape of the mires, their surface patterns, slope, hydrology and drainage conditions, etc. were noted and boundaries, etc. were sometimes drawn on the aerial photograph(s). Emphasis was placed on hydromorphological types of mire synsites (e.g. raised bog, blanket bog) and mire features (e.g. pools and strings).

Vegetation - the species composition and distribution of the most important plant communities were noted and rough vegetation maps were sometimes made.

Flora - a checklist (see Moen & Singsaas 1994:64) was compiled for the majority of localities; which included all the vascular plants and all species of *Sphagna*, together with a selection of other bryophyte species and lichens. The occurrence and habitats of phytogeographically interesting species were noted.

Ecology - the depth and type of peat were investigated on some mires, together with determinations of the pH and conductivity of the groundwater in some plant communities.

Human impacts - any mechanical or human impact, and the effects of grazing, scything, etc. were noted.

Colour transparencies and black-and-white photographs were taken of nearly every locality visited. A preliminary opinion of the scientific value, suitability for protection, and conservation value compared with other localities that had been visited, was usually formulated in the field.

3 ASSESSMENT OF CRITERIA FOR USE IN SITE SELECTION

General criteria used when assessing the conservation merit of localities were considered (Table 1). Ratcliffe (1977) together with papers published in connection with the Norwegian national plan for river system conservation (Gjessing 1980, Gjessing et al. 1983) were vital sources of information in this regard. A distinction is drawn between the merit of a locality as a natural feature, its value for science (utility aspect) and that arising from criteria applied when assessing its present state and vulnerability. Criteria 1 to 13 are of general interest when considering the conservation value. The extent to which the criteria as a whole are used in determining the priority to be given to different localities for conservation depends on the body of data available. This determines which criteria can be used when drawing up a protection plan. The respective value of the different criteria in deciding between different mire localities in the mire conservation plan is assessed below.

Table 1. Criteria used when assessing the conservation value of nature in Norway (after Moen 1980). Those given special emphasis when assessing the localities included in the national plan for mire conservation are marked with asterisks (the more asterisks, the greater the importance of the criterion).

As a source of historical information	
1. Value as a natural feature	2. Present-day developments *
3. Productivity	4. Rarity ***
5. Typical area **	6. Clarity, size ***
7. Diversity (variety) **	8. Importance in a wider perspective
Scientific value (utility aspect)	
9. Classic site	10. Key site
11. Research importance	12. Educational importance
13. Value as a reference area	
Assessment of present state and vulnerability	
14. Present state, to what degree unspoilt ***	15. Vulnerability
16. Suitability for conservation *	
Overall assessment	
• Type area	
• Area of special interest	

3.1 VALUE AS A NATURAL FEATURE

Criterion 1. As a source of historical information

All mires are a potential source of knowledge about conditions in former times because the peat layers contain evidence of changes in the vegetation cover over time. However, since adequate information is rarely available (e.g. Våletjern in Hedmark (Holmboe 1903)), this criterion has been attached little importance when weighing up the conservation values of different localities.

Criterion 2. Present-day developments

The mire localities provide information about conditions prevailing at the present-day, or of factors that are operative. Overgrowth of a tarn by a floating peat mat, regeneration of a mire after cessation of hay-cutting, and peat erosion, are examples of the successional processes that take place on mires. These processes are reflected in the structure, flora and vegetation of a mire and are assigned a degree of importance.

Criterion 3. Productivity

Productivity is a fundamental biological attribute, the plants representing the producers. In most mire ecosystems, the production rate is greater than the rate of decay, resulting in peat accumulation. Peat deposits are large carbon reservoirs, and mires are one of the most important terrestrial carbon sinks (Franzen 1992). Hence, peatland resources must be protected in the worldwide battle against the increasing greenhouse effect. Since the fauna are dependent on the plant productivity, highly productive areas are important. Nonetheless, in this context, the conservation of highly productive mire ecosystems is not assigned any particular importance *per se*.

Criterion 4. Rarity

Assessment here is based on the morphological type, structure, vegetation and flora of the mire. A distinction is also made between rarity on a major scale (countrywide) and a minor scale (locally). The presence of several rare plant species, or of several species that are of great phytogeographical interest, is given special weight, as is the presence of rare types of mire or mire vegetation.

Criterion 5. Typical area

The locality comprises types of mire, vegetation and/or flora that are typical (representative) for a particular region. The inclusion of typical gradations within the mire vegetation and of gradations between that and other types of natural vegetation is of great importance. In general, there is a multitude of localities that encompass such normal gradations and precisely which localities are selected for conservation is thus often of little importance. In regions with a large number of mires, all with more or less the same structure, chance played a certain role in deciding which particular area was visited and subsequently proposed for conservation. When alternative proposals existed, these were set out in the respective area descriptions. This criterion was considered important.

Criterion 6. Clarity, size

The locality includes mire formations that exhibit clear interrelationships or processes. Size *per se* is not assigned any great importance, though it generally enhances the value of other criteria (e.g. diversity).

Within any one climatic area, terrain conditions determine the type of mire that develops. Formation of well-developed types often requires the existence of extensive areas of even topography and of particular types of underlying surface deposits. Mires are able to develop without hinderance in such «favourable» localities, so that peat formation gradually alters the terrain conditions and extensive raised bogs may develop and become more or less independent of the original condition of the terrain. Climatic factors are of primary importance for the formation and subsequent development of such mires. The existence of such well-developed mire synsites and complexes has been assigned great significance when drawing up the national mire conservation plan.

Criterion 7. Diversity (Variety)

A distinction is made between different kinds of variety, whether in regard to morphological type, structure, vegetation or flora, etc. The presence in a locality of many types of mires and mire vegetation merits a high score. The floristic checklists for the different localities provide a picture of the floristic richness. Considerable importance was attached to this criterion.

Criterion 8. Importance in a wider perspective

Mires are components in the hydrology of the catchment areas and may both increase the reliability of water flow to lower-lying areas and provide useful means of maintaining water quality. These important interests for mire protection in general were not, however, used as criteria when ranking several comparable localities. Mires may represent one aspect of an extensive landscape area that contains other features that are important in terms of nature conservation. The Forra mires in Nord-Trøndelag, for example, are situated in an area that also includes interesting aquatic and forest ecosystems (Moen & Jensen 1979). When considering the conservation of Norwegian nature in general, the combination of such interests within a single area represents an important criterion. However, such an assessment in connection with the establishment of priorities between mire localities has deliberately not been assigned a priority. Where such a multiplicity of conservation interests is recognised, this was noted in the respective report. When the fieldwork itineraries were being drawn up, a certain degree of priority was given to visiting mires that lay in or near areas already earmarked for conservation.

3.2 SCIENTIFIC VALUE (UTILITY ASPECT)

Criterion 9. Classic site

This criterion has been applied in cases where previous investigations have been carried out that would allow monitoring of temporal changes in mires. The existence of a long-standing scientific record can add considerably to the value of a locality, but there are very few localities of this kind in Norway.

Criterion 10. Key site

Some localities hold the key to the interpretation and documentation of certain scientific values. Since too little scientific knowledge is available about the great majority of localities in Norway, this criterion was not used to decide the conservation merit of mire sites that were inspected.

Criterion 11. Research importance

The existence of scientific documentation and specific on-going research may be important. For instance, in localities where hydrology, peat and water chemistry are well known, it is easier to carry out new, specialised investigations on such aspects as microflora and microfauna. The value of a locality for research purposes is usually allied with the importance of other criteria (e.g. 9 and 10) and for the same reasons as given for those criteria, this criterion was not attached importance when ranking localities on the national plan for mire nature reserves.

Criterion 12. Educational importance

Mires are of value as study and teaching objects at all levels of education. This criterion was not considered important in determining the value of localities on an international, national or regional scale, but it was found useful on a local scale in a few instances.

Criterion 13. Value as a reference area

This criterion is concerned with the value of protecting an area from disturbance so that the natural ecosystem can be studied as free as possible from outside interference. This is valuable *per se* and is of additional importance in allowing valid comparisons to be made with areas that have been subjected to disturbance of one kind or another. It represents an important criterion of general applicability when creating a network of undisturbed nature reserves. Ombrotrophic mires, in particular, have great value as reference areas, since they represent the only natural features that are solely dependent on precipitation. Ombrotrophic mires, therefore, are particularly well suited for studies of changes in the deposition of substances carried in precipitation. However, this criterion was not used when ranking several comparable localities.

3.3 ASSESSMENT OF PRESENT STATE AND VULNERABILITY

Criterion 14. Present state, to what degree unspoilt
Since pristine mires subjected to no human influence are now rare over wide areas of Norway, this criterion is of great importance. Nevertheless, human influence on a mire is not necessarily a negative factor and conservation of such mires is a key concept in the national mire plan. This applies in particular to mires that, in the past, were regularly mown for hay and to mires and heathlands that were regularly burnt and then grazed. These types of human influence were once widespread and affected extensive areas of mire and heathland. In contrast, ditching on a large scale, and other comparable, technical and irreversible disturbances, always diminish the value of a mire for conservation purposes.

Some mires affected by human influence can be considered to have a «potential conservation value» which bears little relationship to their present state. This applies to mires that have been affected and appear worthless, yet which could be restored to a more valuable state; a number of examples of this are given in Wheeler et al. (1995). In Norway, this problem arises in the case of a few special types of mires. Pristine condition was assigned great importance in the work on the national mire conservation plan.

Criterion 15. Vulnerability
This is a complex criterion, comprising many different facets. Localities that are considered to be vulnerable because of their situation were mostly not considered for conservation. On the other hand, a locality may be the site of a plant community or species that could be damaged by quite minor human influence, or by changes in agricultural practices, and which must therefore be protected and conserved. These conditions may also be covered by other criteria (e.g. rarity). Vulnerability was therefore not considered as an especially important criterion in the work on the national mire conservation plan.

Criterion 16. Suitability for conservation
Certain mires may be too exposed to danger (e.g. because they are situated close to a housing estate), whereas equivalent mire types in other areas may be situated in much less vulnerable surroundings. Attempts were made to choose areas for conservation that were under minimal threat from destructive factors, and also to find areas not threatened by seepage of polluted water, etc. When compiling the itinerary, priority was always given to inspecting mire localities that bordered on already protected sites (e.g.

close to an already established forest nature reserve) or were situated within the catchment area of protected watercourses (see criterion 8).

4 OVERALL ASSESSMENT

4.1 GENERAL

Criteria 1-16 represent aids that allow a rational decision to conserve a particular site. Some are wholly independent by nature, others are interdependent. Instances have also arisen where a high value assigned to one criterion has tended to lower the values assigned to others (e.g. a high score for clarity often results in a low score for diversity). All the criteria are not of equal importance, either, and cannot be given the same degree of importance in different parts of Norway. For instance, a wide variety of plant species on a mire will be considered of much more importance in the Agder counties than in Trøndelag, since mires in Agder, in general, are much poorer in species (scarcity of rich-fen vegetation). A further example of the selective use of criteria in different areas is that the same importance is not given to the degree to which a mire in a densely populated region is still unspoilt (e.g. Jæren and the lowlands bordering Oslofjord) as it is in areas where intact mires are extensive.

Absolute values for each of the sixteen criteria have not been given for each locality in the reports issued in conjunction with the national plan for mire nature reserves. During the work on the plan, there has been a continuous progression to identify the «best» localities. Special weight has been attached to the following criteria: 4 (rarity), 5 (typical area), 6 (clarity) and 7 (diversity). When comparing one locality with another, the criteria concerning scientific value (nos. 9-13) have not been considered important. The assessment made of the present state of a mire (no. 14) has been decisive when assessing the conservation value of a locality and the criterion of suitability (no. 16) has also been important.

Each locality is further assessed in relation to its conservation value as a type site and as a site of special interest, respectively.

4.2 CONSERVATION VALUE AS A TYPE AREA

This is the value of a mire as a representative locality for a wider or more restricted area, e.g. on the scale of the country as a whole, or of a vegetation region (criterion 5, typical area). On an even broader perspective (international or national), it is particularly important to protect mire complexes within which the individual mire synsites are very clearly developed (criterion 6, clarity).

Mires vary in kind from one part of the country to another and the primary objective of the mire conservation plan has been to preserve a selection of all the regional types. A subdivision of the natural landscape into regions has been a prerequisite of the work on the national plan. Abrahamsen et al. (1977) and Nordiska Ministerrådet (1984) subdivided Scandinavia *sensu lato* («Norden») into 60 regions, on the basis of a variety of natural component parts). Later, a more detailed regional subdivision of Norway into vegetation zones (Dahl et al. 1986, Moen 1987) and sections (Moen & Odland 1993) has been published. Moen (1994: 343) published a preliminary map of mire regions of Norway.

4.3 CONSERVATION VALUE AS A CRITERION OF SPECIAL INTEREST

Interesting ecosystems of less common, or more extreme, types require to be conserved. Mires provide the only conditions under which a number of specialised plant species can survive. This category also includes rare plant communities, special developments of morphology, surface patterns, etc. (the most important criteria are rarity (no. 4) and diversity (no. 7)).

Before it is possible to arrive at a comprehensive assessment of the conservation value of mires, detailed knowledge of the entire range of mire morphology and structure, floras and vegetation is needed. Work on the national plan for mire nature reserves has suffered to some extent from the absence of previous investigations of Norwegian mires. Since a successful conservation programme for Norwegian mires can only be developed on the basis of such knowledge, it was essential to combine survey with scientific research on the mires.

Faunal investigations have not been undertaken in conjunction with the work on the national plan. Instead, the assumption has been that, by conserving mires based on criteria of mire morphology and structure, vegetation and flora, representative animal communities will also be protected. A systematic survey of the avifauna of the mires and other wetlands has, however, been undertaken in conjunction with a separate plan for the conservation of wetlands.

4.4 CONSERVATION GROUPS

All the mires have been classified into conservation groups (following Sjörs 1971), based on the criteria discussed in the foregoing sections.

Group 1 a Worthy of conservation from an international viewpoint
Each country was requested at the start of Project TELMA in 1967 (e.g. Sjörs 1971) to try to decide on the conservation of a small number of large, well-developed, mire complexes which had international value. A prerequisite was that these mires had been thoroughly investigated scientifically. Although this requirement was not fulfilled in all cases, 17 mires in Norway were proposed for inclusion in the TELMA plan (Moen 1979). The Norwegian list of mires worthy of conservation from an international viewpoint should be adjusted, as two of the 17 localities have been destroyed, and some new localities should be added. Of the 11 Norwegian localities included in the European Network of Biogenetic Reserves, the majority are mire localities. In addition a number of wetland areas are included in the Ramsar Convention list (Hansen 1992).

Group 1 b Worthy of conservation nationally: type areas
An attempt has been made to protect as wide a variety as possible of the mire types by granting conservation status to a number of large, typical mire complexes.

Group 1 c Worthy of conservation nationally: areas of special interest
The mires in this group are usually small, but have the highest conservation values. A majority are small rich fens in the lowlands. Rich-fen vegetation only develops on calcareous mineral soil which, in the lowlands of southern Norway, is virtually restricted to relatively densely populated regions (Moen 1994). This explains why the important types of rich fen, which are very suitable for cultivation, are in great danger of disappearing from Norway. Some plant species making up this vegetation are also in danger of extinction. This subgroup also includes some localities with special types of mire morphology and structure.

Group 2 Worthy of conservation because of their regional interest
To ensure the conservation of as wide a spectrum as possible of Norwegian mires, a large number of mires that fall into this category also require protection. The group includes both large and small mires and, to some extent, mires that on further investigation may prove worthy of being upgraded to group 1. These mires often achieve the highest scores on a county basis. Like group 1, they can be further subdivided into type areas (2 b) and areas of special interest (2 c).

All the mires in groups 1 and 2 fall into the category covered by the Nature Conservation Act.

Group 3 Worthy of conservation because of their local interest
Because their main interest is of a local nature, these mires do not require to be preserved by the Nature Conservation Act. Group 3 can also be subdivided into type areas (3 b) and areas of special interest (3 c).

Group 4 Those of little worth for conservation

Group 5 Those not worthy of conservation

Applying the criteria for evaluating conservation status is a complicated process and a certain degree of subjectivity cannot be denied. The overall assessment of conservation status is also a difficult matter, as also is the question of how many mire nature reserves should be created to ensure coverage of the entire variation within an area. Priority must be given to those mires included in group 1, whereas a selection of the mires in group 2 may suffice. As mentioned previously, many alternative choices exist over large parts of Norway in regard to conservation of typical mires. Information about the possible alternative sites has been included in all the scientific reports. Ideally, as shown in Figure 1, an assessment of all the mires present in an area (i.e. mires already protected, those inspected, and all other mires) is called for before drawing up the final priorities. In areas where aerial photograph coverage is good it has been possible to include the «other mires» in the final assessment and the alternative possibilities to the mires that were visited are, once again, mentioned in the reports.

5 CONSERVATION OF MIRES

The present Nature Conservation Act for Norway was passed in 1970. Until then, only 36 areas (less than 1% of the land area) were protected by law, three of which were mire/wetland reserves. Today, more than 1100 areas (more than 6% of the land area) are protected in Norway (Hansen 1992), not including Svalbard.

5.1 PUTTING THE MIRE PLAN INTO EFFECT

All areas where nature is protected in Norway (national parks, reserves, etc.) have been established by the government through the lengthy procedure of Royal decrees (Hansen 1992). Prior to the mid-1970s, conservation legislation concerned individual objects and features of very limited extent. Since then, the work has concentrated on thematic protection plans for each county. The Department of Environmental Affairs in the offices of the county governors, the Directorate for Nature Management, and the Ministry of the Environment are responsible for these county plans. After a scientific report has been compiled (point D in Figure 1), the procedure for putting the plans into effect can be summarised as follows: 1) a draft conservation plan is drawn up and submitted for comments to landowners, organisations at the local level, and administrative authorities and agencies at local and county levels; 2) the County Governor presents his final proposal for a conservation plan; 3) the plan is submitted for comments to national organisations, agencies and ministries at the national level; 4) the Directorate for Nature Management finalises the conservation plan proposals; 5) the Ministry of the Environment presents the proposals to the government which adopts the conservation plan through a Royal decree.

5.2 EXPLOITATION AND THREATS

More than 25% of the original mire area of Norway below the forest limit has been drained. Over extensive tracts of the lowlands all the larger mires are affected by drainage reclamation. Peat cutting in former times has affected large areas, particularly along the woodless coast of Norway (Løddesøl 1948, Moen 1973). In contrast to most other parts of Europe, mires in Norway were still being reclaimed for agriculture in recent decades. In the 1970s, about 10,000 ha were drained annually for forestry. Much smaller areas have been drained in the 1980s and 1990s. Drainage of mires has been most threatening in the lowlands, i.e. the boreonemoral and southern boreal regions (Moen 1987), where the percentage of mires is low (e.g. Moen 1994). The upper boreal regions generally have a high percentage of mires (including sloping fens, etc.), and they are less threatened.

5.2 STATUS OF THE PLAN FOR MIRE NATURE RESERVES

A number of national plans for nature protection have been drawn up under the auspices of the Ministry of the Environment. The mire reserve plan and the plan for conserving wetlands (primarily as bird sanctuaries) are two such plans. The extent of protected areas is shown in Table 2.

There are now 217 mire reserves, and about 70 more will be added within a few years. In addition to these reserves, mires are protected in the national parks and in other types of nature reserve, for instance wetland reserves (185, covering 500 km^2, (Table 2)) and alluvial forest reserves (10, covering 18 km^2). The Upper Forra Nature Reserve in the county of Nord-Trøndelag is another example of an additional reserve; it covers 106 km^2 of land area, about 60% of which is mire. The total area of mires in Norway has been estimated at about 3,000,000 ha (nearly 10% of the land surface), 2,100,000 ha of which are situated below the forest limit (Løddesøl 1948). At present, about 5% of the mire area is protected in reserves, national parks, etc.

Table 2. Number (N) and area (km^2) of mire and wetland reserves in Norway as of 1 January 1995 (* county plan incomplete). The addition to mire reserves is the Upper Forra Nature Reserve in Nord-Trøndelag: 106 km^2.

	Mire reserves		Wetland reserves	
Counties	**N**	**km^2**	**N**	**km^2**
Østfold	15	6.2	25	23
Oslo & Akershus	20	9.1	18	64
Hedmark	3*	3.9	19	140
Oppland	16	14	20	79
Buskerud	15	9.8	9	9.7
Vestfold	11	11	10	5.5
Telemark	17	3.7	7	37
Aust-Agder	17	15	6	4.7
Vest-Agder	13	4.2	7	7.3
Rogaland	7	2.8	1*	0.7
Hordaland	10	5.5	1*	0.5
Sogn & Fjordane	0*	0	0*	0
Møre & Romsdal	0*	0	27	46
Sør-Trøndelag	22	73	13	26
Nord-Trøndelag	21+1	159	17	20
Nordland	16	70	1*	13
Troms	13	21	2*	2.3
Finnmark	1*	12	2*	21
Totals	217+1	420 km^2	185	500 km^2

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Classification of mire localities and mire species in central Norway by vegetational regions, Ellenberg species indicator values and climatic data

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ABSTRACT

Såstad S. & Moen A. 1995. Classification of mire localities and mire species in central Norway by vegetational regions, Ellenberg species indicator values and climatic data. *Gunneria 70*: 177-198.

Mire localities (347) in central Norway were assigned to different vegetational regions (5 zones/belts and 5 sections) according to their location on regional maps. The plant species (372) found at these localities were assigned zonal and sectional indicator values based on the relative presence/absence of the species at the localities in the different vegetational regions. In addition, two 'characteristic indicator values' were calculated for each locality based on the Ellenberg temperature and continentality indicator values for the species present at the localities. These data sets were compared to data derived from a climate database. Zonal affinity and Ellenberg's temperature values agreed best with accumulated temperatures above 0°C and 5°C, whereas sectional affinity and Ellenberg's continentality values yielded the highest accordance with temperature range and the mean temperature of the coldest month. The vegetational region classifications showed a high agreement with the climatic data, correlation with Ellenberg's indicator values generally being weaker. The results of this study indicate that adoption of species indicator values directly from Ellenberg is of limited value unless modifications are made to take account of the varying ecological conditions in the regions in which the system is to be applied. In this context, the derivation of species indicator values based on the presence of the species in the different vegetational regions seems more appropriate, at least for scores intended to describe the regional preferences of species.

1 INTRODUCTION

The regional variation in the vegetation of the Nordic countries (as mapped by Ahti et al. (1968) and Nordiska Ministerrådet (1984)) has been used as a basis for distinguishing geographical regions when identifying type sites and reference areas for the purposes of nature conservation. The wide regional variation found over quite short distances in many parts of Norway does not, however, find expression on the small scale used in these maps. Dahl et al. (1986) published a more detailed map for Norway, distinguishing two sections and seven zones. Based on this map, Moen (1987) described the regional vegetation of central Norway in considerable detail, and provided contour maps (isohypses) for the main zones. Separate maps

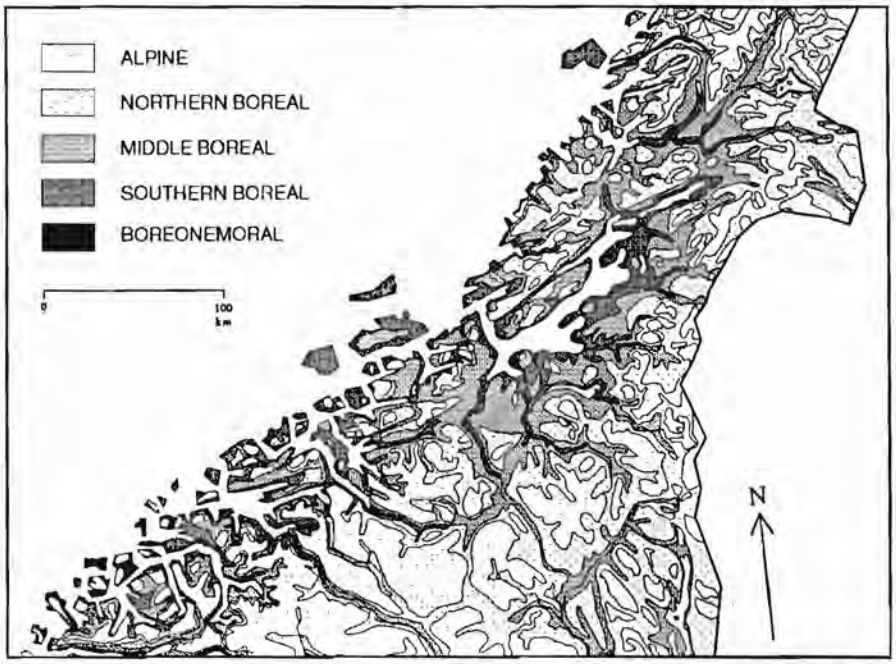

Fig. 1. Vegetational zones in central Norway, modified after Moen (1987). Map basis: the National Atlas of Norway, the Norwegian Mapping Authority.

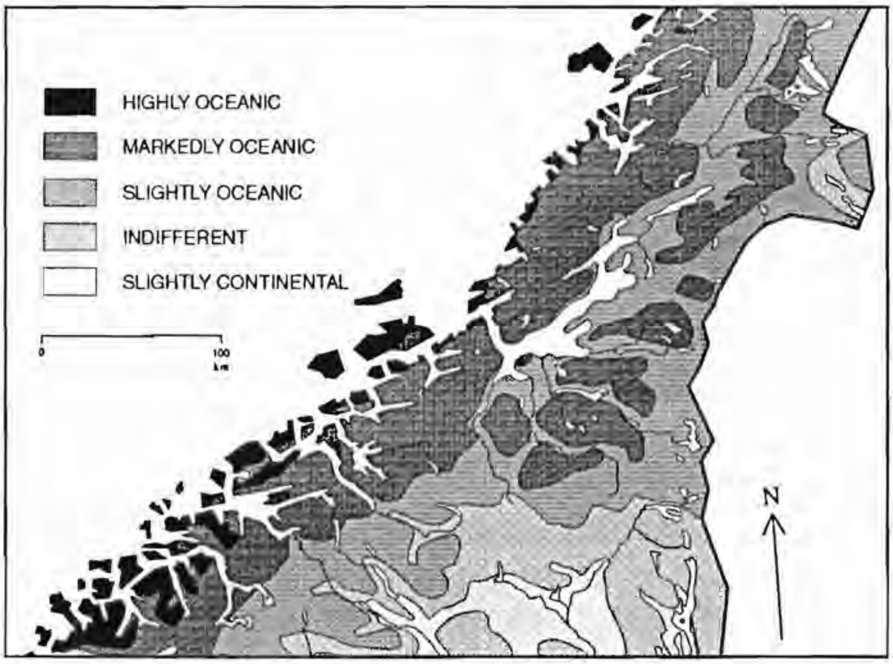

Fig. 2. Vegetational sections in central Norway. After Moen & Odland (1993).

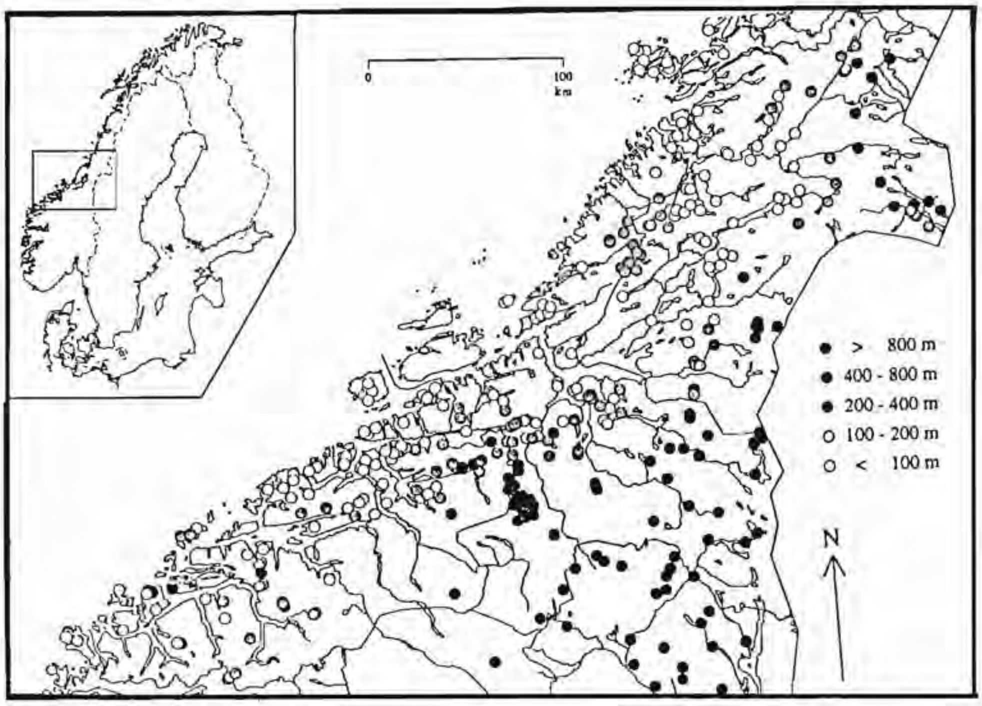

Fig. 3. The 347 mire localities in central Norway used in the present study. The localities are classified according to their mean elevation in m a.s.l.

for five vegetational zones (Fig. 1) and five sections (Fig. 2) in central Norway are now available. Since relatively rough criteria were used to define the zones and sections in these maps, it is now appropriate to evaluate them.

Regional variation in vegetation (zones and sections) is mainly a response to climate (Ahti et al. 1968, Tuhkanen 1984). Localities assigned to different vegetational regions can be related to climatic parameters either directly, by using standard meteorological data, or indirectly, by using, for instance, Ellenberg's ecological indicator values (Ellenberg 1974). In the present study, the enlarged and improved edition of Ellenberg et al. (1991) has been used, in relation to two large-scale climatic factors: T (Temperature value): Occurrence within the temperature gradients from the Mediterranean to the Arctic and from the lowland to the alpine belts of central Europe. K (Continentality value): Occurrence within the gradient from the Atlantic coast to the inner parts of Eurasia, especially with regard to annual temperature ranges. A number of publications have compared

Ellenberg numbers for local environmental factors (light, moisture, reaction, nitrogen) with quantitative data derived from field and laboratory studies. Thompson et al. (1993) found that Ellenberg's numbers (based on central Europe) were also 'reasonable predictors of the ecology of single British populations of the same species', (see also van der Maarel (1993) and Diekmann (1995)). Vevle & Aase (1980), Persson (1981) and Hundt & Vevle (1992) also included Ellenberg's regional factors (temperature and continentality) in their studies, but made no regional studies. Surprisingly, no such regional studies, based on Ellenberg's indicator values, have yet been made in Fennoscandia.

A survey of mire localities in Norway commenced in 1969 (Moen, this volume). It aimed to record representative and valuable mire localities for potential conservation. During the project, more than 1000 check-lists of vascular plants and bryophytes were obtained, and some of this material (347 lists from central Norway) has now been made available (Moen & Såstad 1993). These species inventories cover all vegetational regions and sections where mires are found in central Norway. By comparing the floristic data from these mire localities with the climatic data, we aim to: 1) evaluate the appropriateness of the vegetational zones and sections as mapped in central Norway, and 2) see whether Ellenberg's indicator values for temperature and continentality, developed originally for these species in central Europe, adequately reflect the requirements of populations of these species growing on the mires of central Norway.

2 MATERIAL AND METHODS

In this paper, 'central Norway' comprises the area from latitude 62°N northwards to the southern border of the county of Nordland. This includes the northern parts of the counties of Sogn & Fjordane, Hedmark and Oppland, and all of Møre & Romsdal, Sør-Trøndelag and Nord-Trøndelag.

2.1 SPECIES DATA

A major set of floristic data has been collected during the mire survey of central and southern Norway, including about 10,000 herbarium collections of phanerogams and cryptogams and about 900 field check-lists of the mire flora (Moen & Singsaas 1994). The floral lists for the 347 mire localities from central Norway (Fig. 3) form part of this material. These lists comprise 420 different mire species. Altogether about 35,000 records have been used in our data analysis. The vascular plant nomenclature follows Lid (1994), and that of bryophytes follows Frisvoll et al. (1995).

2.2 DATA FOR THE VEGETATIONAL REGION CLASSIFICATIONS

The 347 mire localities were assigned to 5 different vegetational zones by using the zonal map (Fig. 1) and contour maps defining the altitudinal limits of the zones (Moen 1987). The mire localities were assigned to 5 vegetational sections by using the sectional map (Fig. 2). Table 1 shows how the localities are distributed among the various zones and sections, and the zone and section categories that were merged to form the 3 and 4 groups, respectively, used to analyse the classification success.

2.3 DATA ON CLIMATE

Climatic data were obtained from a database for terrestrial climate (Leemans & Cramer 1991), which includes weather records from most of the stations operated by the Norwegian Meteorological Institute for the normal period 1931-1960, by spatial interpolation to the latitude and longitude values for each mire in the check-list of localities. The interpolation technique used was a triangulation of all data points followed by smooth surface fitting (Leemans & Cramer 1991). The following bioclimatic indices were computed from the climatic data at each locality according to Prentice et al. (1993): annual precipitation (APREC), average temperatures of the coldest and warmest months (MTCO and MTWA), accumulated temperature during the growing season (growing degree days) above 0°C and 5°C (GDD0 and GDD5), and annual potential evapotranspiration (APET). APET was calculated from interpolated data on temperature, precipitation, sunshine hours and latitude, using a simple deterministic bucket model (Cramer & Prentice 1988). Annual temperature ranges were calculated for each locality, as MTWA-MTCO.

2.4 LOCALITY-CENTRED COMPARISON

To compare the variables on a locality level, three types of data were employed:

1) The classification categories for each locality according to zone and section.
2) A 'characteristic indicator value' calculated from the Ellenberg indicator values for the species present at each locality. The scores were derived using the formulae:

$$CIV_T = \frac{\sum_{i=1}^{n} T_i}{n}, CIV_K = \frac{\sum_{i=1}^{n} K_i}{n}$$

Table 1. Distribution of the 347 mire localities into vegetational zones and sections. The number of localities within each combination of section and zone is given, and the total number of localities within each section and zone appears as the row and column totals, respectively. Boxes indicate classes which were merged to analyse the classification success. BN = boreonemoral, SB = southern boreal, MB = middle boreal, NB = northern boreal, LA = low alpine, O3 = highly oceanic, O2 = markedly oceanic, O1 = slightly oceanic, OC = indifferent, C1 = slightly continental.

Zone / Section	BN	SB	MB	NB	LA	Section total
O3	3	42	8	3	2	58
O2	-	63	86	13	-	162
O1	-	33	38	21	-	92
OC	-	-	10	14	-	24
C1	-	-	6	5	-	11
Zone total	3	138	148	56	2	347

Where CIV_T and CIV_K are the characteristic indicator value for temperature and continentality, respectively; T_i and K_i are the indicator values for temperature and continentality for the ith species; n is the number of species for each locality listed with an indicator value by Ellenberg et al. (1991). Species with indicator values which were absent or marked 'unknown' were omitted when calculating the 'characteristic indicator values'. The formulae are analogous to those used by Persson (1981), but since the present data only included presence-absence values, no weighting according to cover values could be made.

3) The interpolated climatic variables (as above) for each locality.

The zone and section classifications were compared to the direct (interpolated climatic data) and indirect (characteristic indicator values) estimates of the local climatic conditions. The means for each 'characteristic indicator value' and interpolated climatic variable in each zone and section were calculated and used to determine a degree of 'classification success' for each of these variables. A locality was defined as having been 'correctly classified' when its value for a given variable was closer to the mean of the region (zone or section) to which it had been originally classified, than to the mean of any other region. The percentage of correctly classified localities served as a measure of agreement between the variables and the original zone and section classification (cf. discriminant analysis, Abbott et al. 1985). The proportions of the total variance in these variables accounted for by the zone and section classification were also calculated.

2.5 SPECIES-CENTRED COMPARISON

To compare the variables at species level, three additional types of data were employed:

1) A score for each species derived from its presence at localities situated in different zones and sections. This score was derived using the formulae:

$$RSS_Z = \frac{\sum_{j=1}^{n} Z_j}{n}, RSS_S = \frac{\sum_{j=1}^{n} S_j}{n}$$

Where RSS_Z and RSS_S are the regional species scores for zone and section, respectively; Z_j and S_j are weightings assigned to the zone and section to which locality j belongs {zones and sections were given weights from 1 (boreonemoral zone) to 5 (low alpine zone), and 1 (highly oceanic section) to 5 (slightly continental section), respectively); n is the number of localities in which the species was present.

2) The indicator values for temperature (T) and continentality (K) are those given in Ellenberg's lists (1991).

3) A score derived for each species from the climatic conditions at the localities where it was present. The score was derived using the formula:

$$CSS = \frac{\sum_{j=1}^{n} X_j}{n}$$

Where *CSS* is the climatic species scores for a given climatic parameter; X_j is the value for this climatic parameter (from the list mentioned above) at locality *j*; *n* is the number of localities where the species was present.

To evaluate their ability to predict the local climatic conditions, the two sets of indicator values (1 and 2) were compared with the climatic species scores (3) using Pearson product-moment correlation co-efficients. The two regional species scores (RSS_Z and RSS_S) are correlated because the zones and sections are interdependent (cf. Table 1). In consequence, partial correlation co-efficients (Sokal & Rohlf 1981) between the regional species scores and the climatic species scores were calculated, controlling for the other regional species scores.

Taxa that occurred at three or fewer localities were omitted from the species-centred comparisons which, after deletion, include 372 taxa. Species absent from, or scored as indifferent, in the Ellenberg et al. (1991) list were excluded from the analyses involving Ellenberg's indicator values (221 and 258 species remained in the analyses concerned with the indicator values of temperature and continentality, respectively). The data for the Ellenberg indicator values and the regional and climatic species scores for the taxa included in the species-centred comparisons are shown in the Appendix table, following the References.

3 RESULTS

3.1 ANALYSES OF LOCALITIES

Boreonemoral mires (3 localities) only occur in the lowlands in the far southwestern part of central Norway. Southern boreal, middle boreal and northern boreal mire localities are very common (139, 148 and 53 localities, respectively). Low alpine mires also occur throughout central Norway, although only 2 of these localities were included here. The three oceanic sections (O3, O2, O1) contain the vast majority of localities; the indifferent section (OC) and the slightly continental section (C1), in particular, containing only a few (Table 1).

The accumulated temperatures in excess of 5°C best predicted the zonal affinity of the localities (83.0% correctly classified). Accumulated temperatures over 0°C, the mean temperature of the warmest month, and the annual potential evapotranspiration also showed more than 70% classification success. The other climatic variables yielded much higher rates of misclassification. The characteristic indicator values based on Ellenberg's index of temperature conformed better to the zonal classification than did the continentality values (57.0% and 47.5%, respectively), but they were both lower than the values for most of the calculated climatic variables (Table 2).

Annual temperature range and mean temperature of the coldest month best predicted the sectional affinities of the localities (67.4% and 66.6% correctly classified). The other climatic variables showed less accordance with the sectional classification. The characteristic indicator value based on Ellenberg's index of continentality showed a high percentage of correctly classified localities, much higher than the temperature index values (60.5% and 40.9%, respectively). The percentage of correctly classified localities was generally lower for the sections than for the zones. However, since only four sections and three zones, respectively were involved (cf. Table 1), a higher number of localities could be expected to be correctly classified to zone than to section by pure chance (prior probability of 33% compared to 25%), and therefore the numbers of correctly classified localities are not directly comparable.

3.2 ANALYSES OF SPECIES

Much higher correlations with the climatic species scores were found for the zonal and sectional indicator values than for the Ellenberg scores (Table 3, Figs. 4 and 5). Species scores derived from the accumulated temperature values above 0°C and above 5°C correlated best with the species scores derived from the zones (-0.95 and -0.97, respectively), whereas the values for annual temperature range, mean temperature of the coldest month and annual precipitation correlated best with the section scores (0.96, -0.96 and -0.94, respectively). The values for the partial correlation co-efficients imply that some of the correlations found between climate and zone or section are artefacts. It appears, for instance, as if the temperature in the warmest month (MTWA) increases in the most oceanic sections. This, however, is due to an over-representation of boreonemoral and southern boreal areas near the coast. This artificial relationship was removed when partial correlation was applied. Accumulated temperature above 0°C and 5°C correlated best with Ellenberg's temperature values (0.47 and 0.50), whereas the annual temperature range and the mean temperature of the coldest month correlated best with the continentality values (0.51 and -0.48). These correlations, however, were much lower than the correlations found with the zone and section scores.

Table 2. The percentage of localities classified to the correct zone or section by each climatic variable and by the Ellenberg site score. 'Variance accounted for' represents the proportion of the total variance in each variable attributable to differences among the groups. Prior probabilities are the percentage of correctly classified cases expected by chance alone. The null hypothesis that there is no difference between the group means is rejected at the $p < 0.0001$ level for all variables. APET = annual potential evapotranspiration, APREC = annual precipitation, GDD0 and GDD5 = accumulated temperatures above 0° and 5°C, MTCO and MTWA = mean temperature in the coldest and warmest months, and MTWA-MTCO = annual temperature range.

	Zone (3 groups, prior probability 33%)		Section (4 groups, prior probability 25%)	
	Percentage of localities correctly classified	Variance accounted for	Percentage of localities correctly classified	Variance accounted for
APET	71.1	0.61	34.6	0.27
APREC	48.4	0.15	47.8	0.51
GDD0	77.0	0.67	45.2	0.50
GDD5	83.0	0.74	30.6	0.36
MTCO	57.9	0.40	66.6	0.72
MTWA	73.8	0.61	36.3	0.18
MTWA-MTCO	52.2	0.18	67.4	0.72
Ellenberg's indicator values:				
temperature	57.0	0.30	40.9	0.33
continentality	47.5	0.12	60.5	0.57

Table 3. Correlation and partial correlation coefficients between species scores derived from climatic data (CSS) and the two types of classification: (1) Ellenberg's indicator values of species, and (2) regional species scores (RSS) as regards zones and sections. *; not significant at the $p < 0.001$ level. Abbreviations as in Table 2

	(1) Indicator values from Ellenberg		(2) Regional species scores (n = 439)			
	Temperature T, (n = 280)	Continentality K, (n = 321)	Zone	Section	Zone when controlling for section	Section when controlling for zone
APET	0.47	-0.33	-0.94	-0.75	-0.86	-0.15*
APREC	0.33	-0.47	-0.74	-0.94	-0.12*	-0.86
GDD0	0.47	-0.40	-0.95	-0.88	-0.92	-0.78
GDD5	0.50	-0.33	-0.97	-0.82	-0.92	-0.50
MTCO	0.42	-0.48	-0.86	-0.96	-0.75	-0.93
MTWA	0.46	-0.19*	-0.91	-0.65	-0.83	0.12*
MTWA-MTCO	-0.35	0.51	0.74	0.96	0.06*	0.90

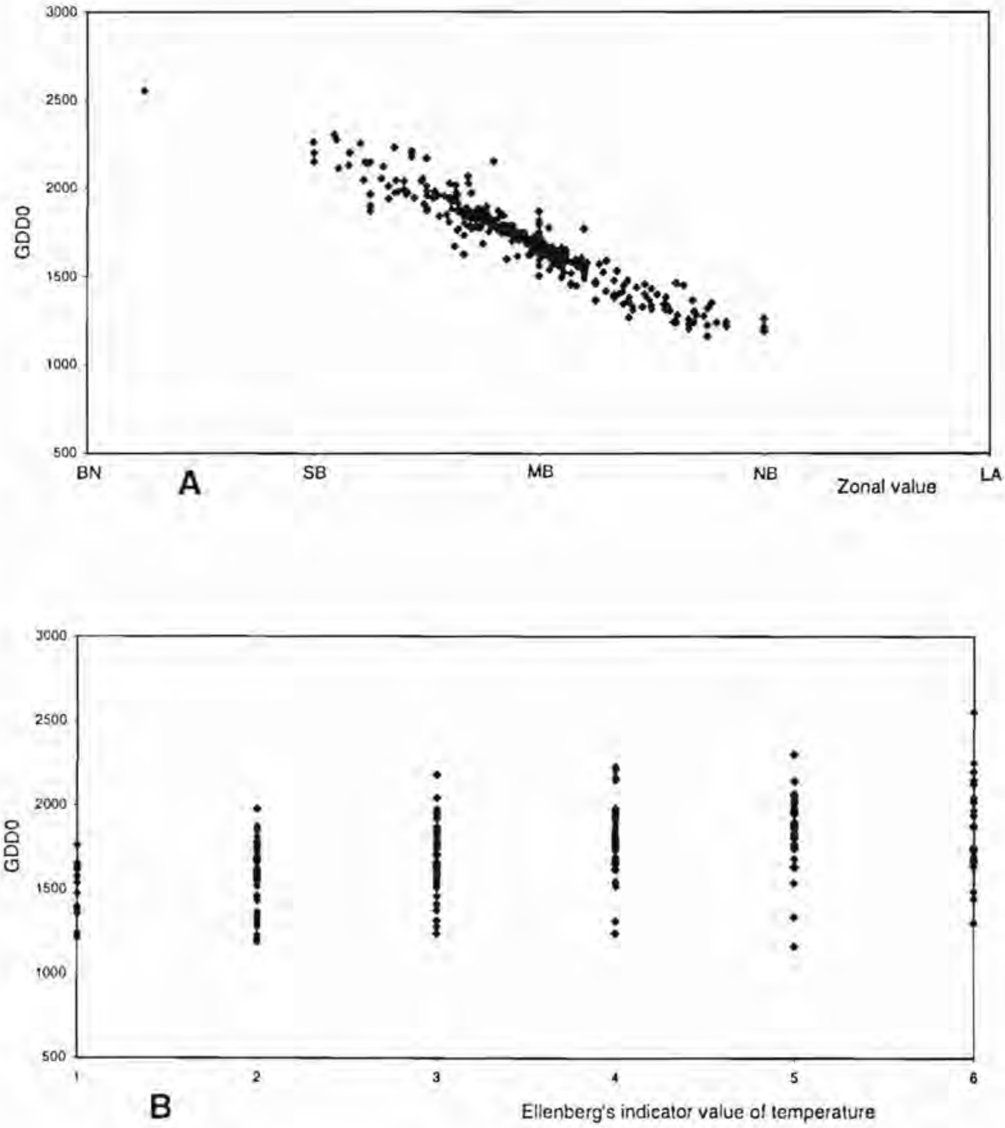

Fig. 4. Species scores showing the relationship between the climatic species values for accumulated temperatures above 0°C during the growing season (GDD0), and A) the regional species score for the different zones, and B) the Ellenberg indicator value of temperature. Scores of 372 and 221 species are plotted in A and B, respectively. See the text for the calculation of species scores. BN = boreonemoral zone; SB = southern boreal zone; MB = middle boreal zone; NB = northern boreal zone; LA = low alpine zone.

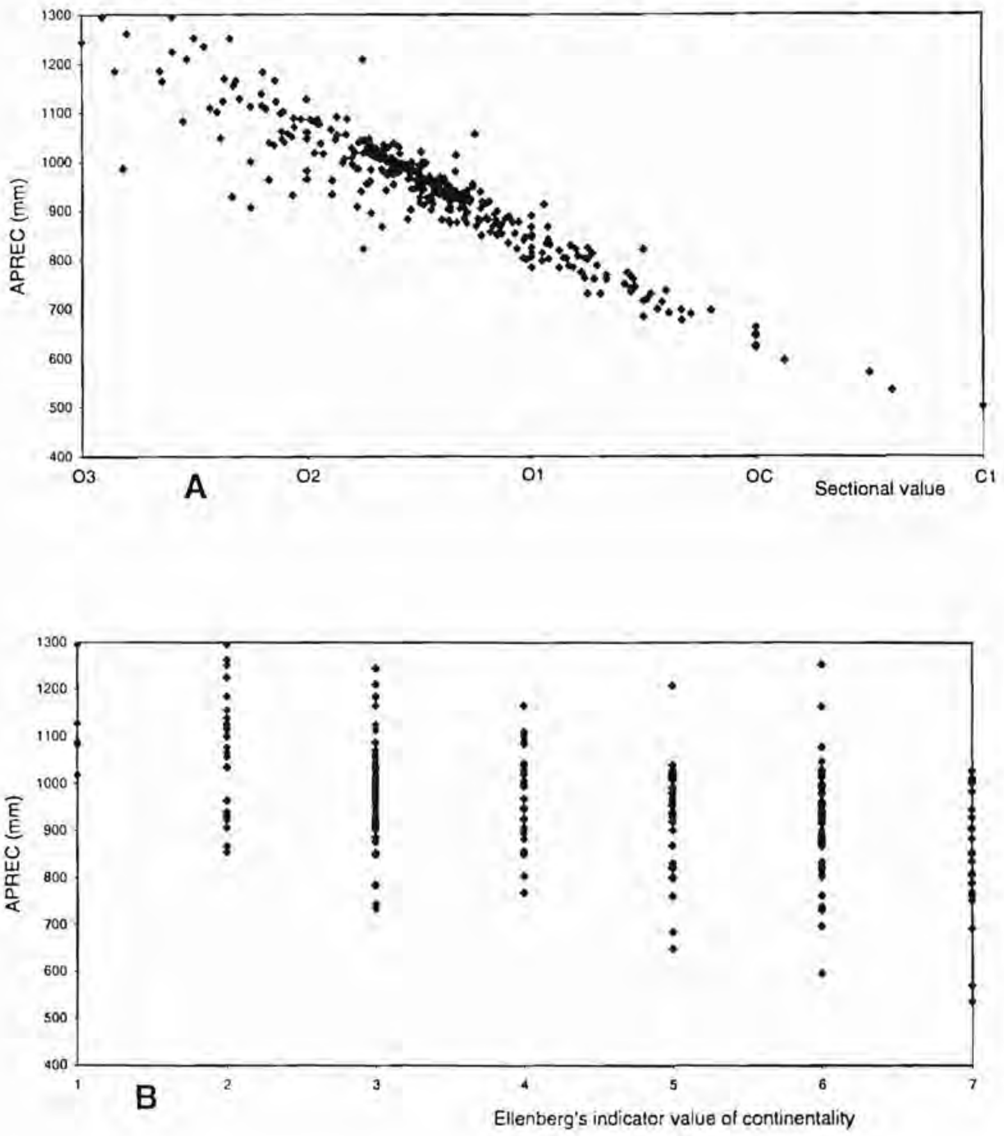

Fig. 5. Species scores showing the relationship between the climatic species values for annual total precipitation (APREC), and A) the sectional species value, and B) the Ellenberg indicator value of continentality. Scores of 321 and 440 species are plotted in A and B, respectively. See the text for the calculation of species scores. O3 = highly oceanic section; O2 = oceanic section; O1 = slightly oceanic section; OC = indifferent section; C1 = slightly continental section.

A number of species are more or less ubiquitous on mires in central Norway, e.g. *Calluna vulgaris*, *Eriophorum angustifolium*, *E. vaginatum*, *Molinia caerulea*, *Trichophorum cespitosum*, *Vaccinium uliginosum* and *Sphagnum papillosum* have frequency values above 95%. Others have more restricted distributions, such as the alpine plants *Epilobium anagallidifolium* and *Sparganium hyperboreum*, which occur mainly in low alpine/northern boreal sites and have a zonal score of 4. The lowest zonal scores (< 2) are found among lowland species such as *Holcus lanatus* and *Carex flacca*. These species were also found to have the highest scores for the accumulated temperature values during the growing season (GDD0 and GDD5). Eastern species, such as *Carex globularis* and *C. capitata*, have the highest sectional scores (> 4.5) and the highest differences in temperature between the warmest and the coldest months (MTWA-MTCO), whereas the lowest sectional scores and lowest temperature ranges are found among the western oceanic species, such as *Carex binervis* and *Luzula sylvatica*.

4 DISCUSSION

In an analysis such as this, significant correlations can be expected between parameters considered to express parallel gradients. What is more interesting, however, is to examine how far the classification approaches based on the vegetational regions and Ellenberg's criteria accord with the estimated local climatic conditions.

The zonal classification of vegetation is thought to be closely correlated with the cumulative warmth received during the growing season (e.g. Ahti et al. 1968, Moen 1987). The results presented here support this assumption, the 'accumulated temperatures' being the variables that were best able to predict the zonal affinity for the localities, and which correlated best with the zonal species scores (Tables 2 and 3). Although it showed a much weaker relationship, Ellenberg's indicator temperature value correlated best with the zonal occurrence of species. The sectional classification of vegetation is assumed to relate to a complex of thermal and hygric factors varying from oceanic to continental (e.g. Tuhkanen 1984, Moen & Odland 1993). The high degree of classification success and species-score correlations yielded by the annual temperature range, the mean temperature of the coldest month and the annual precipitation (Tables 2 and 3) accord with these assumptions. The higher values found for the inferred temperature indices indicate that these are more relevant than the precipitation index. However, the interpolation technique used for the data from the meteorological stations seems to yield less accurate precipitation than temperature values. The reason for this may be that a majority of the meteorological stations in Norway are situated in the lowlands. Everywhere in Norway, the yearly precipitation increases from the lowlands to the mountains. The zone of maximum precipitation (much of it as snow) occurs west of the mountains at a distance of some 50 km from the west coast (Fægri 1960). Since temperature, but not precipitation, values were adjusted according to site altitude, the precipitation values for a number of the upland mire localities are far too low, a factor which can blur potential relationships. Ellenberg's indicator value of continentality showed an ability to predict the zonal affinities of the localities that was almost as great as that for the annual temperature range and the mean temperature of the coldest month. However, at species level, the Ellenberg numbers showed much lower correlation with climate than did the sectional indicator values.

The general conclusions that may be drawn from this study are that the interpolated climatic data seem better able to predict the zonal and sectional affinities of the species' localities than do the Ellenberg site scores (Table 2), and that the climatic data correlate better with the species indicator values based on zones and sections than those based on Ellenberg's indicator values (Table 3). This indicates that application of the 'species indicator value' system of Ellenberg (intended for central Europe) to mire data for central Norway is an inferior method to a direct application of scores derived from the relative presence of the species in the vegetational zones.

Very few investigations in Fennoscandia have employed Ellenberg's temperature and continentality index values. The majority have used the other four ecological indicator values (light, moisture, reaction and nitrogen) listed by Ellenberg (see e.g. Thompson et al. 1993, van der Maarel 1993, Diekmann 1995). In contrast to these, the temperature and continentality values are not based on actual measurements, but on distributions (N-S, lowland-alpine and E-W). This means that when the characteristic temperature and continentality indicator values for the localities are compared with their zonal and sectional affinities, two different patterns of distribution are in fact being compared (one from central Europe and one from central Norway). It is thus not surprising that the climatic data were found to show better agreement with the plant distribution patterns within, than outside, the same area.

The results indicate that the zonal and sectional distribution of vegetation is closely linked to differences in the variables describing different aspects of climate. Even though this suggests that transferring a 'species indicator value' system, like that of Ellenberg et al. (1991), is of limited value unless modifications are made to meet the varying conditions in the region in which the system is being applied. When it is applied in this new area it still seems to reflect the aspects of climate for which it was designed. However, to obtain scores that aim to describe the regional preferences of a species, the derivation of 'local species indicator' values may be more appropriate. These could be based on the weighted averages for any species in the vegetational zones and sections where they occur, or, when available, be derived from interpolated climatic variables for localities at which the species are found (see the Appendix following the References).

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Appendix. List of the 372 plant species with frequency >3 for the 347 mire localities of central Norway, used in the species-centred analysis. Ellenberg's T and K values after Ellenberg et al. (1991). See the text for the calculation of regional species scores for zone (RSSz) and section (RSSs), and climatic species scores: APET = annual potential evapotranspiration, APREC = annual precipitation, GDD0 and GDD5 = accumulated temperatures above 0° and 5°C, MTCO and MTWA = mean temperature in the coldest and warmest months, and MTWA-MTCO = annual temperature range.

Species name	No of records	Ellenberg's T	Ellenberg's K	RSSz	RSSs	APET	APREC	GDD0	GDD5	MTCO	MTWA	MTWA-MTWCO
Agrostis canina	95	5	5	2.84	2.59	374	935	1762	751	-4.68	12.84	17.52
Agrostis capillaris	177	-	3	2.85	2.47	375	981	1765	764	-4.53	13.00	17.52
Agrostis stolonifera	29	-	5	2.72	2.28	371	956	1773	751	-4.26	12.78	17.04
Alchemilla sp.	133	-	-	3.11	2.63	367	951	1638	685	-5.33	12.53	17.87
Alnus incana	243	4	5	2.72	2.41	378	1029	1842	813	-4.03	13.35	17.38
Alopecurus aequalis	4	-	5	2.75	3.50	371	683	1683	689	-7.10	12.43	19.53
Alopecurus geniculatus	5	6	3	3.20	2.80	361	885	1489	607	-5.86	12.04	17.90
Andromeda polifolia	336	4	5	2.76	2.34	376	1016	1832	793	-3.99	13.11	17.09
Anemone nemorosa	70	-	3	2.81	2.34	376	1033	1820	787	-3.80	13.10	16.91
Angelica archangelica ssp. archangelica	32	6	5	3.38	2.94	357	821	1446	586	-7.03	12.00	19.03
Angelica sylvestris	109	-	4	2.90	2.58	369	949	1717	734	-5.34	12.87	18.21
Anthoxanthum odoratum	168	-	-	2.98	2.51	369	968	1712	731	-4.90	12.84	17.74
Arctostaphylos alpinus	87	2	5	2.98	2.24	366	939	1723	703	-4.43	12.39	16.83
Bartsia alpina	138	3	3	3.19	2.52	364	942	1601	658	-5.39	12.35	17.74
Betula nana	322	3	6	2.78	2.38	375	993	1813	787	-4.18	13.11	17.29
Betula pubescens	329	-	-	2.76	2.37	375	1007	1823	792	-4.10	13.13	17.23
Bistorta vivipara	184	2	-	2.97	2.64	369	925	1685	725	-5.29	12.86	18.15
Calamagrostis purpurea	184	-	-	2.92	2.64	370	939	1715	749	-5.23	13.09	18.32
Calamagrostis stricta	44	5	-	3.05	3.25	365	801	1538	655	-7.02	12.52	19.54
Calluna vulgaris	336	-	3	2.75	2.32	376	1015	1842	799	-3.93	13.15	17.08
Caltha palustris	122	-	-	2.86	2.57	372	957	1747	750	-4.83	12.91	17.74
Cardamine amara	17	-	4	2.59	3.24	387	803	1846	848	-5.36	13.79	19.16
Cardamine pratensis ssp. dentata	27	6	-	2.93	2.52	370	910	1732	725	-4.83	12.62	17.45
Cardamine pratensis ssp. polemonioides	8	-	-	3.25	4.00	360	644	1365	551	-9.01	11.86	20.88
Carex acuta	6	-	-	3.00	2.67	368	936	1632	713	-6.05	12.93	18.98
Carex appropinquata	4	5	5	2.25	2.25	368	822	1898	807	-3.45	13.08	16.52
Carex aquatilis ssp. aquatilis	12	6	5	3.58	4.00	357	648	1304	515	-9.52	11.64	21.16
Carex atrata	9	2	3	3.67	3.44	344	734	1203	441	-8.66	11.04	19.70
Carex atrofusca	32	-	-	3.75	3.56	347	699	1222	455	-9.00	11.19	20.18
Carex bigelowii	82	3	3	3.27	2.59	358	931	1569	633	-5.66	12.17	17.84
Carex binervis	11	5	1	2.09	1.09	391	1295	2298	935	0.53	13.05	12.53
Carex brunnescens	16	2	-	3.19	3.19	366	785	1549	661	-7.11	12.64	19.75
Carex buxbaumii ssp. buxbaumii	86	6	5	3.06	2.69	367	918	1638	705	-5.71	12.88	18.59
Carex buxbaumii ssp. mutica	59	-	-	3.53	2.97	353	839	1398	563	-7.59	11.99	19.57
Carex canescens	210	4	-	2.90	2.54	371	955	1734	748	-4.88	12.95	17.84
Carex capillaris	101	1	-	3.16	2.71	363	873	1577	659	-5.95	12.46	18.41
Carex capitata	5	4	7	3.60	4.60	354	534	1240	482	-10.42	11.54	21.96
Carex chordorrhiza	142	5	7	3.00	2.77	368	904	1632	702	-5.83	12.77	18.61
Carex demissa	154	-	1	2.58	1.94	382	1088	1953	848	-2.50	13.27	15.77
Carex diandra	9	6	7	2.33	2.44	374	882	1938	855	-3.71	13.54	17.26
Carex dioica	240	4	-	2.84	2.42	373	982	1771	761	-4.41	12.94	17.34
Carex echinata	296	-	3	2.77	2.34	375	1016	1824	790	-4.03	13.11	17.14
Carex elongata	4	6	3	2.25	3.00	384	848	1869	872	-5.25	14.10	19.35
Carex flacca	11	-	3	2.00	1.18	383	985	2256	951	-0.09	13.39	13.48
Carex flava	178	-	2	3.07	2.66	367	923	1634	701	-5.59	12.80	18.38
Carex globularis	4	-	-	3.25	5.00	379	502	1472	651	-11.13	12.95	24.08
Carex heleonastes	4	5	7	3.75	4.50	345	569	1160	423	-10.00	11.05	21.05
Carex hostiana	68	5	2	2.72	2.06	378	1036	1862	802	-3.48	13.11	16.59
Carex lasiocarpa	278	4	-	2.79	2.46	374	980	1786	780	-4.51	13.14	17.65
Carex lepidocarpa	36	5	2	2.50	2.56	382	932	1884	859	-3.95	13.79	17.74
Carex limosa	296	4	-	2.80	2.43	374	990	1796	782	-4.37	13.11	17.48
Carex livida	79	-	-	3.10	3.08	364	841	1545	651	-6.67	12.46	19.14
Carex microglochin	26	3	3	3.62	3.46	350	744	1279	488	-8.32	11.37	19.69
Carex nigra ssp. juncella	30	-	-	3.10	3.53	363	730	1497	620	-7.86	12.24	20.11
Carex nigra ssp. nigra	314	-	3	2.77	2.31	376	1013	1833	790	-3.93	13.06	16.99

Species name	No of records	Ellenberg's T	Ellenberg's K	RSSz	RSSs	APET	APREC	GDD0	GDD5	MTCO	MTWA	MTWA-MTWCO
Carex norvegica ssp. norvegica	16	4	4	3.56	3.44	352	769	1311	508	-8.07	11.54	19.61
Carex pallescens	78	4	3	2.97	2.45	370	963	1694	724	-4.85	12.82	17.67
Carex panicea	296	-	3	2.79	2.29	375	1015	1821	783	-3.94	13.02	16.96
Carex pauciflora	318	3	5	2.75	2.34	376	1023	1838	800	-3.98	13.18	17.16
Carex paupercula	190	-	-	2.87	2.53	372	957	1740	752	-4.72	12.95	17.67
Carex pulicaris	62	4	2	2.50	1.85	381	1033	1978	849	-2.50	13.24	15.74
Carex rariflora	24	-	-	3.75	3.00	348	814	1316	498	-7.35	11.32	18.67
Carex rostrata	326	-	-	2.77	2.38	375	1005	1817	788	-4.14	13.10	17.24
Carex rotundata	17	-	-	3.35	3.18	354	828	1399	568	-7.42	11.98	19.40
Carex saxatilis	29	-	-	3.69	3.52	346	720	1239	466	-8.67	11.24	19.91
Carex serotina ssp. pulchella	9	6	3	2.22	2.11	384	933	2041	894	-3.12	13.52	16.64
Carex serotina ssp. serotina	9	-	3	2.44	2.22	379	908	1941	840	-3.98	13.23	17.21
Carex stenolepis	13	-	-	3.69	3.00	349	805	1293	496	-7.82	11.45	19.28
Carex vaginata	154	3	6	3.03	2.64	369	916	1661	707	-5.29	12.71	18.00
Carex vesicaria	42	4	-	2.95	2.81	366	917	1622	712	-6.50	13.09	19.59
Cerastium cerastoides	9	1	-	4.00	3.22	343	774	1212	438	-7.98	10.93	18.91
Cerastium fontanum	42	3	4	3.02	2.76	366	882	1651	689	-5.41	12.51	17.92
Cirsium helenioides	99	4	5	3.03	2.55	366	919	1648	694	-5.47	12.62	18.09
Cirsium palustre	59	5	3	2.78	2.29	376	1032	1820	792	-4.07	13.13	17.20
Coeloglossum viride	33	-	-	3.39	2.64	355	873	1475	583	-6.25	11.87	18.12
Corallorhiza trifida	32	4	7	3.03	2.38	369	982	1674	721	-4.94	12.86	17.80
Cornus suecica	254	4	3	2.72	2.13	377	1054	1878	814	-3.39	13.19	16.58
Crepis paludosa	111	-	3	3.01	2.39	369	972	1699	714	-4.70	12.67	17.37
Cystopteris montana	6	-	4	3.50	3.00	354	849	1430	574	-6.32	11.93	18.25
Dactylorhiza fuchsii	23	-	-	3.04	2.39	362	974	1611	669	-5.39	12.49	17.87
Dactylorhiza incarnata ssp. cruenta	9	-	-	3.56	3.44	355	742	1342	532	-8.39	11.86	20.24
Dactylorhiza incarnata ssp. incarnata	94	5	3	2.85	2.47	372	994	1751	760	-4.63	13.10	17.73
Dactylorhiza lapponica	15	-	-	3.20	2.60	365	881	1520	638	-6.65	12.46	19.11
Dactylorhiza maculata	200	-	2	2.74	2.11	378	1065	1879	805	-3.25	13.06	16.31
Danthonia decumbens	10	-	2	2.40	1.80	385	1138	1990	860	-2.01	13.21	15.22
Deschampsia cespitosa ssp. cespitosa	263	-	-	2.87	2.49	372	978	1753	759	-4.67	13.01	17.68
Deschamspia flexuosa	265	-	-	2.78	2.31	374	1008	1819	783	-4.06	13.05	17.11
Drosera anglica	304	4	3	2.67	2.23	378	1040	1882	825	-3.60	13.32	16.92
Drosera rotundifolia	303	4	3	2.64	2.17	379	1054	1910	836	-3.34	13.34	16.68
Eleocharis mamillata	10	5	-	2.30	1.90	385	1040	2052	901	-2.56	13.51	16.07
Eleocharis quinqueflora	100	-	3	2.99	2.55	370	919	1669	714	-5.27	12.75	18.01
Empetrum nigrum	337	-	-	2.76	2.34	376	1011	1834	794	-3.98	13.11	17.09
Epilobium alsinifolium	32	2	2	3.25	3.00	359	866	1462	594	-6.50	11.97	18.48
Epilobium anagallidifolium	6	2	3	4.00	3.00	340	784	1188	430	-8.32	10.97	19.28
Epilobium angustifolium	75	-	5	2.88	2.77	367	937	1733	770	-5.55	13.36	18.92
Epilobium davuricum	27	-	-	3.07	3.07	367	867	1595	688	-6.24	12.76	19.00
Epilobium hornemannii	35	-	-	3.49	2.97	352	845	1372	539	-7.18	11.70	18.88
Epilobium lactiflorum	9	-	-	3.11	2.56	362	921	1524	632	-5.79	12.37	18.16
Epilobium palustre	93	5	-	2.80	2.39	374	952	1799	766	-4.29	12.89	17.18
Equisetum arvense ssp. arvense	65	-	-	3.02	2.63	367	880	1648	701	-5.66	12.72	18.38
Equisetum fluviatile	255	4	-	2.78	2.42	375	996	1806	788	-4.35	13.16	17.52
Equisetum hyemale	33	5	5	3.00	2.70	367	928	1638	686	-5.70	12.53	18.23
Equisetum palustre	233	-	5	2.92	2.58	371	952	1717	743	-5.08	12.97	18.04
Equisetum pratense	30	4	7	3.20	2.87	364	853	1546	652	-6.46	12.50	18.96
Equisetum scirpoides	7	-	-	3.14	3.43	358	773	1461	602	-7.51	12.16	19.67
Equisetum sylvaticum	218	4	-	2.90	2.46	373	998	1751	755	-4.63	12.96	17.59
Equisetum variegatum	27	3	7	3.30	3.33	357	760	1415	572	-7.96	11.98	19.94
Erica tetralix	174	5	1	2.48	1.70	385	1128	2048	884	-1.63	13.30	14.93
Eriophorum angustifolium	342	-	-	2.76	2.33	376	1012	1832	793	-3.98	13.10	17.08
Eriophorum gracile	4	4	5	2.25	2.00	384	981	1960	900	-3.37	13.93	17.30
Eriophorum latifolium	184	-	3	2.84	2.33	374	1004	1791	776	-4.15	13.08	17.23
Eriophorum scheuchzeri	10	2	-	3.70	3.50	349	716	1277	491	-8.49	11.39	19.88
Eriophorum vaginatum	343	-	-	2.76	2.34	376	1012	1835	795	-3.97	13.12	17.08
Euphrasia frigida	205	3	3	2.92	2.40	371	986	1740	745	-4.54	12.90	17.44
Festuca rubra	111	-	5	2.69	2.39	376	981	1824	793	-4.11	13.13	17.24
Festuca vivipara	90	-	-	2.77	1.89	375	1046	1891	793	-2.75	12.84	15.59
Filipendula ulmaria	220	5	-	2.89	2.55	372	951	1740	756	-4.92	13.04	17.96
Frangula alnus	8	6	5	2.00	2.25	402	1207	2146	1010	-2.50	14.39	16.89
Galium boreale	157	6	7	2.98	2.61	369	928	1676	724	-5.29	12.89	18.18
Galium palustre	131	5	3	2.72	2.46	377	965	1817	792	-4.32	13.14	17.47

Species name	No of records	Ellenberg's T	Ellenberg's K	RSSz	RSSe	APET	APREC	GDD0	GDD5	MTCO	MTWA	MTWA-MTWCO
Galium trifidum	5	-	-	3.40	4.00	352	624	1266	489	-9.38	11.52	20.90
Galium uliginosum	36	5	-	2.94	2.81	371	880	1681	723	-5.54	12.81	18.35
Geranium sylvaticum	133	4	4	3.10	2.70	365	906	1617	684	-5.77	12.63	18.40
Geum rivale	109	-	5	3.13	2.83	365	867	1588	668	-6.08	12.51	18.60
Glyceria fluitans	9	-	3	2.11	1.89	392	1061	2109	946	-2.18	13.89	16.07
Gymnadenia conopsea	40	-	2	3.25	2.85	357	854	1459	597	-7.12	12.16	19.28
Gymnocarpium dryopteris	114	4	5	2.75	2.41	373	1015	1819	804	-4.30	13.37	17.67
Hammarbya paludosa	19	5	3	2.74	2.21	385	1016	1876	843	-3.85	13.54	17.39
Hierochloe odorata	50	6	7	3.06	2.62	367	944	1664	726	-5.51	13.01	18.52
Hippuris vulgaris	28	5	-	3.00	2.29	366	895	1750	719	-4.35	12.45	16.81
Holcus lanatus	4	6	3	1.25	1.00	397	1245	2551	1081	1.18	13.67	12.50
Huperzia selago	226	3	3	2.87	2.29	373	1027	1787	763	-4.07	12.91	16.98
Isoetes lacustris	5	4	2	3.20	1.60	368	1101	1768	691	-2.98	12.28	15.26
Juncus alpinoarticulatus	149	-	6	3.00	2.56	368	940	1664	709	-5.25	12.75	18.00
Juncus arcticus ssp. arcticus	6	-	-	3.33	3.50	351	820	1383	546	-7.27	11.67	18.93
Juncus articulatus	110	-	3	2.60	1.95	381	1070	1937	840	-2.75	13.24	16.00
Juncus biglumis	19	-	-	3.68	3.21	351	806	1362	538	-7.59	11.72	19.31
Juncus bufonius	18	5	-	2.78	2.33	374	984	1826	786	-3.72	13.02	16.74
Juncus castaneus	46	-	-	3.57	2.98	356	801	1382	549	-7.51	11.79	19.30
Juncus conglomeratus	88	5	3	2.24	1.63	388	1124	2136	926	-1.13	13.46	14.59
Juncus effusus	22	5	3	2.41	2.05	384	1086	1962	850	-2.53	13.28	15.81
Juncus filiformis	198	4	5	2.86	2.52	372	962	1751	759	-4.75	13.00	17.75
Juncus squarrosus	57	5	2	2.68	1.40	384	1224	2064	852	-0.99	12.87	13.86
Juncus stygius	36	4	4	2.97	2.50	371	945	1653	711	-5.47	12.82	18.29
Juncus supinus	70	6	2	2.63	1.67	383	1155	2013	850	-1.55	13.05	14.60
Juncus triglumis	67	2	7	3.43	2.90	358	834	1434	578	-7.00	11.96	18.96
Juniperus communis	225	-	-	2.75	2.30	376	1013	1838	788	-3.77	13.00	16.77
Kobresia simpliciuscula	18	1	7	3.61	3.61	349	691	1240	467	-8.99	11.31	20.31
Leontodon autumnalis	60	-	3	3.12	2.55	363	901	1589	645	-5.75	12.22	17.96
Leucorchis albida	5	-	-	3.00	2.00	369	964	1724	706	-4.34	12.46	16.80
Linum catharticum	12	-	3	2.42	1.83	375	963	1971	847	-2.41	13.27	15.68
Listera cordata	32	4	3	3.03	2.50	367	915	1662	699	-4.85	12.68	17.53
Listera ovata	35	-	3	2.94	2.23	368	984	1723	732	-4.39	12.82	17.21
Lobelia dortmanna	4	5	2	2.75	1.75	378	907	1800	772	-4.60	12.97	17.57
Loiseleuria procumbens	31	2	3	3.65	2.65	353	931	1446	555	-5.82	11.57	17.39
Luzula multiflora coll.	172	-	4	2.92	2.40	372	994	1746	739	-4.40	12.77	17.17
Luzula sudetica	92	3	4	3.20	2.82	363	856	1545	643	-6.42	12.36	18.78
Luzula sylvatica	5	4	2	2.80	1.20	379	1262	2147	814	0.48	12.34	11.86
Lycopodiella inundata	43	4	2	2.63	2.00	384	1127	1925	837	-2.45	13.19	15.64
Lycopodium annotinum	108	4	3	2.94	2.40	370	991	1746	751	-4.44	12.97	17.41
Lysimachia thyrsiflora	14	6	1	2.36	2.21	388	1019	1969	903	-3.55	13.87	17.42
Malanthemum bifolium	79	-	6	2.94	2.52	372	993	1732	754	-4.76	13.08	17.85
Melampyrum pratense	222	5	3	2.77	2.34	374	980	1809	780	-4.16	13.05	17.21
Menyanthes trifoliata	318	-	-	2.75	2.35	376	1006	1832	796	-4.05	13.15	17.20
Molinia caerulea	335	-	3	2.75	2.31	376	1019	1838	796	-3.93	13.13	17.06
Montia fontana	10	4	2	3.00	1.80	370	1114	1864	769	-2.22	12.73	14.95
Myrica gale	104	6	2	2.15	1.88	391	1098	2124	951	-1.84	13.79	15.63
Myriophyllum alterniflorum	16	5	2	2.38	1.94	375	931	1978	840	-2.54	13.06	15.59
Nardus stricta	182	-	3	3.02	2.48	369	977	1696	717	-4.84	12.72	17.56
Narthecium ossifragum	271	4	1	2.61	2.03	380	1083	1939	846	-2.90	13.33	16.23
Nuphar sp.	13	-	-	2.31	1.62	385	1048	2120	929	-1.22	13.58	14.79
Nymphaea sp.	61	-	-	2.52	1.93	381	1051	1944	854	-2.92	13.40	16.32
Oreopteris limbosperma	22	4	2	3.00	1.86	375	1122	1793	744	-2.94	12.65	15.59
Orthilia secunda	33	-	3	3.12	2.67	368	875	1617	687	-5.76	12.69	18.45
Oxyria digyna	17	2	-	3.47	3.06	353	912	1453	567	-6.82	11.84	18.66
Parnassia palustris	195	-	-	3.02	2.67	367	934	1663	715	-5.52	12.87	18.39
Pedicularis lapponica	24	-	-	3.79	3.58	347	713	1236	462	-8.75	11.20	19.95
Pedicularis oederi	55	2	7	3.49	2.96	355	803	1366	542	-7.55	11.74	19.29
Pedicularis palustris	229	-	-	2.90	2.56	370	943	1717	743	-5.10	12.97	18.07
Pedicularis sceptrum-carolinum	12	5	7	3.50	3.42	352	750	1335	535	-8.30	11.85	20.15
Pedicularis sylvatica	32	5	2	2.69	1.66	387	1251	2024	854	-1.36	12.97	14.33
Petasites frigidus	15	-	-	3.73	4.00	354	621	1274	497	-9.63	11.59	21.22
Phalaris arundinacea	20	5	-	2.60	2.20	380	1008	1943	881	-3.33	13.82	17.15
Phegopteris connectilis	106	4	3	2.77	2.39	373	1036	1818	804	-4.28	13.38	17.66
Phleum alpinum	27	3	3	3.37	2.93	356	853	1412	567	-6.87	11.89	18.77

Species name	No of records	Ellenberg's T	Ellenberg's K	RSSz	RSSs	APET	APREC	GDD0	GDD5	MTCO	MTWA	MTWA-MTWCO
Phragmites australis	69	5	-	2.55	2.16	380	998	1954	867	-3.02	13.56	16.59
Picea abies ssp. abies	162	3	6	2.82	2.59	371	954	1754	784	-5.10	13.45	18.55
Pinguicula villosa	15	-	-	3.67	3.67	350	697	1254	477	-9.12	11.37	20.49
Pinguicula vulgaris	298	-	3	2.78	2.29	375	1013	1823	784	-3.97	13.04	17.01
Pinus sylvestris	285	-	7	2.70	2.36	378	1027	1854	818	-3.98	13.35	17.33
Plantago lanceolata	7	-	3	2.86	1.86	374	1165	1778	753	-3.06	12.70	15.76
Platanthera bifolia	28	-	3	2.82	2.07	370	1015	1755	757	-3.89	13.01	16.90
Platanthera chlorantha	4	-	3	2.50	1.75	384	1112	1979	835	-2.08	12.92	15.00
Poa alpina	18	3	5	3.83	3.28	347	760	1238	459	-8.31	11.16	19.47
Poa pratensis ssp. pratensis	30	-	-	2.93	2.70	373	906	1737	745	-5.09	12.90	17.99
Polygala serpyllifolia	30	4	2	2.43	1.40	389	1295	2204	907	-0.08	13.03	13.12
Polygala vulgaris	5	-	3	2.40	2.00	391	1060	2034	906	-2.10	13.62	15.72
Potamogeton alpinus	14	4	-	3.29	3.00	362	844	1524	635	-6.71	12.26	18.96
Potamogeton natans	30	5	5	2.77	2.03	377	1017	1857	810	-3.65	13.18	16.83
Potamogeton polygonifolius	29	6	2	2.21	1.34	390	1184	2249	959	-0.22	13.43	13.66
Potentilla erecta	316	-	3	2.76	2.28	376	1015	1843	795	-3.82	13.08	16.91
Potentilla palustris	248	-	-	2.87	2.51	372	959	1757	761	-4.72	13.01	17.74
Prunella vulgaris	50	-	3	2.82	2.20	374	994	1769	758	-4.14	12.91	17.05
Prunus padus	12	5	3	2.67	2.67	380	1013	1835	791	-4.52	13.00	17.52
Pyrola minor	62	-	-	3.18	2.71	364	892	1576	652	-5.92	12.34	18.26
Pyrola rotundifolia	21	-	5	2.90	3.05	365	797	1612	687	-6.50	12.74	19.24
Ranunculus acris	112	-	3	2.97	2.63	369	929	1683	714	-5.12	12.70	17.82
Ranunculus flammula	20	-	3	2.10	1.15	387	1185	2272	951	0.05	13.29	13.25
Ranunculus reptans	11	6	-	2.91	3.00	373	824	1733	746	-5.46	12.86	18.33
Rhynchospora alba	140	5	3	2.30	2.18	389	1086	2052	934	-2.61	13.93	16.54
Rhynchospora fusca	12	5	2	2.50	1.92	387	1056	2007	894	-2.43	13.61	16.04
Rubus chamaemorus	336	3	7	2.76	2.33	376	1011	1831	794	-3.99	13.13	17.12
Rumex acetosa	75	-	-	2.92	2.36	370	971	1742	726	-4.32	12.59	16.90
Sagina procumbens	17	-	3	2.94	2.35	365	940	1704	703	-4.45	12.46	16.92
Salix arbuscula	24	-	-	3.42	3.71	355	689	1328	525	-8.89	11.73	20.62
Salix aurita	202	-	3	2.53	1.98	383	1086	1980	867	-2.51	13.43	15.94
Salix caprea	75	-	3	2.72	2.48	371	943	1782	778	-4.84	13.20	18.04
Salix glauca	192	-	-	3.02	2.71	368	931	1637	702	-5.67	12.78	18.45
Salix hastata	24	3	7	3.33	3.29	356	787	1377	553	-7.89	11.92	19.81
Salix herbacea	13	2	3	3.77	2.85	350	849	1348	512	-6.72	11.35	18.07
Salix lanata	21	-	-	3.57	3.05	351	813	1334	518	-7.47	11.53	19.00
Salix lapponum	156	-	-	3.10	2.85	365	898	1605	688	-6.17	12.78	18.95
Salix myrsinifolia ssp. myrsinifolia	57	-	-	3.04	2.75	365	868	1616	681	-5.78	12.54	18.32
Salix myrsinites	33	-	-	3.39	3.45	355	740	1360	544	-8.15	11.81	19.96
Salix pentandra	45	5	7	2.60	2.78	376	848	1807	800	-5.08	13.34	18.43
Salix phylicifolia	156	-	-	3.10	2.72	367	916	1633	692	-5.63	12.66	18.29
Salix repens	4	5	-	2.25	2.00	385	1047	2143	866	-1.90	12.88	14.77
Salix reticulata	6	2	-	3.67	3.67	349	677	1228	459	-9.22	11.18	20.40
Saussurea alpina	150	1	7	3.09	2.68	367	903	1617	681	-5.56	12.57	18.14
Saxifraga aizoides	75	3	3	3.35	2.63	361	903	1530	619	-6.05	12.11	18.16
Saxifraga oppositifolia	4	2	3	2.50	1.75	361	1000	1871	742	-2.50	12.25	14.75
Saxifraga stellaris	36	3	2	3.61	2.61	355	964	1461	556	-5.76	11.56	17.33
Scheuchzeria palustris	146	5	5	2.82	2.51	375	1019	1768	784	-4.80	13.30	18.10
Schoenoplectus lacustris	4	-	-	2.50	2.25	386	1017	1953	876	-3.07	13.62	16.70
Schoenus ferrugineus	31	4	4	2.74	2.35	378	998	1822	809	-4.09	13.41	17.50
Scirpus sylvaticus	6	5	4	2.50	2.17	385	1005	1978	922	-3.57	14.13	17.70
Scutellaria galericulata	6	6	5	2.00	1.83	393	1039	2197	1000	-1.35	14.07	15.42
Selaginella selaginoides	223	3	3	2.86	2.50	372	975	1740	745	-4.62	12.89	17.51
Solidago virgaurea	192	-	-	2.91	2.46	371	978	1740	748	-4.73	12.92	17.66
Sorbus aucuparia	161	-	-	2.64	2.24	378	1041	1879	818	-3.56	13.23	16.79
Sparganium angustifolium	38	-	3	2.84	2.26	375	953	1841	785	-3.80	12.96	16.76
Sparganium hyperboreum	8	-	-	4.00	3.13	346	783	1259	472	-7.86	11.29	19.15
Sparganium natans	9	5	5	2.33	1.67	371	928	2007	850	-2.16	13.11	15.27
Stellaria alsine	12	4	3	3.00	2.75	380	1056	1813	773	-4.49	12.98	17.48
Stellaria borealis	12	-	-	3.42	4.00	355	662	1308	516	-9.03	11.68	20.72
Stellaria nemorum	14	-	4	3.14	2.71	364	895	1577	662	-5.59	12.44	18.03
Succisa pratensis	245	5	3	2.68	2.13	378	1045	1885	816	-3.31	13.18	16.49
Thalictrum alpinum	122	-	-	3.20	2.77	363	878	1541	646	-6.30	12.43	18.73
Tofieldia pusilla	196	2	-	3.00	2.59	369	957	1674	712	-5.20	12.75	17.95
Trichophorum alpinum	174	-	-	3.01	2.70	368	920	1647	707	-5.55	12.79	18.34

Species name	No of records	Ellenberg's T	Ellenberg's K	RSSz	RSSs	APET	APREC	GDD0	GDD5	MTCO	MTWA	MTWA-MTWCO
Trichophorum cespitosum ssp. cespitosum	343	-	-	2.76	2.34	376	1013	1835	795	-3.96	13.12	17.08
Trichophorum cespitosum ssp. germanicum	22	-	-	2.23	1.55	390	1234	2145	920	-0.87	13.31	14.18
Trientalis europaea	248	5	7	2.80	2.35	375	1005	1811	787	-4.13	13.12	17.25
Triglochin palustris	138	-	-	2.84	2.41	374	976	1762	756	-4.45	12.89	17.34
Trollius europaeus	4	3	5	3.50	3.25	345	801	1315	527	-9.08	12.13	21.20
Tussilago farfara	25	-	3	2.88	2.56	371	913	1696	737	-4.99	12.98	17.98
Utricularia intermedia	61	6	-	2.84	2.64	376	907	1741	769	-4.93	13.20	18.13
Utricularia minor	41	6	-	2.88	2.44	374	992	1751	760	-4.64	12.98	17.62
Utricularia ochroleuca	18	6	2	2.61	2.06	379	1076	1879	822	-3.34	13.21	16.56
Vaccinium myrtillus	326	-	5	2.77	2.36	376	1007	1828	793	-4.04	13.12	17.16
Vaccinium oxycoccus ssp. microcarpus	311	-	-	2.77	2.42	375	994	1807	788	-4.30	13.14	17.44
Vaccinium oxycoccus ssp. oxycoccus	80	-	-	2.49	2.66	382	979	1907	880	-4.34	13.98	18.31
Vaccinium uliginosum ssp. uliginosum	335	-	5	2.76	2.34	376	1011	1832	793	-4.00	13.11	17.11
Vaccinium vitis-idaea	310	-	5	2.74	2.35	376	1010	1840	800	-3.97	13.16	17.14
Valeriana sambucifolia ssp. sambucifolia	55	6	5	3.00	2.78	368	917	1696	732	-5.71	12.94	18.64
Veronica alpina	12			3.83	3.17	344	787	1216	444	-8.12	11.02	19.14
Veronica scutellata	15	5	3	2.67	2.53	379	926	1799	798	-4.52	13.31	17.83
Veronica serpyllifolia	5	-	3	3.00	2.80	366	914	1560	651	-5.74	12.34	18.08
Vicia cracca	39	5	-	2.64	2.28	376	960	1863	826	-3.84	13.42	17.27
Viola biflora	48	3	4	3.19	2.73	365	923	1581	664	-5.61	12.48	18.09
Viola epipsila	30	5	7	2.97	3.33	373	768	1625	711	-6.94	12.91	19.86
Viola palustris	264	-	3	2.85	2.38	374	1007	1788	769	-4.24	12.98	17.23
Cetraria islandica	92	-	6	2.75	2.51	376	989	1792	794	-4.65	13.30	17.95
Cetraria nivalis	24	1	6	3.33	3.25	359	731	1398	568	-8.11	12.00	20.10
Cladonia stellaris	145	2	6	2.70	2.70	375	934	1781	792	-5.03	13.31	18.34
Cladonia uncialis	36	4	6	2.56	2.53	381	997	1838	838	-4.61	13.68	18.29
Icmadophila ericetorum	55	3	6	3.20	2.85	361	869	1511	627	-6.53	12.33	18.86
Ochrolechia frigida	27	-	-	2.67	2.74	374	947	1730	777	-5.54	13.37	18.91
Siphula ceratites	22	-	-	2.82	1.82	374	1107	1868	791	-2.37	12.87	15.24
Aneura pinguis	153	-	5	2.85	2.44	375	993	1773	765	-4.35	13.00	17.35
Bazzania trilobata	6	4	6	2.50	1.50	389	1252	2163	913	-0.37	13.18	13.55
Bryum pseudotriquetrum	125	-	5	2.94	2.62	371	941	1684	726	-5.20	12.87	18.07
Bryum weigelii	13	2	6	3.46	3.31	355	730	1324	525	-8.62	11.68	20.29
Calliergon giganteum	36	3	5	3.06	3.08	367	830	1594	683	-6.37	12.70	19.07
Calliergon richardsonii	24	2	7	3.08	3.21	369	808	1587	681	-6.84	12.65	19.49
Calliergonella cuspidata	77	3	5	2.74	2.45	373	977	1772	774	-4.41	13.14	17.55
Campylium stellatum	218	2	6	2.89	2.50	371	954	1730	739	-4.73	12.85	17.59
Catoscopium nigritum	21	2	6	3.14	3.24	360	762	1453	602	-7.60	12.20	19.80
Cinclidium stygium	69	2	6	3.01	2.94	367	876	1611	693	-5.93	12.73	18.67
Climacium dendroides	24	3	5	3.08	3.13	368	819	1559	663	-6.63	12.54	19.18
Cratoneuron filicinum	11	-	5	2.64	2.55	371	969	1761	757	-4.41	13.02	17.43
Ctenidium molluscum	7	4	5	3.00	2.29	368	982	1731	732	-4.20	12.73	16.93
Dicranella palustris	28	2	6	3.21	2.46	363	943	1575	637	-5.62	12.11	17.72
Dicranum bonjeanii	25	3	6	3.12	2.52	366	956	1646	699	-5.30	12.70	18.00
Dicranum leioneuron	90	3	6	2.61	2.28	382	1046	1918	854	-3.32	13.55	16.87
Fissidens adianthoides	56	3	5	2.91	2.52	370	955	1700	735	-5.02	12.94	17.97
Fissidens osmundoides	5	2	6	3.00	3.20	375	821	1624	709	-6.72	12.88	19.60
Gymnocolea borealis	85	-	-	3.07	2.61	368	927	1624	693	-5.42	12.70	18.12
Hypnum jutlandicum	30	3	3	2.43	1.47	390	1210	2175	912	-0.52	13.16	13.68
Jungermannia exsertifolia	13	2	6	3.69	3.08	349	801	1301	493	-7.59	11.35	18.94
Leucobryum glaucum	20	3	4	2.70	1.45	378	1083	1971	804	-2.12	12.76	14.88
Loeskypnum badium	168	-	-	2.98	2.61	372	957	1690	725	-4.99	12.81	17.81
Lophozia bantriensis	25	2	6	3.08	2.68	365	926	1593	681	-5.77	12.70	18.47
Lophozia rutheana	66	1	6	2.97	2.71	369	923	1652	718	-5.69	12.93	18.63
Meesia triquetra	8	2	6	3.38	4.13	361	594	1344	546	-9.71	11.99	21.70
Moerckia hibernica	6	3	6	2.67	3.00	369	889	1624	702	-5.55	12.78	18.33
Oncophorus wahlenbergii	5	1	6	3.40	3.60	361	736	1382	555	-8.50	11.84	20.34
Oncophorus virens	5	1	6	3.40	3.80	357	696	1354	538	-8.34	11.76	20.10
Paludella squarrosa	48	2	6	3.06	3.27	366	812	1568	673	-6.76	12.66	19.42
Palustriella decipiens	35	1	2	3.11	2.71	368	940	1624	696	-5.39	12.73	18.11
Palustriella commutata coll.	76	3	5	3.09	2.63	367	935	1629	695	-5.43	12.70	18.13
Philonotis calcarea	14	2	4	2.64	2.50	375	926	1767	777	-4.39	13.20	17.59
Philonotis fontana	74	-	6	3.16	2.66	365	939	1595	668	-5.52	12.47	17.99
Philonotis seriata	6	1	6	3.33	2.83	360	892	1477	599	-6.07	11.93	18.00
Plagiomnium elatum	27	2	4	2.78	2.59	374	968	1751	775	-4.74	13.27	18.01

Species name	No of records	Ellenberg's T	Ellenberg's K	RSSz	RSSs	APET	APREC	GDD0	GDD5	MTCO	MTWA	MTWA-MTWCO
Plagiomnium ellipticum	14	2	4	2.86	3.14	370	804	1597	691	-6.38	12.78	19.16
Pohlia wahlenbergii	17	-	6	3.47	2.88	352	883	1399	547	-6.71	11.62	18.32
Preissia quadrata	6	2	6	3.17	2.33	360	866	1446	592	-6.55	12.17	18.72
Pseudobryum cinclidioides	8	2	6	2.63	3.25	374	823	1669	740	-6.28	13.11	19.39
Pseudocalliergon trifarium	82	2	6	3.17	2.84	364	880	1553	658	-6.28	12.52	18.80
Racomitrium lanuginosum	259	-	6	2.61	2.05	380	1076	1935	845	-2.94	13.34	16.27
Rhizomnium pseudopunctatum	40	2	6	3.10	2.90	368	887	1607	692	-6.18	12.78	18.96
Rhytidiadelphus loreus	21	3	4	2.48	1.57	382	1110	2038	854	-1.50	13.05	14.56
Rhytidiadelphus triquetrus	18	3	6	2.67	2.11	377	961	1841	816	-4.06	13.39	17.46
Riccardia multifida	10	4	5	2.70	2.20	375	1026	1767	745	-4.05	12.74	16.79
Sanionia uncinata	20	-	-	3.05	2.55	368	966	1642	707	-5.53	12.83	18.35
Scapania uliginosa	20	2	5	3.30	2.50	364	991	1588	636	-4.99	12.00	16.99
Scapania undulata	27	3	5	3.19	2.74	365	953	1570	644	-5.56	12.22	17.77
Scorpidium revolvens coll.	225	-	6	2.91	2.48	371	961	1733	740	-4.71	12.85	17.56
Scorpidium scorpioides	195	2	6	2.95	2.57	370	940	1695	726	-5.12	12.82	17.94
Sphagnum angermanicum	23	-	-	3.04	2.22	368	986	1773	761	-3.37	13.10	16.46
Sphagnum angustifolium	168	3	6	2.65	2.31	378	1026	1871	814	-3.81	13.22	17.03
Sphagnum annulatum coll.	47	-	-	2.98	2.34	371	980	1693	719	-4.75	12.68	17.43
Sphagnum auriculatum	116	3	4	2.64	1.90	382	1101	1955	837	-2.42	13.11	15.53
Sphagnum austinii	106			2.16	1.63	392	1169	2197	959	-0.77	13.59	14.36
Sphagnum balticum	81	2	6	2.68	2.69	378	914	1786	802	-5.08	13.44	18.52
Sphagnum capillifolium + rubellum	334	3	5	2.73	2.32	376	1018	1845	800	-3.90	13.15	17.05
Sphagnum centrale	51	3	-	2.94	2.51	373	937	1711	744	-4.81	12.96	17.77
Sphagnum compactum	295	3	6	2.74	2.30	376	1025	1843	803	-3.88	13.19	17.07
Sphagnum contortum	82	3	6	2.83	2.45	375	980	1759	767	-4.52	13.10	17.62
Sphagnum cuspidatum coll.	157			2.36	2.01	385	1085	2039	904	-2.52	13.65	16.17
Sphagnum fuscum	319	2	7	2.77	2.39	375	1001	1814	788	-4.20	13.12	17.32
Sphagnum girgensohnii	160	2	6	2.79	2.51	374	998	1778	777	-4.52	13.14	17.66
Sphagnum lindbergii	255	1	6	2.85	2.49	372	976	1763	766	-4.65	13.08	17.72
Sphagnum magellanicum	305	3	6	2.69	2.27	378	1029	1868	814	-3.71	13.23	16.94
Sphagnum majus	123	3	6	2.67	2.32	380	1014	1856	813	-3.72	13.21	16.93
Sphagnum molle	63	5	4	2.60	1.68	385	1165	2021	861	-1.62	13.11	14.73
Sphagnum palustre	14	4	6	2.36	1.36	389	1164	2225	940	-0.50	13.34	13.84
Sphagnum papillosum	331	2	4	2.73	2.29	377	1027	1852	804	-3.79	13.16	16.96
Sphagnum platyphyllum	36	3	6	3.03	2.64	369	900	1640	697	-5.72	12.63	18.35
Sphagnum pulchrum	200	3	4	2.71	2.26	377	1043	1859	817	-3.78	13.33	17.11
Sphagnum quinquefarium	30	3	4	2.53	2.13	380	1090	1942	849	-3.01	13.34	16.35
Sphagnum recurvum coll.	250	3	6	2.78	2.34	376	1021	1831	790	-3.92	13.06	16.99
Sphagnum riparium	60	2	6	3.00	2.92	365	875	1591	677	-6.36	12.63	18.99
Sphagnum russowii	134	2	6	3.07	2.63	366	926	1618	684	-5.61	12.60	18.21
Sphagnum squarrosum	24	-	5	2.88	2.46	375	901	1746	766	-5.14	13.15	18.29
Sphagnum strictum	46	2	3	2.63	1.80	382	1182	1973	837	-1.93	13.02	14.95
Sphagnum subfulvum	113	1	5	3.04	2.73	368	917	1613	692	-5.82	12.73	18.55
Sphagnum subnitens	263	4	4	2.77	2.26	375	1019	1827	784	-3.84	13.02	16.85
Sphagnum subsecundum coll.	209	2	6	2.89	2.32	374	1012	1783	758	-4.11	12.84	16.95
Sphagnum tenellum	309	3	4	2.72	2.23	377	1038	1867	813	-3.65	13.22	16.87
Sphagnum teres	151	-	6	2.97	2.60	370	930	1673	712	-5.19	12.71	17.91
Sphagnum warnstorfii	183	2	6	2.98	2.69	369	932	1664	713	-5.47	12.81	18.27
Splachnum ampullaceum	10	3	6	3.10	2.70	370	883	1660	713	-5.29	12.88	18.17
Splachnum luteum	9	-	-	3.11	3.00	364	844	1572	662	-6.16	12.62	18.78
Splachnum sphaericum	15	2	6	3.20	2.87	364	870	1565	653	-5.83	12.41	18.23
Splachnum vasculosum	15	1	6	3.20	3.07	366	832	1540	642	-6.57	12.41	18.98
Tomentypnum nitens	70	2	6	3.14	3.16	363	802	1517	640	-7.10	12.47	19.57
Warnstorfia exannulata	122	2	6	3.06	2.65	369	941	1660	701	-5.14	12.62	17.76
Warnstorfia fluitans	79	-	6	2.82	2.47	371	979	1771	782	-4.75	13.29	18.03
Warnstorfia sarmentosa	146	1	6	3.07	2.59	368	945	1646	694	-5.24	12.63	17.87
Warnstorfia tundrae	11	-	-	3.00	3.45	363	760	1503	635	-7.11	12.40	19.51
Maximum value		6	7	4	5	402	1295	2551	1081	1.18	14.4	24.1
Minimum value		1	1	1.25	1	340	502	1160	423	-11	10.9	11.9
Mean value		3.6	4.4	2.9	2.6	370	942	1712	728	-4.9	12.8	17.7
Median value		3	5	2.9	2.52	371	953	1738	745	-4.8	12.9	17.7
Coefficient of variation (%)		40	37	13	21.5	2.83	13.1	13.3	16.2	41.1	4.89	9

The botanical value of the protected mire sites in the bog and southern aapa mire zones of Finland

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ABSTRACT

Eurola, S. & Hanhela, P. 1995. The botanical value of the protected mire sites in the bog and southern aapa mire zones of Finland. *Gunneria 70*: 199-204.

The study is based on a total of 619 km of line surveys on 246 plots randomly chosen in the mire conservation areas. The results are compared with the total (i.e. virgin and drained) and the virgin peatland vegetation of the same zones studied previously by the same method. The mire conservation plan for Finland satisfactorily protects the mire landscape and complexes containing mire expanse vegetation (poor fens, bog hollows, pine bogs/mires, birch and pine fens). Mire margin vegetation, in the form of spruce mires, is less well protected. Because this marginal vegetation is floristically valuable and includes 2/3 of the total number of peatland plant species, the vegetation of rich fens, swamps and springs requires more protection.

1 INTRODUCTION

The basic plan for mire conservation in Finland (Maa- ja metsätalousministeriö 1981) includes about 600 conservation areas (4900 km^2), 267 (700 km^2) of which are situated in the bog zone and 201 (1660 km^2) in the southern aapa mire zone (Fig. 1). A supplementary mire conservation programme has been prepared, covering 523 mires, including some particularly small areas, amounting to 1200 km^2 dispersed throughout the country (Heikkilä 1994). This paper shows to what extent existing nature reserves and national parks, along with areas in the proposed basic mire conservation plan, adequately cover the protection requirements of the Finnish peatlands, as indicated by the investigation made by Eurola et al. (1991). Suikki & Hanhela (1993, 1994) have published some results from the bog areas.

2 METHODS

The inventory was made on 246 randomly chosen plots measuring 0.5 x 0.5 km, 94 on bogs and 152 in the southern aapa mire zone. A line method was used, the distance between the lines being 50 m. The total length of the lines was 619 km (238 + 381). The mire vegetation was allocated to 56 mire type sites in the bog zone and 66 in the southern aapa mire zone. In addition, 3 wooded mire types were recognised.

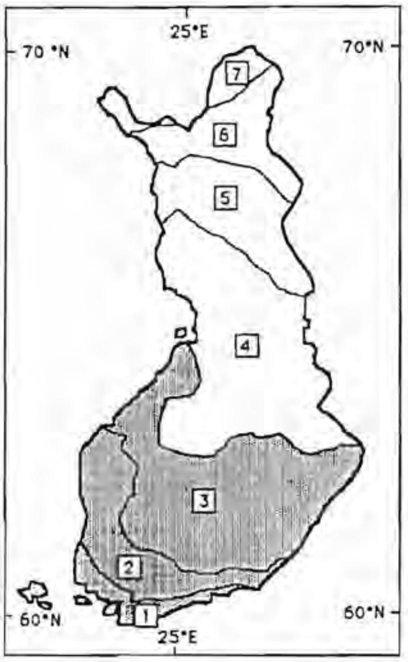

Fig. 1. The zone of raised bog complex types in Finland (Ruuhijärvi 1983).

3 RESULTS

Mire expanse vegetation is well protected (pine bogs and mires), and even over-represented (birch and pine fens, poor fens and wet bogs). The same applies to rich fen, swamp and spring vegetation (Table 1); however, spruce mires are greatly under-represented. These last four types of mire sites have a high floristic value as about 2/3 of Finnish mire plants grow on such sites, which represent mire margin vegetation. As a whole, the conservation programme protects mire landscapes and mire complexes better than the flora and small-scale mire margin vegetation. The supplementary plan will greatly improve the situation in this respect (Heikkilä 1994).

The protected area (as a percentage of the extent of that type in the zones studied here) of each of the 10 most common mire site types is shown in Table 2. The poor mire vegetation covers 50-70% of all peatlands. Not one site type dominated by mire margin vegetation is found in the protected group, in contrast to the total and virgin groups where spruce mire site types are still seen; the bog zone is particularly poorly represented (Table 2B). The supplementary conservation programme is really necessary.

Table 1. Percentages of the nine mire type groups in the whole study area (A), the bog zone (B) and the southern aapa mire zone (C). The figures for total coverage and virgin peatlands are based on Eurola et al. (1991). "Total" means all, estimated for each zone, and "virgin" means natural, undrained peatlands (the latter values being percentages of the "total" figures that still survive). The "protected" figures are calculated for each zone from the protected areas covered by this study. 1) combined types, 2) includes ombrotrophic *Fuscum*-hollow bog sites of the raised bogs

	total	**virgin**	**protected**
A.			
Spruce mires	15.7	3.8	3.3
Pine bogs/mires	43.8	9.1	33.8
Poor fens, wet bogs	13.0	6.4	37.1
Rich fens	0.05	0.02	0.6
Birch fens 1)	3.4	0.9	4.1
Pine fens 1)2)	16.4	5.3	20.4
Swamps	0.6	0.5	0.6
Spring vegetation	0.02	0.01	0.1
Drained peatland forests	7.1		0.03
Total	**100.0**	**26.0**	**100.0**
B.			
Spruce mires	19.9	5.8	3.6
Pine bogs/mires	43.4	10.2	39.8
Poor fens, wet bogs	6.3	3.2	23.1
Rich fens	0.05	0.05	0.04
Birch fens 1)	3.2	1.1	5.9
Pine fens 1)2)	14.6	6.3	26.1
Swamps	0.9	0.7	1.4
Spring vegetation	0.003	-	0.07
Drained peatland forests	11.6		0.03
Total	**100.0**	**27.3**	**100.0**
C.			
Spruce mires	11.8	1.9	3.3
Pine bogs/mires	44.1	8.1	32.0
Poor fens, wet bogs	18.9	9.4	42.7
Rich fens	0.05	0.02	0.9
Birch fens 1)	3.7	0.7	3.2
Pine fens 1)2)	18.0	4.4	17.7
Swamps	0.4	0.3	0.2
Spring vegetation	0.01	0.01	0.07
Drained peatland forests	3.0		0.06
Total	**100.0**	**24.8**	**100.1**

Endangered types of mire sites are defined as sites where only 0.1% or less of that type remains in a virgin state; most of these mire types have always been rare. Examples are herb-rich spruce mires and fens, swamps and spring-influenced mires. Of the endangered types, there are, respectively, 15, 19 and 21 in the whole country, the bog zone and the southern aapa mire zone (Eurola et al. 1991). The types are mainly the same in the bog and southern aapa mire zones.

Most Finnish peatlands have already been drained; 74% of peatlands in the entire study area, 73% in the bog zone and 75% in the southern aapa mire zone (Eurola 1991; Table 2, column 2). The influence of drainage is also seen to a certain extent in the conservation areas, even though most of the vegetation there is still in a virgin condition (Table 3). To protect an entire peatland, the whole area requires protection. The presence of only a few spruce mire sites in the protected areas demonstrates the present deficiency in this respect, i.e. the boundaries of the conservation areas do not adequately meet the requirements.

Table 2. Percentages of the ten most common mire site types in the whole study area (A), the bog zone (B) and the southern aapa mire zone (C). The figures for the total and the virgin mire types are based on Eurola et al. (1991). "Total", "virgin" and "protected" are explained in Table 1.

	total	virgin	protected
A.			
Eriophorum vaginatum pine bogs	10.4	8.6	13.7
Ordinary dwarf shrub pine bogs	10.0	6.0	9.1
Carex globularis pine mires	5.5	3.4	
Vaccinium myrtillus spruce mires	4.7	4.0	
Thinly-peated pine mires	4.3	5.0	
Oligotrophic tall-sedge pine fens	3.9	5.3	4.0
Carex globularis spruce-pine mires	3.7		
Herb-grass spruce mires	3.5		
Mesotrophic flark fens	3.3		
Drained *Myrtillus* peatland forests	3.3		
Mesotrophic flark fens		9.4	
Fuscum-hollow bogs		6.2	7.3
Empetrum-Fuscum pine bogs	3.6	3.1	
Oligotrophic flark fens	3.5	7.2	
Oligotrophic ordinary low-sedge fens			6.2
Oligotrophic tall-sedge fens			4.7
Oligotrophic *Papillosum* fens			4.1
Oligotrophic low-sedge pine fens			4.0
Total	**52.6**	**55.0**	**61.1**

Table 2 continued

	total	virgin	protected
B.			
Ordinary dwarf shrub pine bogs	16.9	10.0	13.6
Eriophorum vaginatum pine bogs	8.9	8.9	17.0
Myrtillus spruce mires	6.3	5.9	
Drained *Myrtillus* peatland forests	6.1		
Fuscum-hollow bogs	5.0	11.5	17.3
Herb-grass spruce mires	4.7	5.2	
Calluna-Fuscum pine bogs	4.5	4.6	
Oligotrophic tall-sedge pine fens	3.6	5.9	
Equisetum sylvaticum spruce mires	3.3	4.0	
Ordinary spruce-pine mires	3.2		
Empetrum-Fuscum bogs		4.4	2.6
Thinly-peated spruce mires		4.0	
Oligotrophic ordinary low-sedge fens			5.4
Oligotrophic tall-sedge fens			4.7
Ombrotrophic low-sedge bogs			4.5
Oligotrophic low-sedge pine fens			4.2
Ombrotrophic hollow bogs			3.1
Oligotrophic tall-sedge pine fens			2.6
Total	**62.5**	**64.4**	**75.0**

	total	virgin	protected
C.			
Eriophorum vaginatum pine bogs	11.8	8.4	12.3
Carex globularis pine mires	7.9	4.8	
Thinly-peated pine mires	6.6	8.0	
Mesotrophic flark fens	5.6	17.1	4.2
Carex globularis spruce-pine mires	5.5	3.1	
Oligotrophic low-sedge pine fens	4.2		
Oligotrophic tall-sedge pine fens	4.2	4.7	5.2
Ordinary dwarf shrub pine bogs	3.7		6.6
Myrtillus spruce mires	3.3		
Ordinary spruce-pine mires	3.3		
Oligotrophic flark fens		6.3	11.5
Oligotrophic low-sedge fens		4.7	
Mesotrophic tall-sedge pine fens		3.5	3.7
Empetrum-Fuscum bogs		2.8	
Oligotrophic ordinary low-sedge fens			7.0
Oligotrophic *Papillosum* fens			5.6
Oligotrophic tall-sedge fens			5.0
Total	**56.1**	**63.4**	**65.2**

Table 3. State of the protected peatlands in percentages in the whole study area (A), the bog zone (B) and the southern aapa mire zone (C).

	A	B	C
Virgin, in %	84.2	78.9	87.6
Influenced by nearby drainage	1.8	1.7	1.8
Recently drained (= no change yet)	9.3	12.7	7.2
Transitional	4.7	6.8	3.3
Drained peatland forest (= greatly changed)	0.05	0.03	0.06
Undetermined	0.06	-	0.09
Spruce mires	66.8	49.7	80.6
Pine bogs/mires	79.5	70.9	86.1
Poor fens, wet bogs	83.3	90.9	91.6
Rich fens	90.9	50.0	91.9
Birch fens	73.7	66.7	82.8
Pine fens	84.3	86.4	82.4
Swamps	95.9	96.9	89.8
Spring vegetation	98.7	100.0	97.9

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Protected mires in Finland

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ABSTRACT

Aapala, K., Lindholm, T. & Heikkilä, R. 1995. Protected mires in Finland. *Gunneria 70*: 205-220.

Nearly 70% of the original approximately 10 million ha of Finnish mires has already been used for forestry, peat extraction, agriculture and water reservoirs. Most of this exploitation has occurred during the last few decades. The quantity and quality of the network of protected mires in Finland are evaluated here, every type of protected area on state-owned land being included. There are 837,700 ha of mires in the 458 state-owned protected areas. Most of the protected mires are in northern Finland, where 13% of the original peatland has been protected; in southern Finland only 2% is protected. The proportion of virgin mires outside protected areas is 50% and 23%, respectively. The most common mire types in the protected areas are pine bogs in the ombrotrophic bog zone and fens in the aapa mire zone. There are 6500 ha of drained mires in 171 nature reserves. In the southern part of the country almost 10% of the protected mires have been drained. The problem in the aapa mire zone is that mires in protected areas are affected by drainage in the areas surrounding them because the reserve boundary does not take in the entire drainage basin.

1 INTRODUCTION

Mires form one-third of the total land area of Finland and are thus an indispensable part of the Finnish landscape. Economic pressure to use mires, earlier mainly for agriculture and forestry but later also to some extent for peat, has been very intensive, and mire conservation became an urgent task some 30 years ago. Already before then a few scientists had expressed concern that the natural diversity of Finnish mires would not be preserved for future generations (e.g. Isoviita 1955, Keltikangas 1955, Söyrinki 1964). Finland has now exploited more mires than the other Nordic countries together (Bernes 1993).

The aim of mire conservation is to protect the natural diversity and uniqueness of these ecosystems. This is not only to save the diversity of fauna and flora but also to retain the original water balance. The irreplaceable archive of past history locked up in the peat also merits protection. To save this diversity, a large network of protected mires is needed.

A few years ago, the Finnish Forest and Park Service carried out a survey of the proportion of forests that are conserved in Finland (Ruhkanen et al. 1992). These results were also used in the national strategy for conserving nature in forests (Hautojärvi et al. 1994). Suikki & Hanhela (1994) at the University of Oulu studied the mire types and the status (natural or drained) of the mires in the National Mire Protection Programme in southern Finland, but an overall picture of mire conservation in Finland has not existed previously (Aapala & Lindholm 1995). As part of the National Biodiversity Research Programme, the Nature Conservation Unit is co-ordinating research projects about endangered biotopes and the development of a network of protected areas (e.g. Väisänen & Jäppinen 1994). The aim of this work is to evaluate the quantity and quality of the network of protected mires in Finland and provide basic information for the development of a network of protected areas.

2 SHORT HISTORY OF THE USE AND CONSERVATION OF FINNISH MIRES

The original mire area in Finland was about 10 million ha. For climatic and topographical reasons the proportion of mires differs in different parts of the country. In the middle and northern boreal coniferous forest zones the percentage of the total land area taken up by mires may have exceeded 60%, whereas in southern coastal areas it was less than 10%.

Today, only a fraction of Finnish mires are in a natural condition. Nearly 70% of them have been used for forestry, peat extraction, agriculture and water reservoirs. Drainage for forestry purposes has been by far the most extensive use of Finnish mires. Records of forestry drainage date back to the 19th century, but it was not until the 1960's that drainage reached such proportions that it shook the conservationists from their sleep. Nearly 6 million ha of mire have now been drained for forestry (Lappalainen & Hänninen 1993).

Agriculture and the peat industry have not used peatlands to such an extent as forestry, but they destroy the natural mire ecosystem even more thoroughly. Cultivation of peatlands had its origins in the 17th century, or even earlier (Soininen 1974). At the beginning of this century, mires were mostly used for agriculture. After the extensive cultivation of peaty soils during the 1940's and 1950's, the area of mires in use for agriculture has remained almost unchanged. Altogether, 700,000 ha of mire have been drained for agriculture (Lappalainen & Hänninen 1993). The agricultural use of mires has been selective and mainly mires that are rich in nutrients have been cultivated.

Industrial peat extraction began in the 19th century, but took almost a century to reach significant proportions. The extraction of horticultural peat expanded rapidly in the 1960s and fuel peat extraction followed in the 1970s (Suoninen 1982). In 1993, 48,000 ha of peatlands were used by the peat industry (Turveteollisuustilastoja 1994). It has been estimated that 600,000 ha of mire in Finland are suitable for energy production (Lappalainen & Hänninen 1993).

The first nature reserves specially designated to save pristine mire ecosystems were the Vaskijärvi, Häädetkeidas, Sompio and Runkaus Strict Nature Reserves established in 1956. A special plan for mire conservation for the whole country was completed in the 1960s by the Finnish Association for Nature Protection and the Finnish Peatland Society. The National Board of Forestry (now the Finnish Forest and Park Service) protected about 150,000 ha of these mires. In the programme for new national parks and strict nature reserves (Tallgren et al. 1976), 24 of the previously mentioned mire areas were considered suitable for national parks or strict nature reserves. Based on these earlier plans, an official programme, the National Mire Protection Programme (NMPP), was set up in the 1970s. This was approved by the Finnish government in 1979 and 1981. It covers about 500,000 ha of mires (Haapanen et al. 1977, 1980), some 400,000 ha of which have been designated as mire reserves. This programme concentrates mainly on large, internationally and nationally important mire complexes. To save examples of threatened mire site types (such as rich fens and some types of spruce mires (Heikkilä 1994)) and regionally important mires, an additional list of mires has been proposed for protection (Heikkilä 1995).

3 MATERIAL AND METHODS

When evaluating forestry resources, forest stands are classified according to their vegetation and productivity. Mires are distinguished as separate biotopes distinct from forests growing on mineral soil. Stands are classified as mires when the organic layer covering the mineral soil is peat, or when more than 75% of the ground is covered by mire vegetation. Mires and forests on mineral soil are divided into three classes according to their productivity: forest land of good productivity, where the estimated annual timber production exceeds $1 m^3/ha$, forest land of low productivity (0.1-0.9 $m^3/ha/year$), and non-productive land with less than 0.1 $m^3/ha/year$. Mires in the first productivity class are often regarded as forests, as was the case in the Finnish Forest and Park Service's forest conservation report (Ruhkanen et al. 1992). In the present study, mires in all three productivity classes are included. The results of these two reports therefore overlap somewhat.

The evaluations of forestry resources made by the Finnish Forest and Park Service take place at intervals of 10-15 years and cover all state-owned land, in forestry management areas as well as protected areas. For this study, information about the mire types and the area covered by mire in each protected area was obtained from the evaluations made by the Finnish Forest and Park Service and the Finnish Forest Research Institute.

The main groups of mire types used both for forestry evaluation and for botanical classification of mires are **spruce mires**, **pine mires**, **fens** and **rich fens**. In addition to these, thinly-peated spruce mires and thinly-peated pine mires are distinguished as separate types in the evaluations of forestry resources. This system is based on a variety of ecological factors, the most important being nutrient status and wetness.

Spruce mires are minerotrophic mires with hummock and intermediate level vegetation. Spruce (*Picea abies*) and/or deciduous trees and shrubs (e.g. *Betula pubescens*, *Alnus glutinosa*, *Salix* species) form the tree and shrub layers. Vegetation in the field layer is dominated by grass and herb species (e.g. *Calamagrostis purpurea*, *Equisetum sylvaticum*, *Cirsium helenioides*), with *Vaccinium myrtillus* and *V. vitis-idaea*. The ground layer consists of forest moss species and *Sphagnum* species (e.g. *Polytrichum commune*, *Pleurozium schreberi*, *Sphagnum girgensohnii*, *S. centrale*).

The field and ground layer vegetation on **thinly-peated spruce mires** is a combination of forest and mire species, with the latter covering more than 50%. Spruce is the dominant tree species.

Pine mires are ombro-oligotrophic mires where pine (*Pinus sylvestris*) is the dominant tree species. The field layer is dominated by dwarf shrubs (*Ledum palustre*, *Vaccinium uliginosum*, *Chamaedaphne calyculata*, *Betula nana*, *Empetrum nigrum*, *Calluna vulgaris*), or in some cases by *Carex globularis* or *Eriophorum vaginatum*. Various *Sphagnum* species (*Sphagnum angustifolium*, *S. capillifolium*, *S. fuscum*, *S. magellanicum*, *S. russowii*) with some forest mosses (*Dicranum polysetum*, *D. bergeri*, *Pleurozium schreberi*, *Polytrichum strictum*) and *Cladina* lichens are characteristic for the ground layer.

Some less demanding spruce mire species (*Picea abies*, *Betula pubescens*, *Carex globularis*, *Equisetum sylvaticum*, *Polytrichum commune*) may be found on **thinly-peated pine mires**. Dwarf shrubs dominate the field layer and peat mosses (*Sphagnum angustifolium*, *S. capillifolium*, *S. russowii*, *S. fuscum*) the ground layer.

Fens (including oligotrophic, mesotrophic and meso-eutrophic fens) are open mires with intermediate or flark level vegetation. Sedges and *Sphagnum* species form the dominant vegetation.

Rich fens are also open mires, but instead of *Sphagnum* species, brown mosses (e.g. *Campylium stellatum, Cinclidium stygium, Tomentypnum nitens, Drepanocladus revolvens*) dominate the ground layer. Eutrophic species are also characteristic for the field layer (e.g. *Saxifraga hirculus, Carex flava, Eriophorum latifolium*).

For more detailed information about the regional distribution of mires in Finland and the system of mire site types see Ruuhijärvi (1983) and Eurola et al. (1984).

A mire complex is an individual mire, or a distinct area of a larger mire region, that includes several mire types. Mire complexes occurring in the same area, with similar vegetation, ecology, morphology and peat stratigraphy, form a mire complex type. The main mire complex types in Europe are swamps, flat fens, raised bogs, aapa mires, palsa mires and polygonal mires on the arctic tundra (Ruuhijärvi 1988). Of these, mainly raised bogs, aapa and palsa mires occur in Finland (Fig. 1).

Every type of protected area on state-owned land is included in this analysis. Most of these areas are administered and managed by the Finnish Forest and Park Service and the remainder by the Finnish Forest Research Institute. Strict nature reserves, national parks, mire reserves, herb-rich forest reserves and a group of special nature reserves are protected under the terms of the Nature Conservation Act.

Strict nature reserves are strictly protected areas where access is prohibited and only scientific research is allowed. **National parks** represent the most valuable and characteristic habitats and land forms. **Mire reserves** are designed for conserving mires and the basic aim has been to protect entire mire complexes with all their edge habitats. **Herb-rich forest reserves** protect species-rich deciduous forests. The **other reserves** on state-owned land are protected for a variety of reasons, e.g. to conserve old forests. Except for strict nature reserves, the protected areas are, in general, open to the public.

Special primeval and **landscape forests** are protected by the decision of the Finnish Forest and Park Service or the Finnish Forest Research Institute. The former are preserved as typical examples of habitats and the latter as landscape and recreation areas. Landscape forests and special **recreation areas** may include patches of virgin forests and mires. **Wilderness areas**

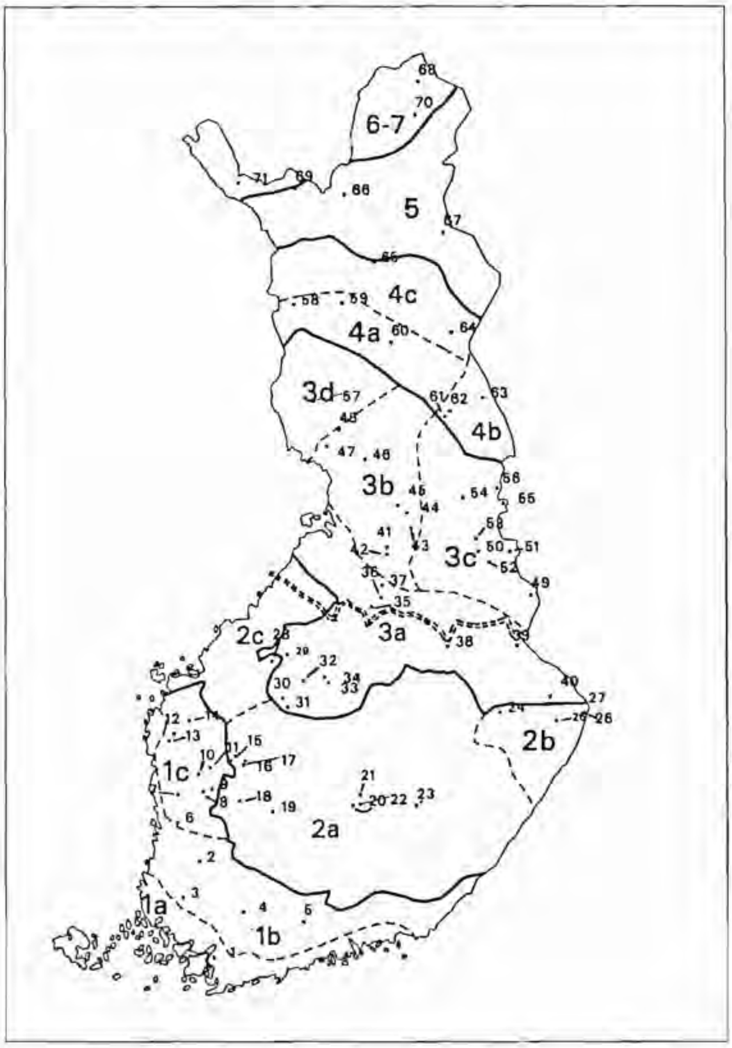

Fig. 1. Mire vegetation regions in Finland and the boundary (==) between southern and northern Finland used in this work. Key areas for mire conservation in Finland are numbered from 1 to 71 (list of areas in Table 2). Mire vegetation zones: 1 CONCENTRIC BOGS 1a Plateau bogs, 1b Concentric bogs in southern Finland, 1c Concentric bogs in western Finland; 2. ECCENTRIC BOGS AND *SPHAGNUM FUSCUM* BOGS 2a Eccentric bogs and *Sphagnum fuscum* bogs on the Finnish lake plateau, 2b Eccentric bogs and *Sphagnum fuscum* bogs in northern Karelia, 2c Eccentric bogs and *Sphagnum fuscum* bogs in central Ostrobothnia; 3. SEDGE AAPAS 3a Sedge aapa mires in Suomenselkä and northern Karelia, 3b Sedge aapa mires in the southern part of northern Ostrobothnia, 3c Sedge aapa mires in the Kainuu region, 3d Sedge aapa mires in the northernmost part of northern Ostrobothnia; 4. FLARK AAPAS 4a Southern type of flark aapas, 4b Sloping mires in Kuusamo and Kainuu, 4c Central and northern types of flark aapa mires; 5. NORTHERN AAPA MIRES; 6. PALSA MIRES IN LAPLAND; 7. OROHEMIARCTIC MIRES IN LAPLAND.

have been established in the north under the terms of the Wilderness Act. In practice, mires within them have been left intact. The intention of wilderness areas is to preserve wilderness nature, Sami culture and the livelihood of Sami people.

A feature common to all these types of protected area is that mires within them are left intact. Forestry used to be allowed on mineral soil in some mire reserves, but this practice has now been abandoned by decision of the Finnish Forest and Park Service.

Most of the protected areas in Finland are on state-owned land. Those on private land are not included in this study, even though they contain some important mire complexes, e.g. Kesonsuo in eastern Finland and Kotkanneva in western Finland.

The distribution of the types of protected mires and the area they cover has been analysed regionally using phytogeographical and administrative divisions. Of these divisions, only the mire vegetation zones and the division of south and north Finland applied by the forestry board (Fig. 1) are used in this paper.

The material we have used has some shortcomings. The classification of mires into six site types is quite rough when compared to the botanical classifications with 59 site types (Lukkala & Kotilainen 1951), or 73 (Eurola et al. 1994). Information on site types is totally lacking for some reserves in Lapland and for some others that have only recently been acquired by the state. In these cases, the area of mire included in the reserves was measured on topographical maps on a scale of 1:20 000 .

Comparative material about the total area covered by mires in Finland is only available from the forestry board districts, based on the national forest survey. The lack of comparative material from the mire vegetation zones, which is the basis for the NMPP, has made it difficult to evaluate the success of mire conservation. To get a more complete picture of the results, relevant literature has been consulted and specialists have been interviewed.

4 RESULTS

The 458 state-owned areas that are protected contain 837,700 ha of mires. This is about 8% of the original 10 million ha, and about 18% of the mires that are still in their natural state. The survey found no mires in 135 state-owned protected areas.

Table 1. The area (ha) of protected mires, and the number of nature reserves including mires and not including mires in each mire vegetation zone. Mire vegetation zones as in Figure 1.

Mire vegetation zone	Protected mires (ha)	No. of nature reserves including mires	No. of nature reserves not including mires
1a	710	15	20
1b	7084	28	10
1c	11851	19	2
2a	9601	89	30
2b	3698	9	2
2c	2968	8	0
3a	37783	75	17
3b	75241	43	13
3c	26324	43	10
3d	10606	23	8
4a	20030	17	5
4b	13309	6	0
4c	69884	28	9
5	283657	36	4
6+7	264956	19	5

The area of protected mires clearly differs in different parts of the country (Table 1). Most of the protected mires (96%) are in the aapa mire region, especially its two northernmost zones (over 60% of all protected mires). Of the original mire area, less than 2% has been protected in southern Finland (Fig. 1) and 13% in northern Finland. The proportion of virgin mires outside protected areas is 23% in southern Finland and 50% in northern Finland.

Most of the protected mires are in mire reserves (303,236 ha), wilderness areas (294,920 ha) and national parks (171,794 ha). The importance of different types of protected area differs from one region to another (Fig. 2). Mire reserves are very important in the sedge and flark aapa mire zones (zones 3 and 4 in Fig. 1) where more than 70% of protected mires are in mire reserves. The least important mire reserves (13 % of protected mires) are in the pounikko aapa mire zone (zone 5) where, instead, national parks contain almost half of the protected mires. National parks are also very important for mire conservation in the concentric bog zone (zone 1). In the palsa and orohemiarctic mire zones (zones 6 and 7), wilderness areas contain over 70% of all protected mires.

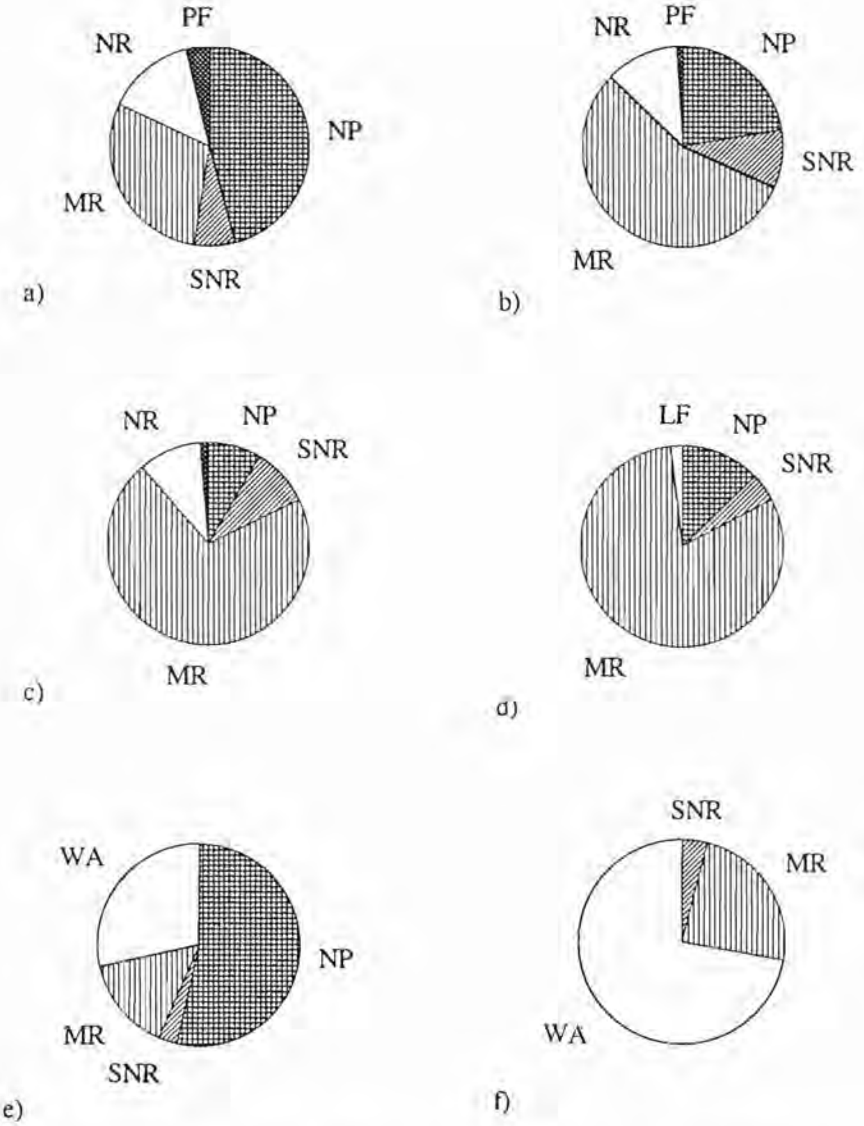

Fig. 2 The proportion of different types of protected area in mire vegetation zones: a) Zone 1 (+ HR, RA,LF), b) Zone 2 (+ HR, LF), c) Zone 3 (+ HR, RA, LF), d) Zone 4 (+ HR, NR, PF), e) Zone 5 (? HR, PF, LF), f) Zones 6+7 (+ HR, PF). (NP = national park, SNR = strict nature reserve, MR = mire reserve, NR = nature reserve, PF = primeval forest, LF = landscape forest, WA = wilderness area, HR = herb-rich forest reserve, RA = recreation area).

Table 2. Key areas for mire conservation in different subzones. Figure 1 shows their location. (MR = mire reserve, NP = national park, SNR = strict nature reserve, NR = nature reserve, WA = wilderness area in the north)

No.	Zone	Name	Type	No.	Zone	Name	Type
1	1a	Punassuo	MR	36	3a	Törmäsenrimpi-Kolkanneva	MR
2	1b	Isoneva	MR	37	3a	Rumala-Kuvaja-Oudonrimmet	MR
3	1b	Puurijärvi-Isosuo	NP	38	3a	Tiilikkajärvi	NP
4	1b	Vaskijärvi	SNR	39	3a	Rasvasuo-Kitkasuo	MR
5	1b	Torronsuo	NP	40	3a	Patvinsuo	NP
6	1b	Järvisuo-Ritassaarensuo	MR	41	3b	Säippäsuo-Kivisuo	MR
7	1c	Haapakeidas	MR	42	3b	Tolkansuo	MR
8	1c	Kaurakeidas-Kavettakeidas-Pitkäniemenkeidas	MR	43	3b	Iso Tilansuo-Housusuo	MR
9	1c	Häädetkeidas	SNR	44	3b	Olvassuo	SNR
10	1c	Kauhaneva-Pohjankangas	NP	45	3b	Oravisuo-Näätäsuo-Sammakkosuo	MR
11	1c	Jäkäläneva-Isoneva	MR	46	3b	Lapiosuo-Iso Äijönsuo	MR
12	1c	Harjaisneva-Pilkoonneva	MR	47	3b	Martimoaapa-Lumiaapa-Penikat	MR
13	1c	Varisneva	MR	48	3b	Runkaus	SNR
14	1c	Levaneva	NR	49	3c	Elimyssalo	NR
15	2a	Haukilamminneva-Murtomaanneva	MR	50	3c	Lokkisuo-Teerisuo	MR
16	2a	Haukkaneva-Nikulinneva	MR	51	3c	Lososuo-Saarijärvensuo	MR
17	2a	Silmäneva	MR	52	3c	Tulisuo-Varpusuo	MR
18	2a	Seitseminen	NP	53	3c	Säynäjäsuo-Matalasuo	MR
19	2a	Siikaneva	MR	54	3c	Iso Ahvensuo-Karhusuo	MR
20	2a	Haapasuo-Syysniemi	NR	55	3c	Martinselkonen	NR
21	2a	Katajaneva	MR	56	3c	Vieremänsuo	MR
22	2a	Rokasuo	MR	57	3d	Kilsiaapa-Ristivuoma	MR
23	2a	Iso-Huppio	MR	58	4a	Teuravuoma-Kivijärvenvuoma	MR
24	2b	Viklinsuo-Rapalahdensuo	MR	59	4a	Näätävuoma-Sotkavuoma	MR
25	2b	Kesonsuo	private	60	4a	Haikara-aapa-Vitsikkoaapa	MR
26	2b	Ruosmesuo-Hanhisuo	MR	61	4b	Karitunturi	MR
27	2b	Koivusuo	SNR	62	4b	Riisitunturi	NP
28	2c	Pilvineva	MR	63	4b	Oulanka	NP
29	3a	Kotkanneva	private	64	4c	Joutsenaapa-Kaita-aapa	MR
30	3a	Pohjoisneva-Haapineva	MR	65	4c	Pomokaira-Tenniöaapa	MR
31	3a	Saarisuo-Valleussuo	MR	66	5	Lemmenjoki	NP
32	3a	Salamajärvi, Salamaperä	NP,SNR	67	5	Urho Kekkonen National Park	NP
33	3a	Väljänneva	MR	68	6+7	Kaldoaivi	WA
34	3a	Kivineva	MR	69	6+7	Pöyrisjärvi	WA
35	3a	Kansanneva-Kurkineva-Muurainsuo		70	6+7	Sammuttijänkä-Vaijoenjänkä	MR
				71	6+7	Lätäseno-Hietajoki	MR

One of the main objectives of mire conservation in Finland has been to safeguard examples of the different types of mire complex, and key areas of these can be found in every mire vegetation zone. They are usually the largest reserves where the typical features of the subzone are well developed.

In the ombrotrophic bog region, the most representative protected mire complexes are usually spaced far apart. However, in western Finland several large, well-developed protected mires form a loose network extending from the concentric bog zone to the eccentric bog zone, and both these types of mire complex are well represented. Southern aapa mires can also be found in these protected areas. The most important reserves in this network are listed in Table 2; their locations are in Figure 1. The best examples of the types of mire complex in other subzones are also found in Table 2.

The network of protected mires is better developed in the aapa mire area and the list of good examples is much longer. In the sedge aapa mire zone (3), the best networks of protected mires can be found in subzones 3b and 3c where there are large areas of protected mires with all the typical mire complex types well represented (Table 2, Fig. 1).

The best examples of flark aapa mires in subzone 4a are the Näätävuoma-Sotkavuoma, Teuravuoma-Kivijärvenvuoma and Haikara-aapa Mire Reserves. Subzone 4b is known for its rich fens and sloping mires on hillsides. The best examples of the former can be found in the Oulanka National Park and of the latter in the Riisitunturi National Park and the Karitunturi Mire Reserve.

Since more than 70% of all protected mires in Finland are found from subzone 4c northwards, typical mire complex types are clearly very well represented in that region. Consequently, only protected areas containing the largest areas of mire are mentioned here: the Lemmenjoki National Park (79,783 ha of mires), the Kaldoaivi Wilderness Area (50,895 ha), the Urho Kekkonen National Park (45,193 ha), the Pöyrisjärvi Wilderness Area (31,003 ha) and the Pomokaira-Tenniöaapa Mire Reserve (30,476 ha). The best areas for palsa mires are the Sammuttijänkä-Vaijoenjänkä and Lätäseno-Hietajoki Mire Reserves.

The most common mire types in the protected areas are pine mires and fens. In the ombrotrophic bog area, pine mires form 45% and fens 42% of all protected mires. In the aapa mire area, the proportions are 19% and 65%, respectively.

Both thinly-peated spruce mires and thinly-peated pine mires are quite rare mire types in the protected areas. Other spruce mires are slightly more common, forming 4% of the protected mires in both the bog and the aapa mire regions.

More than half of all the protected, thinly-peated pine mires and almost half of all types of spruce mires can be found in the national parks and strict nature reserves, even though only 26% of all protected mires are in such areas.

Rich fens are very poorly represented in existing protected areas. In the southern part of the country, only a few protected areas contain fragments of rich fens. In northern Finland, the situation is slightly better, but on the whole there is cause for serious concern. According to Eurola et al. (1991), 95% of the rich fens that were intact in the early 1950's had been drained in the course of 35 years.

Not all mires inside the boundaries of protected areas are pristine ecosystems, especially in southern Finland where almost 10% of protected mires have been drained. Altogether, there are 6500 ha of drained mires in 171 protected areas. From subzone 4c northwards, there are no drained mires in protected areas.

5 DISCUSSION

In southern Finland (Fig. 1), the area of virgin mires has been reduced from 3.2 to 0.9 million ha in 40 years. In northern Finland, about 3.5 million ha (60%) of the original mire area has remained in its natural state (Ilvessalo 1956, Aarne 1993).

Nevertheless, more mires have been protected in the northern part of the country than in the southern part. A similar situation prevails as regards the conservation of forests in Finland (Ruhkanen et al. 1992). One reason for this is that state-owned land, which contains all the protected areas covered by these studies, is mainly situated in the northern part of the country. Since draining mires for forestry purposes is not economically profitable in northern Finland, there has not been such intensive pressure to use them as in southern Finland.

Most mire types are best preserved within large mire complexes. This is especially the case with fens and pine bogs. Typical vegetation in the raised bog area consists of different types of ombrotrophic bogs and fens. In the aapa mire area fens form the dominant vegetation. Since many mire reserves have been established principally as examples of regional mire complexes, poor fens and pine bogs are very well represented in the protected mires.

In the 1950s, most Finnish mires were still in their natural state. Pine bogs then formed 42% of the mires in both the south and the north, and fens 14% in the south and 32% in the north (Ilvessalo 1956). Fens dominate strongly, especially in the aapa mire area, in the current protected areas when their present extent (42% in the south, 65% in the north) is compared with their original extent here. Because most types of fen mire are unsuitable for forestry, protecting fens has been politically easier than protecting mires which are suitable for draining for forestry (e.g. forested pine mires and spruce mires). The proportion of pine mires in the protected areas in southern Finland is quite representative of the original situation, even though they have been heavily drained.

Some rare or endangered mire types characteristically occur in small patches. They may also require special environmental conditions which are not necessarily present in large mire areas. For example, spruce mires can often be found as narrow strings in the ecotone between forest and mire ecosystems at the margin of the mire complex. Unfortunately, these margins have often been left out of the conservation areas. This is one reason why the area taken up by spruce mires in the protected areas is so low (less than 5%), even though the proportion of these mires in the 1950's was much higher (26% in southern and 18% in northern Finland) (Ilvessalo 1956). Another reason is that spruce mires have been heavily drained; in the bog zone 67% and in the southern aapa mire zone 84% of spruce mires have been drained (Eurola et al. 1991). Several types of spruce mire are regarded as threatened either regionally or nationally (Heikkilä 1994).

National parks and strict nature reserves are designed to save large, entire landscapes rather than special ecosystems or biotopes. Mire complexes inside these areas are thus conserved in their entirety with all their marginal biotopes. Despite good intentions, mire reserves usually represent only part of the entire mire area and it is usually the habitats at the edge of the mire that are left out of the conservation area.

Several rich fens are included in the National Mire Protection Programme and especially in the additional programme, but so far only a fraction of these rare and endangered habitats have been protected by law. All rich fen types are regarded as threatened in Finland (Heikkilä 1994).

Even though drainage is not a very serious problem in the protected areas as a whole, the area of drained mires is considerable in certain regions. For example, in the Seitseminen National Park in western Finland, 60% of the mires (1250 ha) have been drained. A major restoration plan has recently been drawn up (Heikkilä & Lindholm 1994) to restore the natural assets of drained mires in this park. Similar plans are also needed for the other protected areas that contain drained mires.

Another problem is that drainage in surrounding areas, especially in the aapa mire region, may have profound effects on the protected ecosystems. Unfortunately, it is not uncommon for ditches to run right at the edge of the protected area. Re-evaluation of the boundaries of these protected areas is therefore needed to ensure the sustainability of the conservation work.

Much work has been done to conserve mires in Finland, but since the ecological and regional differences in Finnish mires are so huge it is understandable that the current state of protection and detailed knowledge of protected mires are still unsatisfactory in many respects. More mire protection is needed in southern Finland especially; for instance, all existing virgin mires should be protected. The problem there is that mires that remain in their natural condition usually occur as fragments of larger areas and only a few large, entire mire complexes are left. Thus, a general restoration programme should also be prepared. Most land in southern Finland is, moreover, privately owned and it costs a great deal for the state to buy areas for conservation purposes. Too little detailed knowledge about the mire types is currently available, but on the whole more attention and effort is definitely needed to protect rich fens and spruce mires.

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The effects of mire drainage and the initial phases of mire restoration on the vegetation in the Seitseminen National Park, western Finland

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ABSTRACT

Heikkilä, H. & Lindholm, T. 1995. The effects of mire drainage and the initial phases of mire restoration on the vegetation in the Seitseminen National Park, western Finland. *Gunneria 70*: 221-236.

The development of vegetation on ombrotrophic and oligotrophic middle boreal mires in the Seitseminen National Park, western Finland, after forestry drainage and restoration, is being studied. The area was ditched about 20 years before the study began. Changes in vegetation have not been drastic, but the hydrology of the mires has changed significantly. Flark-level species have mostly disappeared, although hummock species have generally survived the change in hydrology and the increase in tree cover. Some forest species, e.g. *Hylocomium splendens*, have become more abundant. *Polytrichum commune* is now dominant on incompletely drained sites and where there is an imbalance in nutrient availability. The changes in vegetation are usually more significant on minerotrophic than on ombrotrophic mires.

In theory, it is easier to restore mires drained for forestry than those drained for agriculture or peat extraction. However, success depends on various factors: the time elapsing after drainage, the degree of change in the vegetation, and the technical possibilities for allowing water to flow into the mire again from the surroundings. Many questions still remain unanswered, and many more years of monitoring and additional studies are needed to obtain quantitative answers to them.

1 INTRODUCTION

1.1 THE NEED FOR MIRE RESTORATION IN FINLAND

In the past, 30% of Finland was covered with mires (Lappalainen & Hänninen 1993). They have been utilised and partially destroyed over centuries, but most were still intact at the beginning of the 20th century. The most drastic changes happened in the 1960s and 1970s when 60% of the mires were drained for forestry (Päivänen 1990).

Numerous, invaluable, large mire complexes have been drained. Drainage has affected the overall environment as well: the water quality of many rivers and lakes has deteriorated (Sallantaus 1986). Nowadays, there are relatively large areas of drained mires, even in nature reserves (Aapala, Lindholm & Heikkilä 1995). Drainage of nearby areas has also changed the mire hydrology in many nature reserves which themselves have been left intact. Many drainage schemes were economically unprofitable. It has been estimated that 20% of the drained mire area was ombrotrophic bogs or open fens and in these no improvement in tree growth has occurred (R. Heikkilä 1984, Keltikangas et al. 1986, Eurola et al. 1991, Saarinen 1994).

The drainage situation of the mires in the Seitseminen National Park in western Finland resembles the overall situation in southern Finland. This park (Fig. 1) has 1200 ha of drained mires, representing 30% of its total area and half of its mire area. Attempts to restore these mires started in 1987 (Vasander et al. 1992). In principle, all the drained mires in nature reserves should be restored (Helminen 1988, Finnish Forest and Park Service 1993, H. Heikkilä & Lindholm 1995).

1.2 SHORTAGE OF KNOWLEDGE

Little is known about restoration after drainage for forestry (H. Heikkilä & Lindholm 1995), although there is a considerable amount of knowledge in Europe about restoration of mires formerly used for other purposes, such as agriculture and peat excavation (Wheeler et al. 1995). The aims and the consequences are quite different from those involving agriculture or peat excavation. More information is needed if forested mires are to be restored successfully and permanently. It is obvious that due to the ecological diversity of mires, information is needed on a variety of aspects.

In Finland, the improvement in tree growth following mire drainage has been thoroughly studied (Seppälä 1969, Heikurainen & Seppälä 1973, Keltikangas et al. 1986, Paarlahti 1988, Paavilainen & Tiihonen 1988). The reaction of the undergrowth is also known in some cases (Sarasto 1951, 1952, 1957, Kuusipalo & Vuorinen 1981, Reinikainen 1984), but comprehensive data about the vegetation changes that occur in different drainage situations are lacking.

1.3 HYPOTHESIS

The main hypothesis of this study is that the vegetational succession occurring after drainage is in most cases reversible: the mires can be restored. Nonetheless, the original situation at a particular site is usually not reached. The aim is to get some kind of functioning mire ecosystem with approximately the original level of nutrition, tree stand and hydrological conditions.

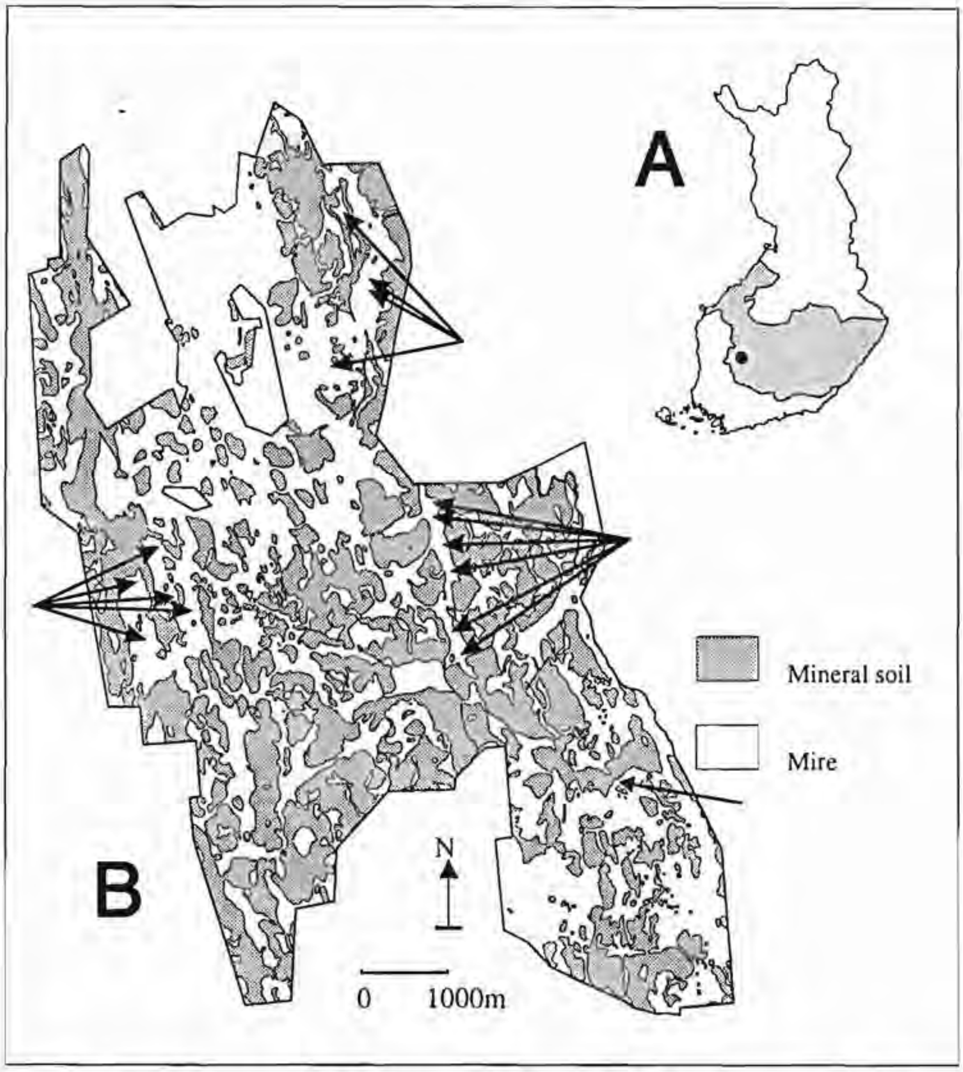

Fig. 1. A. The location of the Seitseminen National Park. The eccentric bog zone (according to Ruuhijärvi 1988) is shaded. **B.** Mires in the Seitseminen National Park. Arrows show the location of study sites.

In Finland, drained mire forests are usually classified according to their nutrient status, in a similar way as for forests on mineral soil. Usually, drained mire forests are classified into seven types (Laine 1989). The mires of Seitseminen are poor in nutrients and therefore only the poorest types (*Vaccinium vitis-idaea* and dwarf-shrub types) of mire forest can develop on drained areas. In this study, the succession after drainage is considered to occur in four main directions. One is that towards a well-forested, dry ecosystem in which dwarf shrubs and forest mosses predominate (drained peatland forest of dwarf-shrub type in Laine (1989)). Another result of drying after drainage is an undesirable situation in which *Polytrichum* species dominate in the ground layer, trees are few and grow poorly and *Betula nana* is the main field layer species, often 1.5 m high. In the case of incomplete drying after drainage, no major changes in the mire vegetation occur. Only the most hygrophilic species disappear, but most of the vegetation still comprises typical mire species. The fourth possibility is that a drainage area has become naturally wet again. This can happen when the mire has been dry for only a relatively short time after drainage, the ditches having soon been filled with peat falling from the sides providing a footing for vegetation. It seems that this natural process of restoration is very rare in old drainage areas. In this study, these various possibilities are examined, along with the opportunities for restoration and the methods required.

2 MATERIAL AND METHODS

2.1 STUDY AREA

2.1.1 Seitseminen National Park

The Seitseminen National Park was established in 1982 and enlarged in 1989. Following its inclusion in the nature protection programme, afforestation was halted in the 1970s. The park is situated in the southern part of the Suomenselkä watershed, in the zone of inland eccentric raised bogs (Ruuhijärvi 1983) (Fig. 1). Its area is 4100 ha, of which 2000 ha are covered with mires, 150 ha are watercourses and the remainder are mainly forested mineral soils.

Most of the area was state-owned long before it became protected. Some areas of old forest had been excluded from forestry use during the present century, but elsewhere forestry was intensive up to the 1970s. Most of the mires were still intact up to the 1960s. The intensive drainage period lasted only 10 years, but during that time half of the mire area was drained. Almost all the small mires were drained and only parts of large, treeless mires were left intact.

2.1.2 Climate, bedrock and soil

The climate of the Suomenselkä area is slightly more humid than that of the surroundings, due to the slightly higher altitude. The lakes in the national park lie about 170 m above sea level, which is 50-70 m higher than the surroundings of the watershed area. Even this slight difference in altitude increases the precipitation in this otherwise flat area.

The mean annual precipitation for the 1961-1990 period for the nearby meteorological station (Länsi-Aure) is 719 mm (Finnish Meteorological

Institute). The annual mean temperature (calculated from the monthly means) for the same period is 2.9°C.

The soils of the Seitseminen area are originally poor and leached. The bedrock is dominated by siliceous plutonic rocks, coarse grained granite, granodiorite and quartz diorite being found within the park. Two small areas of gabbro are found in its southernmost part, and a few areas of Precambrian volcanic rocks, mica schist, amphibolite and uralite porphyrite also occur (Matisto 1961). There are numerous small eskers in the area, the highest of which are supra-aquatic, i.e. they were never covered by the sea or a lake after the retreat of the ice sheet (Ministry of the Environment 1984). Some other glaciofluvial features are also found. Most of the mineral soils are on morainic hills. Peat covers 2000 ha, or 47%, of the national park area. There are some extensive mire complexes with numerous islands of mineral soil. However, most of the mires are small patches, joined together by narrow strips of mire.

2.1.3 Vegetation

The main vegetation types in the Seitseminen National Park are mineral soil forests and mires. The area has always been sparsely inhabited and human impact, apart from forestry, has been minimal.

Since the bedrock and soils are poor in nutrients, the vegetation is mainly oligotrophic and many mires are ombrotrophic. Most of the mineral soil forests are either pine, with *Vaccinium vitis-idaea* as the dominant field-layer species and *Pleurozium schreberi* as the main moss species, or spruce with *Vaccinium myrtillus*, *Pleurozium schreberi* and *Hylocomium splendens*. In some places, dwarf shrubs normally found on mires, e.g. *Empetrum nigrum* and *Ledum palustre*, are also found growing on the mineral soil (Leivo et al. 1989), an indication of the relative humidity of the area.

The virgin mires are either ombrotrophic or minerotrophic low-sedge bogs. Typical raised bog vegetation is also common. Small minerotrophic pine fens are found in wet flushes. Old aerial photos (H. Heikkilä & Lindholm 1994) clearly show that many of the drained mires differed from the remaining virgin mires. Virtually continuous, open, strips of minerotrophic bog lying between hills of mineral soil were common. This vegetation was probably dominated by tall sedges and *Sphagnum papillosum*. Almost all the spruce mires and most of the minerotrophic pine fens have been drained, and their vegetation has changed significantly. All the mire margin areas have been drained, and only the ombrotrophic central areas are largely intact.

2.2 SAMPLE PLOTS AND VEGETATION ANALYSIS

All the mires studied were drained during the period 1965-1970. In many cases, the timber growing on the mires was felled in connection with the drainage. The mires were also fertilised with nitrogen, phosphorus and some with potassium, probably twice, since that was the accepted practice at the time. No other forestry management has taken place since then.

Three sets of data are available. Firstly, data collected in 1987 when six sample plots were laid out in each of which five circular relévés (0.28 m radius) were analysed. The plots were situated systematically in 3 parts of the mire: 2 in a place not to be restored, 2 where ditches were dammed up, and 2 where ditches were dammed up and trees felled (Seppä et al. 1993). The vegetation was analysed using percentage cover estimates.

Secondly, three mires were chosen to represent different types of original mire sites. Two sample plots were situated on a virgin mire and five on a drained mire (Fig. 1). 22 vegetation relévés (1x1 m) were made in each plot and the percentage cover was estimated (Seppä et al. 1993).

Thirdly, rectangular sample plots (each 10x20 m) were laid out and 16 1x1 m relévés were made inside these (H. Heikkilä & Lindholm 1995). The vegetation in 12 plots was analysed using the Pin Point method (Levy & Madden 1933, Goodall 1952, Mueller-Dombois & Ellenberg 1974) in order to obtain more accurate long-term monitoring data. During a test phase of the method in summer 1994, five relévés were analysed from each plot. Only one touch per pin was counted for each species, in order to avoid statistical bias.

The nomenclature of the vascular plants follows Hämet-Ahti et al. (1986), that of mosses Koponen et al. (1977) and that of lichens T. Ahti (1981). Several botanists have been involved in the field work and there was some inconsistency in determining lichens, *Dicranum* species and hepatics, which have consequently been dealt with as groups, even though this has resulted in the loss of some important ecological information.

2.3 NUMERICAL ANALYSIS OF THE VEGETATION

The percentage cover data from the relévés were used to calculate the average cover values for each species in each sample plot. Five relévés were chosen at random to calculate the average cover values for those plots in which more than five relévés had been made. For the relévés made by the Pin Point method, the sums of touches were calculated for each species, and an average for the five relévés was calculated. Ecologically diverse species groups (hepatics, *Dicranum* spp.) were excluded from these analyses, although *Dicranaceae* that had been identified to species level were included. Species which were present at only a single site were excluded from the analyses. The sample plot data were analysed by the ordination method DCA (Hill 1979, ter Braak 1987), using the default parameters in the program package CANOCO, and species ordination was also done by the same procedure.

The species were divided into groups according to their status in the mire vegetation (Eurola et al. 1984). The groups are pine bog species, open fen species and forest species. In each group, the field and ground layers were treated separately. *Polytrichum commune* and *Sphagnum angustifolium*, which were thought to react in a different way from other species (Kuusipalo & Vuorinen 1981), were treated individually, outside the groups. The proportions of the species groups on drained, virgin and restored mires are presented in pie graphs.

3 RESULTS

3.1 DCA-ORDINATION OF SPECIES

The first axis of the DCA-ordination of species (Fig. 2) shows the change from wet site to dry site species. The second axis shows the change from oligo-mesotrophy to ombrotrophy. The species of drained sites are located in the lower right-hand corner.

Some species reflect different situations on drained mires: *Pleurozium schreberi*, *Ledum palustre*, *Vaccinium myrtillus* and *Vaccinium uliginosum* are typical of places which have dried out considerably. There are few other mosses, and vascular plants are also scarce. This vegetation type is usually formed on the sites of former lawns, and in the driest flarks.

Polytrichum commune is the most important ground layer indicator of an incomplete drainage situation. There are several vascular plants in the same group, indicating mainly oligo-mesotrophy and flowing surface water. These sites were originally lawns and flarks. When dried, *Polytrichum commune* forms intensive hummocks.

Sphagnum fuscum, *Calluna vulgaris*, *Empetrum nigrum* and several other species represent a hummock vegetation which has not changed very much. These hummocks have tolerated the drainage quite well, although in the long run *Pleurozium schreberi* increases and *Sphagna* decrease.

Flark species are very scarce in the data, occurring only on virgin sites. The main species indicating ombrotrophic flark conditions is *Sphagnum balti cum* (one virgin site actually contains other flark *Sphagna*, but they are not

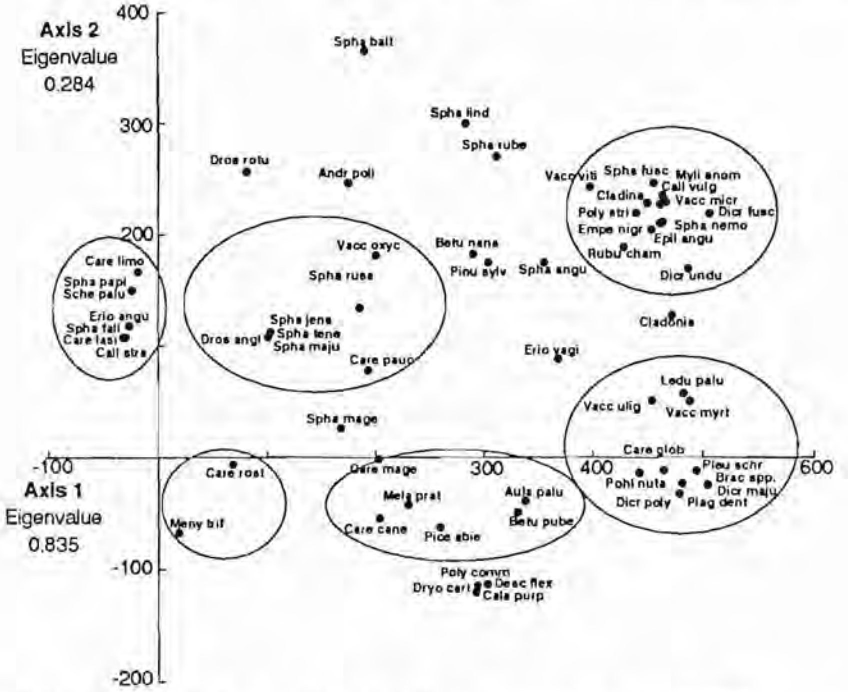

Fig. 2. DCA-ordination of species. Circles indicate supposed species groups.

shown in the figure). Oligotrophic flark conditions are reflected by the presence of *Sphagnum papillosum*, *Carex limosa* and *Eriophorum angustifolium*, among others.

One grouping consists of upper flark and low lawn species, including *Sphagnum jensenii*, *Sphagnum tenellum*, *Sphagnum majus* and *Drosera anglica*.

Between these extremes, there are several species which mainly indicate lawn level vegetation which has changed after the drainage, but not very much. *Eriophorum vaginatum*, *Sphagnum angustifolium* and *Betula nana* are typical of these conditions.

Kuusipalo & Vuorinen (1981) found some successional units in an old drained area. These consist of a) original mire species, which may be ombrotrophic or minerotrophic, b) different successional stages of lawns, and c) forest species. These units form a mosaic-like pattern depending on the drainage status and various other factors. The same units were found in the present study, even though the indicator species were not exactly the same. Several other units also seem to be present because the original mire sites were more heterogeneous than those in the data of Kuusipalo & Vuorinen (1981). The material is not large enough to interpret all these units reliably.

The direction of succession is not clearly seen in the ordination, probably because there are several possible successional directions and stages for different types of mires. On drained mires, many indicators of minerotrophic conditions have disappeared or markedly decreased in frequency, even though some remnants usually remain. This indicates the succession towards poorer conditions after drainage (Kuusipalo & Vuorinen 1981). The fertilisation has not been favourable for the minerotrophic mire species. On the other hand, few species are present which are "alien" to the mire. *Eriophorum vaginatum* and *Betula nana* seem to have utilised most of the nutrients derived from the fertilisation of the oligotrophic mires, apart from those taken up by the tree stand.

Several species are common on virgin sites and totally absent from drained sites; these include *Carex lasiocarpa*, *Drosera anglica*, *Eriophorum angustifolium*, *Rhynchospora alba*, *Scheuchzeria palustris*, *Sphagnum cuspidatum*, *S. jensenii* and *S. majus*. Some of these might have been found in drained areas if more data had been collected, but it is obvious that some of them are sensitive to drainage. Many species are present on the drained sites and absent from the virgin sites, but nothing can be said about them because there are many more drained than virgin sites.

3.2 DCA-ORDINATION OF SAMPLE PLOTS

In the ordination of the virgin and drained mire sites (Fig. 3), the most important ecological factor is the moisture gradient. The wettest sites are situated on the left. The eigenvalue of the second axis is much lower than that of the first axis. It roughly represents the nutrient status, ombrotrophic sites being found in the upper half. The moisture of the sites varies much more than the nutrient status, and thus the second axis is much shorter than the first. Some virgin sites are as dry as drained sites, even though most virgin sites are rather wet.

It is obvious from the DCA-ordination of the sample plots (Fig. 3) that the vegetation of most of the drained sites has not changed dramatically in 25 years. Even though the wettest virgin sites differ clearly from the drained sites, other virgin sites are quite similar to some drained sites. The material seems to be too sparse to draw conclusions about successional directions, although it would seem that initially minerotrophic mires easily become communities dominated by *Polytrichum commune*. Slightly minerotrophic, hummocky sites become ombrotrophic sites which resemble virgin bog sites, or drained stages of them.

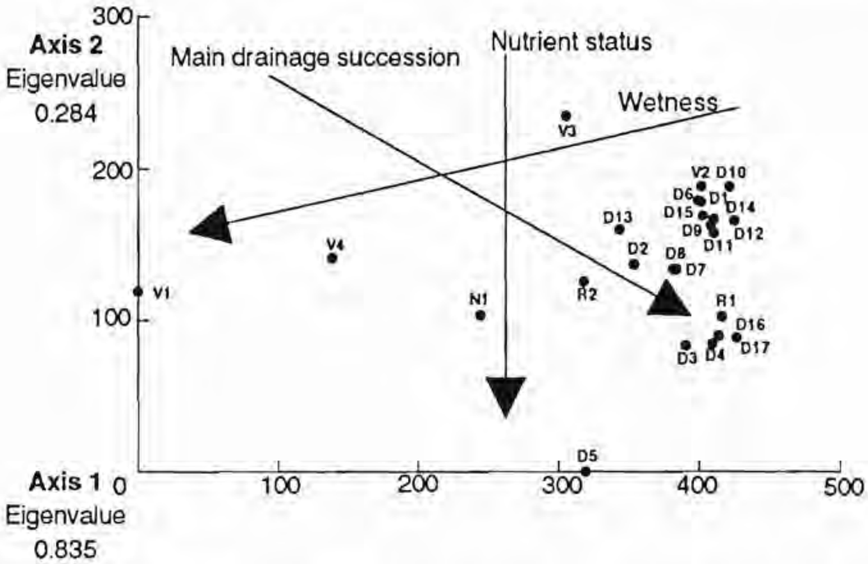

Fig. 3. DCA-ordination of sample plots. Arrows show the approximate trends of the main ecological gradients.

3.3 SPECIES GROUPS OF VIRGIN, DRAINED AND RESTORED MIRES

Virgin mires vary widely in the composition of their species groups (Fig. 4). There are some typical features, however, when they are compared with those of the drained and restored sites. In Seitseminen, forest species are always very scarce on virgin mires. Open fen species occur regularly, even on the most hummocky sites. Forest species, on the other hand, colonise even incompletely drained mires (Fig. 5). Open fen species disappear almost entirely. Depending on the drainage stage, *Sphagnum angustifolium* or *Pleurozium schreberi* may be dominant. On one of the drained sites, *Polytrichum commune* is dominant, indicating incomplete drainage and an imbalance in nutrient availability. Few forest species of the field layer, colonise drained mires. Bog species come to dominate the field layer of most of the drained mires after the disappearance of the fen species.

Forest species are sparse on restored mires, although this may be due to inadequate data (Fig. 6). There are some restored sites where, for instance, *Epilobium angustifolium* spread immediately after restoration (H. Heikkilä & Lindholm 1995). Monitoring of old restoration areas only started in 1994, and it is not yet known whether the fen species will invade them or what species will have disappeared for good.

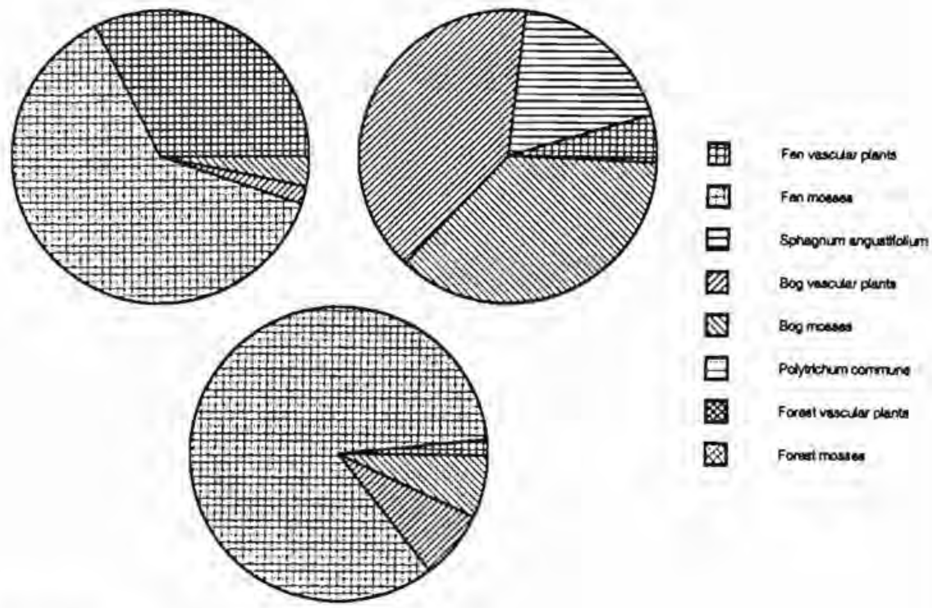

Fig. 4. Species groups of 3 virgin mire sites.

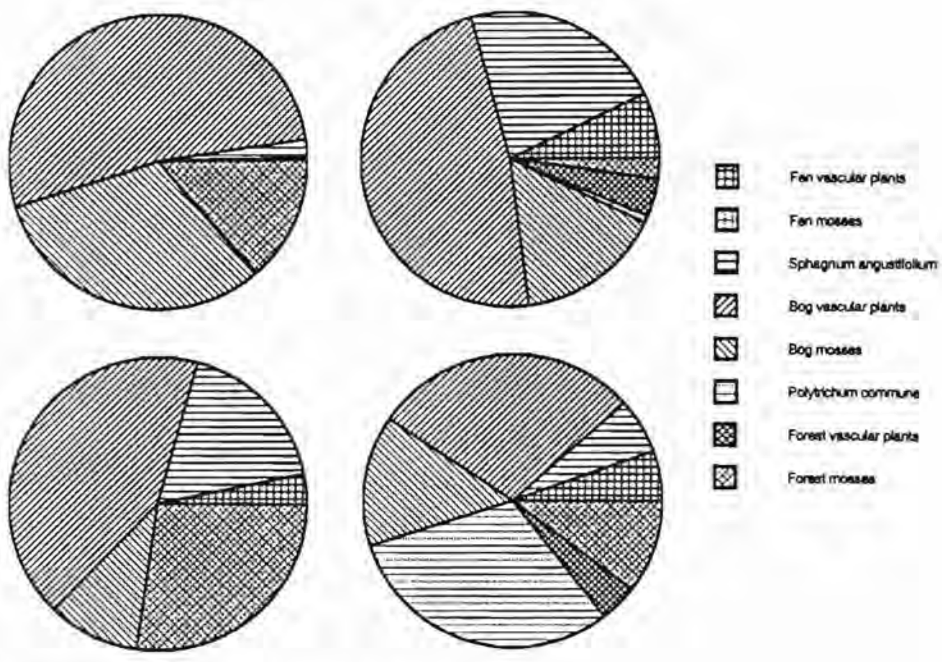

Fig. 5. Species groups of 4 drained mire sites.

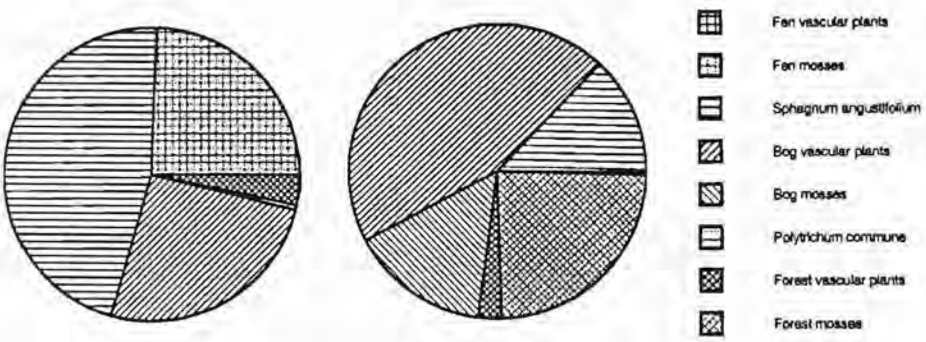

Fig. 6. Species groups of 2 restored mire sites.

4 DISCUSSION

In 25 years, the drained mires of the Seitseminen National Park have not reached the supposed climax stage in which forest species dominate. Some sites have developed into a stage in which forest mosses dominate the ground layer, but the field layer still consists mainly of mire species. However, these sites are small patches on heterogeneous mires. Sarasto (1957) reported that most of the oligotrophic, dwarf shrub-dominated sites he studied had dried out over a period of 25-40 years. Kuusipalo & Vuorinen (1981) state that the successional stage, with a heterogeneous vegetation, may be prolonged for various reasons. The results of the present study support this supposition. In fact, relatively few drained mires in Finland have so far developed into peatland forests (Keltikangas et al. 1986).

It is often regarded as being very difficult to classify drained sites according to their original mire type (Laine 1989). In the light of the present study, it is possible that not every mire site type has an equivalent, drained mire type in the transient stage, as has been thought to be the case in the Finnish mire site type classification (Eurola et al. 1984). The vegetational biodiversity of the mires thus diminishes soon after drainage. This is in accordance with the hydrological changes noted after drainage (E. Ahti 1988). The changes in biodiversity should be studied on a much larger scale, however.

Hydrophilic vascular plants and mosses are rare on drained mires. It would seem, however, that many species which can withstand flowing water may survive in the ditches. On the other hand, those species which demand stable wet conditions disappear rapidly. The hydrophilic mosses found in the ditches are not usually those which were dominant on the flarks of the virgin sites, but are minerotrophic species, such as *Sphagnum riparium* or *Warnstorfia exannulata*.

In theory, restoring mires drained for forestry is easy compared with mires used for agriculture or peat extraction. The acrotelm is still intact, even if the peat quality has changed. In Finland, the water table is not usually lowered over extensive areas, as it is in many areas of intensive agriculture in central Europe. Also, the climate of the boreal zone favours the restoration: precipitation exceeds evapotranspiration for most of the year.

Successful restoration depends on many factors. The most important are the time elapsing after drainage, the degree of change in the mire, and the possibility of getting enough water to flow in to the mire. These in turn depend on other factors. It is comparatively easy to restore the central part of an ombrotrophic raised bog, where no tree growth occurs, the vegetational changes are small and the ecosystem is independent of the surroundings. Small, tree-covered bogs, on the other hand, from which the hollows have long since disappeared, may be very hard to restore. Successful restoration of minerotrophic fens, in particular, depends on the size of the drainage basin and the degree to which the site conditions have changed.

A systematic study of restoration methods and the vegetational succession started in the Seitseminen National Park in 1992. In the first phase, the vegetation of the mires was analysed to provide a survey of the situation 25-30 years after drainage occurred. After an interval of 1-5 years from the time the mire restoration measures started, an intensive monitoring phase of five years duration will take place to study the immediate consequences of the restoration. It is hoped that many questions may then be answered which now have to be left open.

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Wetlands in Västerbotten, Sweden

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ABSTRACT

Forslund, S.R. 1995. Wetlands in Västerbotten, Sweden. *Gunneria 70*: 237-242.

This inventory of wetlands in the county of Västerbotten is one of the most extensive inventories of the natural environment carried out in Sweden. In the boreal zone (alpine areas are not included) inventories have been made of every wetland with an area of at least 50 ha. More than 25% of the county is estimated to be wetland. The survey took in 14% of the county, where 4306 wetland sites cover 700,000 ha. Prior interpretation of black and white aerial photographs provided fundamental knowledge about the wetlands, and sites were visited at 657 wetland locations, or approximately 15% of the total. Mires dominate the wetlands and increase proportionately from the coast, where they cover 70%, to the interior (90%). Just over 400 wetland sites in the county have very high conservation values and 31 mire localities are included in the national mire protection plan for Sweden.

1 INTRODUCTION

The inventory of wetlands in the county of Västerbotten (Fig. 1) began in 1983 and was completed in 1993, and is one of the most extensive inventories concerned with the natural environment carried out in Sweden. Forslund et al. (1993) describe the inventory in full; a summary of the main conclusions is given here.

2 WETLANDS AND MIRES

In the Swedish wetland inventory, wetlands are defined as areas where water lies at or slightly above or below the ground surface for the greater part of the year (Löfroth 1991, Lonnstad & Löfroth 1994). The term "wetland" also includes water bodies covered with a floating raft of vegetation. Wetland can be divided into three categories: mires, shores and other wetlands. Mires are peat-forming areas with mire vegetation which are not strongly influenced by limnogenous, saline or brackish water. They are divided into bogs, fens and mixed mires. Wetlands on shores are strongly influenced by limnogenous, saline or brackish water and may be inundated by lakes, the sea, or streams and rivers. They are divided into limnogenous and saline wetlands. Other wetlands are land that is wet, but is neither peat-forming nor inundated; they include wet heaths, wet meadows and some wet forests.

Fig. 1. Map showing the geographical position of Västerbotten in Fennoscandia.

Fig. 2. The biogeographical regions (Nordiska Ministerrådet 1984a) in Västerbotten. 1-3 - middle boreal zone (1 - coastal plains on the Gulf of Bothnia, 2 - intermediate, 3 - uppermost), 4 - northern boreal zone, 5 - alpine zone.

Figure 2 shows the biogeographical regions in Västerbotten. A quarter of the county is estimated to be wetland. In the boreal zone (alpine areas were omitted) inventories have been made of every wetland with an area of at least 50 ha. The survey covers 14% of the area of the county, amounting to 700,000 ha dispersed across 4306 individual wetlands (Forslund et al. 1993). The mires are well documented, as just over 70% of the total mire area has been covered by the inventory. On the other hand, only 10% of wet forests have been surveyed.

3 METHODS AND MATERIAL

Interpretation of black and white aerial photographs provided fundamental knowledge about the wetlands and formed the basis for selecting and classifying the sites (Göransson et al. 1983). In addition to registering wetlands and mires, other characteristics, such as various hydrological features, tree coverage, moistness, encroachment and cultural-historical remains, have been recorded. Visits have been paid to 657 wetland locations (Fig. 3), or approximately 15% of the total number. Descriptions accompanied by species lists have been made of just over 9000 plant communities representing about 100 types of vegetation (Nordiska Ministerrådet 1984b).

More than 120,000 occurrences have been registered, of which 82,000 are vascular plants of 369 species and 31,000 bryophytes of 200 species. Birds, butterflies, dragonflies and molluscs have been registered at some selected sites.

Categories of conservation value have been identified, based on certain conservation criteria, primarily size, unspoiled qualities (naturalness), variety, representativenes and rarity (Göransson et al. 1983). After comparing sites within a biogeographical region, the sites were automatically graded, this process being facilitated by computer processing.

4 RESULTS

The wetlands have been divided into four categories with respect to their nature conservation value (Göransson et al. 1983). Slightly less than a quarter of the wetland area in the county (403 sites) has been placed in Class 1, representing a very high conservation value (Fig. 4). The sites in Class 4 (10%) have no known nature conservation assets and are substantially affected by exploitation. The number and geographical distribution of the classes varies from one biogeographical region to another.

Fig. 3. Distribution of sites visited during the survey (after Forslund et al. 1993).

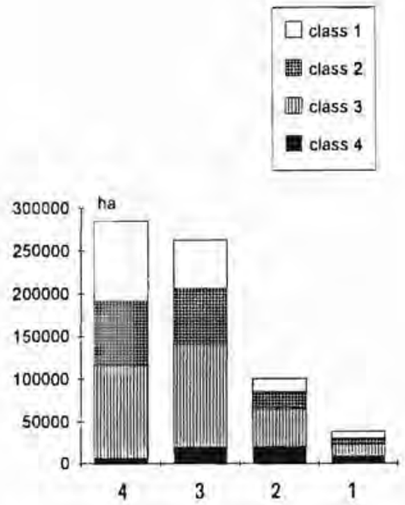

Fig. 4. The wetland area surveyed in each biogeographical region (1 - 4 as in Fig. 2) distributed among four classes. Class 1: very high conservation value; class 4: no conservation value (Forslund et al. 1993).

The size and number of the sites increases from the coast to the interior. Mires dominate the wetland areas in the county and their number increases proportionately in the interior. In the coastal region, mires account for just over 70% of wetlands, while in the northern boreal zone the percentage is 90 (Forslund et al. 1993). The coastal region is more influenced by the sea, lakes, and streams and rivers. The occurrence of certain types of mires, plants and animals also varies noticeably from the coast to the mountains.

The accompanying maps (Fig. 5 A-H) show the distribution of some wetland species occurring in localities visited in the county. The distributional patterns of mire species in northwestern Europe are dealt with in a number of works (e.g. Hultén (1971), Mossornas Vänner (1993), Flatberg et al. (1994)). Based on this literature, the following characteristics for the distribution in northwestern Europe can be given for the eight species in Figure 5: *Myrica gale* (A) is a species with a southern to southwestern tendency, *Sphagnum pulchrum* (B) has a wide distribution, but is most common in southwestern parts, *Calla palustris* (C) and *Peucedanum palustre* (D) are slightly southeastern species, *Ledum palustre* (E) is an eastern species, *Sphagnum aongstroemi* (F) has a slightly eastern to northeastern tendency, and *Saussurea alpina* (G) and *Tofieldia pusilla* (H) are slightly alpine/upper boreal species.

The number of encroachments decreases from the Baltic Sea to the mountains. For example, 30% of the sites in the interior are affected by ditching, whereas in coastal districts 70-90% are affected. The reason for this is the population distribution, most people living near the coast. Ditching for forestry is also more intensive in the eastern part of the county.

The National Environmental Protection Agency has adopted a national mire protection plan (Lonnstad & Löfroth 1994), mostly based on surveys of wetlands. Areas that should be given priority with regard to protection are included in the plan, which numbers 31 mires in Västerbotten. Approximately 57,000 ha of wetlands located below the mountainous part of the county are already protected under the terms of the Nature Conservation Act; most of these are in the northern boreal zone.

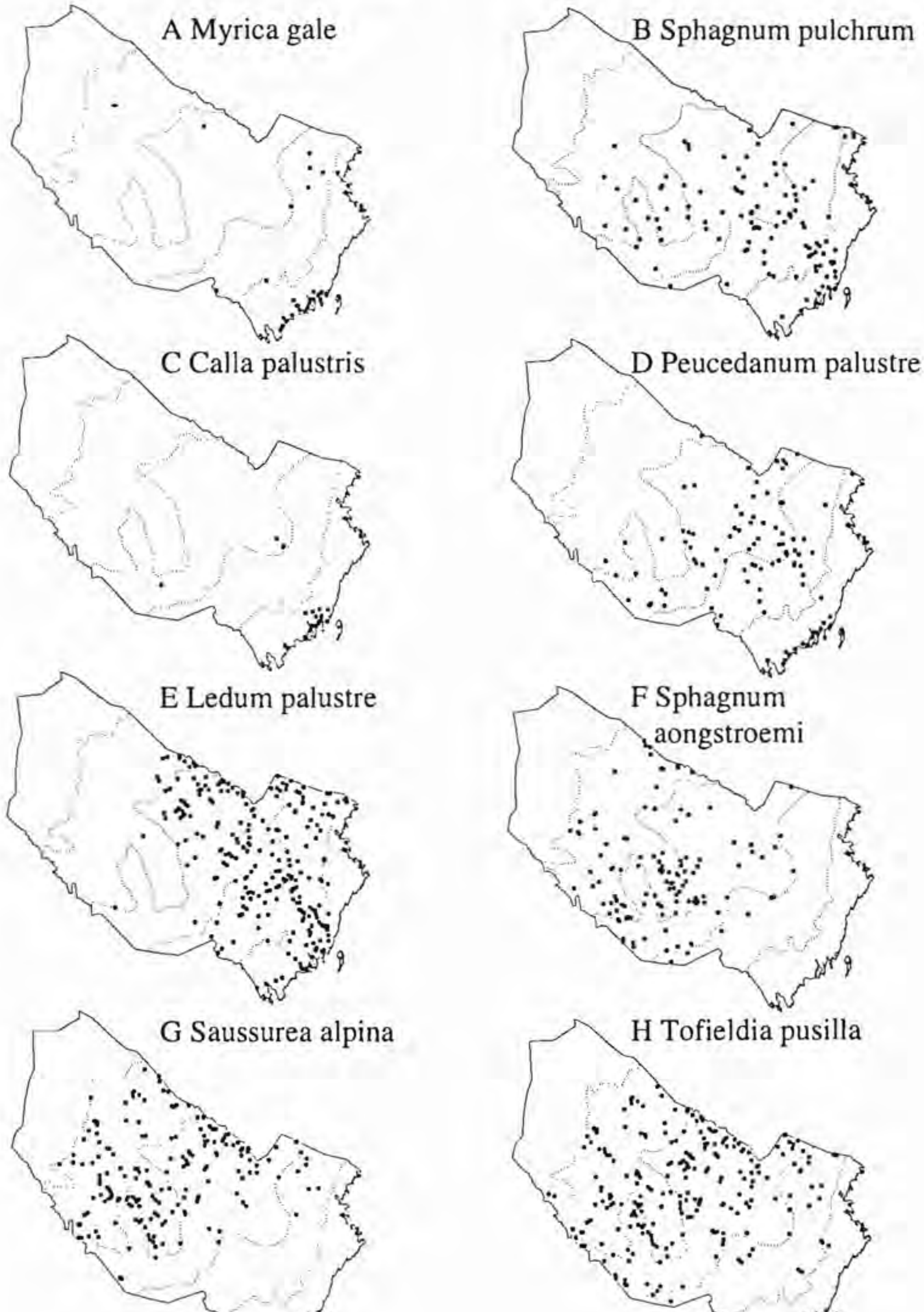

Fig. 5. Distribution of eight mire species in Västerbotten based on the 657 localities visited while preparing the wetland inventory (see Fig. 3).

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Mires in Lesotho

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ABSTRACT

Backéus, I. & Grab, S. 1995. Mires in Lesotho. *Gunneria 70*: 243-250.

Soligenous mires are common at high altitudes in the mountains of Lesotho, southern Africa. The flora and vegetation are distinctive and the mires form ecosystems not found elsewhere. Peat is formed mainly from the roots of vascular plants and is generally shallow. Bryophytes play a subordinate role in the vegetation. Flarks and thufur occur at the highest altitudes. The mires are heavily grazed and are rapidly being destroyed, particularly through gullying caused by intense grazing upslope from the sites. A project to export water to South Africa is now being put into effect. This will severely affect the mires through inundation of sites and increased pressure on remaining land. The new infrastructure in these areas also causes destruction. An appeal is made for international pressure to save the remaining mires in Lesotho.

1 INTRODUCTION

The highest mountains in Africa south of Kilimanjaro are found in Lesotho, the highest summit reaching 3482 m a.s.l. at Thabana-Ntlenyana. Wetlands are frequently found in these mountains, particularly at valley heads.

The lower parts of the country (approximately 1400-1800 m a.s.l.), which may be considered as montane (cf. Killick 1963), are densely cultivated and very few wetlands remain. Most of the country, however, is mountainous and consists of the deeply eroded remnants of a basaltic lava plateau. The lower parts of these mountains have both peat-forming mires and wetlands without peat (vleis). At higher altitudes, the wetlands are peat forming in most places and form distinctive ecosystems not found elsewhere in Africa (cf. van Zinderen Bakker 1965). They are particularly common around 3000 m a.s.l. and above. Their vegetation and hydromorphology have been described by van Zinderen Bakker (1955, 1965), Jacot Guillarmod (1962, 1963, 1964, 1965, 1968, 1969, 1971, 1972), Killick (1978), van Zinderen Bakker & Werger (1974), Grobbelaar & Stegmann (1987), Backéus (1988, 1989) and Schwabe (1989).

Of the three main mountain ranges in Lesotho, the Qathlamba (Drakensberg) is the highest, with an average escarpment altitude of about 3000 m a.s.l. Most of the mountain area is drained through the Senqu (the

Orange River). The natural tree limit may be at about 2200 m a.s.l. or, probably, higher. True alpine (or Austro-Afroalpine) conditions occur above about 2900 m a.s.l.

The climate is strongly characterised by seasonal differences, as in temperate climates, as well as by differences between day and night, as in tropical montane and alpine climates. Monthly mean temperatures at Mokhotlong (2250 m a.s.l.) range from 4.7 °C (June) to 17.4 °C (January) and at Leseng-la-Draai (3050 m a.s.l.) from 0.2 °C to 11.0 °C. Snowfalls frequently occur during colder months and snow may remain for weeks during the winter.

2 HYDROMORPHOLOGY AND CRYOMORPHOLOGY

The mires in Lesotho are mainly soligenous, which is uncommon in Africa. The occurrence of topogenous mires is restricted by the mountainous terrain. After rains, which are often extremely heavy, muddy water flows onto the mires, thus preventing the development of (minero-)ombrotrophic mire complexes.

The peat is mainly formed from the roots of vascular plants. Bryophytes are not important peat formers. Particularly in low and middle altitude mires, the peat is usually highly humified and amorphous. The peat layer in low and middle altitude mires is shallow in most places and peat deeper than a few decimetres is found only in small pockets. At high altitudes, 2 m deep peat can be found. However, information on the depth and age of peat is very scanty.

Thufur (frost-induced mounds) are common mire landforms, particularly above 2800 m a.s.l. Thufur in Lesotho have an average height of 16-17 cm and a diameter of 50-70 cm. They often show downslope elongation (Boelhouwers & Hall 1990, Grab 1994). Some thufur are obviously inactive. However, it has been suggested that some are active in years with appropriate weather when soils sometimes freeze to a depth of more than 15 cm in winter months (Grab 1994). Grab further examined the morphological changes of thufur and suggested that these may be correlated with the changing environmental state of the mires. Thufur may occur on both valley-head mires and sloping mires. Other landforms, such as sublinear ridges, flarks and elongated pools, are restricted to a few gently sloping valley-head mires. A description of one such mire site is found in Backéus (1989). Flarks have not been found anywhere else in Africa. On these mires, hummocks commonly attain an average height of about 40 cm and a width of about 120 cm. The relatively shallow flark pools usually only contain water during the wettest months, whereas deeper pools with a stone or soil bottom may remain for much of the year. The pools often harbour cyanobacteria. The age of these mire features is not known, but they are believed to be products of a past, colder period. Although present climatic conditions may still marginally favour the development of some mire-associated landforms, human interference has led to their accelerated disintegration.

3 FLORA

Backéus (1988) listed 104 vascular plant species from mires in Lesotho. A number of these are also found on mesic mountain slopes whereas others are exclusive mire plants. Three phytogeographical groups within the mire flora were distinguished by van Zinderen Bakker & Werger (1974):

1. Species restricted to the alpine zone of the southern African mountains, e.g. *Haplocarpha nervosa* (Thunb.) Beauverd and *Athrixia fontana* MacOwan.

2. Species occurring in southern, eastern-central and east Africa, e.g. *Lagarosiphon muscoides* Harv., *Aponogeton junceus* Lehm ex Schlechtd. and *Crassula natans* Thunb.

3. Northern tempererate species with outposts in the African mountains, e.g. *Koeleria cristata* (L.) Pers. s.l., *Isolepis fluitans* (L.) R.Br. (= *Scirpus fluitans* L.) and *Ranunculus meyeri* Harv.

Bryophytes play a subordinate role in the mire vegetation. Backéus (1988) recorded 17 species. Among the important ones are *Bryum alpinum* With., *B. argenteum* Hedw., *B. pseudotriquetrum* (Hedw.) Gaertn., Meyer & Scherb. and *Philonotis falcata* (Hook.) Mitt. The genus *Sphagnum* does not occur.

4 VEGETATION

Van Zinderen Bakker & Werger (1974) described three plant associations from high altitude mires which were ecologically differentiated by their degree of wetness. Backéus (1988) differentiated between eleven community types, mainly from middle and low altitudes. The main gradients were found to be wetness and altitude. The most important species of the different communities can be found in Table 1 where they are arranged along the dry - wet gradient. Communities 4, 5 and 11 are found mainly at high altitudes (above 3000 m a.s.l.), communities 1-3 and 6-7 mainly at middle altitudes (2400-2700 (-2900) m a.s.l.) and communities 8-10 only at low altitudes (around 2200 m a.s.l.).

Table 1. Important species in the mire vegetation of Lesotho. Summary of data from sample plots (Backéus 1988). Only species with a frequency of more than 60% in at least one community have been included (indicated with 'X'). + = frequency of 20-60%, - = not occurring or frequency of less than 20%.

Community no.	1	2	3	4	5	6	7	8	9	10	11
	dry <-------------------------> wet										
Kniphofia caulescens s.l.	X	+	X	-	-	-	-	-	-	-	-
Scirpus ficinioides	-	X	-	-	-	-	-	-	-	-	-
Oxalis cf. obliquifolia	-	X	X	-	-	-	-	-	-	-	-
Merxmuellera macowanii	-	+	X	-	-	-	+	-	-	-	-
Pseudognaphalium undulatum	-	-	X	-	-	-	-	-	-	-	-
Cerastium sp(p).	-	-	+	-	X	-	-	-	-	-	-
Ranunculus meyeri	-	-	X	-	-	+	-	X	X	-	-
Isolepis fluitans/angelica	-	-	X	X	X	X	+	-	-	-	-
Crassula vaillantii coll.	-	-	+	X	-	-	-	-	-	-	-
Limosella longiflora	-	-	-	X	-	-	-	-	-	-	-
Athrixia fontana	-	-	-	X	-	-	-	-	-	-	-
Koeleria capensis	-	-	-	X	X	-	-	-	-	-	-
Cotula paludosa	-	-	-	-	X	-	-	-	-	-	-
Haplocarpha nervosa	-	-	+	-	-	X	-	-	-	-	-
Trifolium burchellianum	-	-	-	-	-	X	-	-	+	-	-
Limosella major	-	-	-	-	-	X	-	X	-	-	-
Senecio polyodon	-	-	-	-	-	-	X	-	+	-	-
Isolepis costata	-	-	-	-	-	+	X	X	+	-	-
Juncus oxycarpus	-	-	-	-	-	+	-	X	+	-	-
Agrostis lachnantha	-	-	-	-	-	-	X	X	-	-	-
Pennisetum thunbergii	-	-	-	-	-	-	-	+	X	-	-
Mentha aquatica	-	-	-	-	-	-	-	+	X	-	-
Kyllinga erecta	-	-	-	-	-	-	-	-	X	-	-
Carex cf. subinflata	-	-	-	-	-	-	-	-	-	X	-
Crassula natans	-	-	-	-	-	-	-	-	-	-	X
Lagarosiphon muscoides	-	-	-	-	-	-	-	-	-	-	X
Limosella inflata	-	-	-	-	-	-	-	-	-	-	X

Communities 1-3 are found at comparatively dry sites, often fringing onto the wetter parts of the mire. Communities 4-6 form densely grazed swards of intermediate wetness, often dominated by *Isolepis fluitans* and with minute specimens of various herbs inmixed. Communities 7-10 constitute the wettest parts of the mire, typically where there is moving water and often prominent *Isolepis costata*. Community 11 is found in mire pools at high altitudes. Algae (e.g. *Nitella* sp. and microalgae of the genera *Spirogyra* and *Zygnema*) (van Zinderen Bakker 1965, van Zinderen Bakker & Werger 1974) are also important in these pools.

All the mires are heavily affected by grazing and trampling and this is likely to influence the species composition. The small herbs in communities 4-6 would perhaps be out-competed if grazing did not take place. The mires in Lesotho are physiognomically similar to grazed mires in Sichuan, China (Ekstam 1993) and Tasmania (A.W.H. Damman, pers. comm.).

5 HUMAN INTERFERENCE

Destruction of mires in Lesotho has been reported by Jacot Guillarmod (1962, 1963, 1964, 1967, 1968, 1969, 1972), van Zinderen Bakker & Werger (1974), Rapp (1975), Thompson & Hamilton (1983) and Backéus (1988). The destruction is widespread and mainly caused by the trampling and grazing of domestic animals. Most of the volcanic soils found on Lesotho mountains appear to resist erosion and the peat soils on the mires are even more resistant. Nevertheless, gullies (ravines formed by running water) are frequently formed on hillslopes. Where such gullies form in the mineral soil upslope from a mire, the muddy water may enter the mire with considerable velocity. At many places this has resulted in a sedimentation fan on top of the peat. In severe cases, or where the mire has a conspicuous slope, the gully may continue to cut through the peatland.

A sedimentation fan with sand or gravel will not destroy the mire permanently. Once sedimentation has ceased, it is possible for mire vegetation to colonise on the gravel surface. Gully development within the peat, on the other hand, will cause permanent changes in the hydrology of the site.

Direct interference of the mires themselves tends to be less destructive. The leaves of *Merxmuellera macowanii* are very unpalatable for livestock and their tips are sharp, making it quite unpleasant to walk through. The omnipresence of this species on the middle altitude mires greatly reduces destruction. *Isolepis fluitans* is favoured, especially by goats and sheep, but the species has a remarkable tolerance and can withstand heavy grazing. The turf may be severely damaged by trampling only where cattle walk through the mires in search of water.

Plans exist to export water from Lesotho to South Africa. Construction work on the Lesotho Highlands Water Project has already begun with the building of the Katse Dam in the Malibamatso drainage basin. We feel that this dam poses one of the greatest threats to the mires and associated ecosystems. Lesotho mires are particularly common in the high Qathlamba (Drakensberg) and Central Ranges, which are primary catchments for the Malibamatso. In the highlands, almost all arable land is located along valley bottoms. As a consequence, with the construction of the dams thousands of hectares of cultivated land will be lost. This may lead to an increasing dependence on livestock farming and an augmentation of the grazing pressure in the alpine belt. The dam constructions are also likely to affect traditional farming practices, such as transhumance, and thereby prevent livestock from returning from the alpine belt to their home villages during the winter months.

Further consequences of the water project are the construction of new roads, industrial development and increased tourist pressure. For instance, a new tarred road through Qathlamba from Oxbow to Mokhothlong, built adjacent to the existing gravel road, has already destroyed some of the mires. Recent observations have shown one mire to be destroyed beyond rehabilitation. At several sites, gravel has been dumped adjacent to streams and mires, causing severe silting.

6 CONSERVATION

Lesotho is one of several countries in Africa where a severe shortage of water can be expected in the future (Falkenmark 1989). In this connection, the peatlands of the country are of great importance as water reservoirs. When travelling in the mountains during spells of dry weather, one can clearly see how streams from mineral slopes rapidly dry out whereas those from peatlands continue to hold water for weeks.

The types of soligenous mires that have evolved in Lesotho now occur in a climate with wet summers and cold winters with frost and snow. They are not found anywhere else in southern Africa and in some respects resemble boreal mires. A number of plant species and, possibly, invertebrate animals only occur on these mires.

Various groups and organisations have recently shown growing concern for the Lesotho wetlands. For instance, the environmental division of the Lesotho Highlands Development Authority has committed itself to rehabilitating some wetlands, such as that at Mafika Lisiu in the Bokong Basin. Another conservation effort is the MRA (Managed Resource Area) under which the RMA (Range Management Area) concept forms an integral part. One objective of the RMA is controlled grazing schemes to ease pressure on the wetlands, particularly during the dry, cold winter months. However, such policies are frequently difficult to enforce, particularly as large areas are already severely degraded.

The protection of a substantial number of mire sites in Lesotho would be of paramount importance both for environmental reasons and from the point of view of nature protection and biodiversity. However, so far very little preservation has been undertaken. The Lesotho government, in conjunction with the Natal Parks Board and the Kwazulu Bureau of Natural Resources in South Africa, is now urging community development and a conservation programme. An appeal is hereby made for increased international pressure to save the remaining mires of Lesotho, particularly as these are without doubt an essential water source for much of the subcontinent.

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Canada: peatland sustainability and resources use

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ABSTRACT

Rubec, C. 1995. Canada: peatland sustainability and resources use. *Gunneria 70*: 251-264.

The environmental issues in Canada associated with the use of peat for horticulture and other commercial applications have received considerable public and press attention in the last two years. Some uses are claimed to threaten wildlife habitats and contribute to the overall degradation of soil, water and climate systems. This paper examines the environmental issues raised in a 1992 publication entitled *Canadian Peat Harvesting and the Environment*, as well as the status of the peatland resources of Canada.

In some nations with a long tradition of peat use, all remaining peatlands are often viewed as being worthy of protection from any further development. Consumers, governments, researchers and industries are becoming partners in national and international initiatives to develop peatland conservation and wise-use strategies. In Canada, most of our peatlands are not at significant risk. While less than 0.02% of our vast national peatland resource is in use for direct peat harvesting applications, the flooding of peatlands by hydro-electric schemes and the potential for harvesting of peatlands as fuel for energy production continue to be seen as significant threats to the peatlands of Canada. Many remaining wetlands and peatlands in the southern reaches of the nation continue to be degraded or destroyed for agricultural, port and urban development.

Initiatives by government and non-government environmental interests and peat harvesting corporations are leading to the recognition that sustainable, wise use of peatland resources in Canada is the only acceptable road to follow.

1 INTRODUCTION

"Canadians need and will continue to need peat and peatlands. We cannot and should not halt use altogether, though wise management and intensive use on selected sites must be encouraged" (Warner 1992).

About 90% of the 127 million ha of the wetlands in Canada are classed as peatlands (National Wetlands Working Group 1988). The Canadian definition of peatlands coincides with national criteria for defining organic soils as established by the Canada Soil Survey Committee. These are based on a 40-cm depth of peat soil at the surface as well as aquatic and floristic criteria; this would distinguish them from «mires» which use other identification criteria. The volume of peat present in these peatlands has been estimated by the National Research Council to be over three trillion (3 x 10^9) cubic metres (Tarnocai 1984). Peat utilisation presents a wide range of opportunities as well as limitations. The objective of the present paper is to examine the relationship between peatland uses for horticultural, forestry and energy interests and a range of environmental and sustainability issues related to these uses in Canada.

We read much in the press about concerns that use of peat for applications such as gardening is a threat to our global ecosystem, promoting the view that harvesting of peat for horticultural and other uses must be stopped. A March 1993 national television show in the *Nature of Things* series questioned the rationale for any continued use of peat in Canada, given the major environmental concerns that have developed in European nations for fuel and other peat applications. Why should Canada be any different than these European nations, one could ask?

A national report entitled *Canadian Peat Harvesting and the Environment* (Keys 1992) has indicated that harvesting of peat for horticulture from Canadian sources is not a major threat to the nation's peatland resource or to Canadian wildlife habitats, is not a significant contributor to the production of greenhouse gases, and has a positive contribution to make to the Canadian economy. This report examines the benefits derived from the wise use of Canadian peat resources and potential impacts of an environmental nature. It indicates that Canada is demonstrating that sustainable peatland resource use is possible. This process embraces all interests including environmental groups, industry, researchers and government regulators. Some of the major points in Keys (1992) and in Rubec (1991) are summarised in this paper.

2 DISTRIBUTION OF CANADIAN PEATLANDS

The distribution of wetlands in Canada has been controlled by many factors including surface hydrology and the interaction of climatic and topographical factors. Table 1 lists Canada's wetland occurrence on a provincial basis and provides an overview of comparable peatland distribution.

Major regional and local wetland and peatland inventory programmes have been completed across Canada. A recent report by Geomatics International (1994) prepared for the North American Wetlands Conservation Council (Canada) summarises the status of wetland inventories in Canada and explores opportunities for a national wetland data integration programme which, sadly, still remains elusive in our vast nation. No systematic national wetland inventory has yet been implemented in Canada. For this reason, it remains difficult to assess whether specific peatland types, either regionally or nationally, are rare or at risk to any kinds of development pressure. Major efforts have focused, however, on systematic protection of representative examples of all our wetland and peatland types through federal, provincial and non-governmental programmes. The *National Workshop on Wetland Data Integration* (see Lynch-Stewart & Rubec 1993) provided a specific direction for how we in Canada may proceed. More recently, this led to the establishment of the National Wetland Inventory Project (Environment Canada 1993).

Table 1. Occurrence of wetlands and peatlands in Canada

Province or Territory	Peatland area		Total wetland area	
	ha x 10^3	% of land area in province or territory	ha x 10^3	(%) of land area in province or territory
Alberta	12 673	20	13 704	21
British Columbia	1 289	1	3 120	3
Manitoba	20 664	38	22 470	41
New Brunswick	120	2	544	8
Newfoundland-Labrador	6 429	17	6 792	18
Northwest Territories	25 111	8	27 794	9
Nova Scotia	158	3	177	3
Ontario	22 555	25	29 241	33
Prince Edward Island	8	1	9	1
Quebec	11 713	9	12 151	9
Saskatchewan	9 309	16	9 687	17
Yukon Territory	1 298	3	1 510	3
Canada	111 327	12	127 199	14

Source: National Wetlands Working Group (1988).

A detailed discussion of wetland distribution and of the characteristics of the wetlands in each of Canada's 20 wetland regions is provided in *Wetlands of Canada* (National Wetlands Working Group 1988). Over 70% of Canada's wetlands are estimated to occur within the boreal zone. The majority of these are bog and fen ecosystems; most of the horticulture and other operations utilising peat resources in Canada are within this boreal zone.

3 WETLAND AND PEATLAND UTILISATION

Our peatland resources serve a variety of purposes. In their natural state, they provide many functions including acting as regulators of water flow and quantity and a source of fresh water. Non-consumptive uses include public recreation and education. Consumptive uses include wildlife hunting and fishing. Uses involving the alteration of the wetland's natural state are harvesting of specific goods such as trees, peat or rice. Some peatland utilisation involves the extraction of peat.

3.1 NON-EXTRACTIVE PEATLAND USES

Agricultural uses of peatlands in Canada are generally non-extractive. These areas are used for vegetable production, pastureland and related purposes. The value of market gardening crops derived from peatlands alone exceeds $100 million annually in Canada. Canada's wetlands are further estimated to provide in excess of $10 billion in economic benefits to Canadians each year (Rubec et al. 1988).

Table 2 puts the relative degree of peatland use by agriculture, horticultural peat harvesting, forestry and other interests into context to other sources of wetland conversions in Canada. Up to 17 million ha of Canada's wetlands have been drained for agriculture and another 900,000 ha for urban expansion since Canada was settled. The areas of highest risk to wetlands in Canada are shown in Figure 1. The 41,000 ha in use today for peat horticulture and forestry are insignificant in comparison to the continuing annual losses of thousands of hectares to agriculture and urban/industrial expansion in Canada.

Table 2. Relative impacts of development on wetlands in Canada

Land use	Area of wetland affected since settlement (ha)	Relative percentage (%) of total area
1. Agricultural drainage	17 000 000	85.0
2. Reservoir flooding	900 000	4.5
3. Urban/Industrial development	894 000	4.5
4. Other development	765 000	3.9
5. Ports/Harbours	400 000	2.0
6. Forestry drainage	25 000	0.03
7. Horticultural peat harvesting	16 000	0.02
TOTAL	20 000 000	100.0

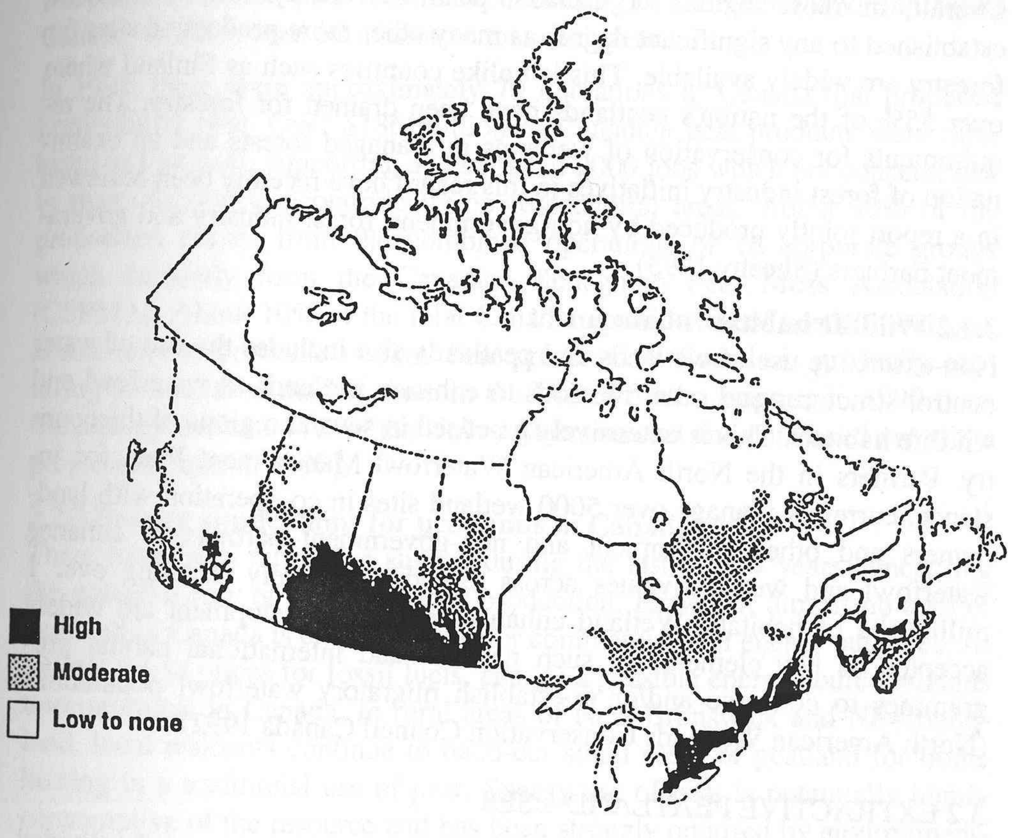

Fig. 1. Wetland areas at risk in Canada.

3.1.1 Peatland forestry in Canada

Most of the harvesting of timber from Canada's large expanse of forested peatlands is carried out in winter during frozen ground conditions, minimising site impacts and facilitating use of appropriate machinery. Peatland drainage is used to enhance tree growth in several European countries, but this is not widely practised in Canada at present. Pilot peatland forestry developments in Alberta, northern Ontario, eastern Quebec and Newfoundland have been undertaken to evaluate peatland drainage as a forest management tool in Canadian conditions.

Less than 25,000 ha (about 0.3%) of Canada's peatlands have been drained for forestry interests (Haavisto & Jeglum 1990). This includes small areas undergoing peatland forestry trials examining hydrological processes, nutrient dynamics and tree growth. Extensive areas of black spruce, tamarack and lodgepole pine are harvested off peatlands each year in Alberta. In Ontario, it is estimated that the trees on 28,000 ha of peatland dominated by black spruce are felled yielding about 20% of the roundwood harvested annually. Overall, in most regions of Canada, peatland forestry has not become established to any significant degree as many other more productive sites for forestry are widely available. This is unlike countries such as Finland where over 55% of the nation's peatlands have been drained for forestry. The requirements for conservation of wetlands in managed forests and an examination of forest industry initiatives in this regard have recently been reviewed in a report jointly produced by non-government, forest industry and government partners (Sheehy 1993).

3.1.2 Wildlife habitat enhancement

Non-extractive use of wetlands and peatlands also includes the use of water control structures and other methods to enhance wetlands as waterfowl and wildlife habitats. This is extensively practised in several regions of the country. Partners in the North American Waterfowl Management Plan, for instance, currently manage over 5000 wetland sites in co-operation with landowners and other government and non-government partners to enhance waterfowl and wetland values across Canada, positively affecting over 1 million ha of habitats. Wetland enhancement and development are widely accepted as key elements in such national and international habitat programmes to conserve and/or re-establish migratory waterfowl populations (North American Wetlands Conservation Council Canada 1992).

3.2 EXTRACTIVE PEATLAND USES

Development of peatlands for the purposes of peat extraction can be divided into two main categories: (i) horticultural peat and other peat moss applications, and (ii) fuel peat use. There was considerable interest in the development of fuel peat in Canada during the mid-1970s, but actual production for this purpose has been almost non-existent. To date, economic factors and the availability of other energy sources have not resulted in peat becoming an attractive energy product in Canada. Production of peat for horticultural and other non-fuel purposes, however, has been undertaken in several regions of Canada.

3.2.1 Horticultural use of peat in Canada

The total volume of horticultural peat shipped in Canada in 1993 was approximately 732,000 tonnes. The rate of peat accumulation averages 0.1 kg/m^2 per year — about 1 tonne/ha (Zoltai 1991). While accumulation rates are lower in many northern peatlands, the total annual accumulation on the 111 million ha of peatland in Canada is still substantially greater than the annual quantity of peat and peat moss harvested. If an average estimated peat accumulation figure of only 0.5 tonne per ha per year can be assumed to be reasonable, the total peat volume accumulating in the natural environment in Canada would exceed 50 million tonnes each year.

In 1993, there were approximately 70 operations in Canada that produced horticultural peat. Over $186 million of Canadian peat products were marketed in that year, supporting an estimated 2000 jobs which are concentrated in many otherwise economically depressed rural areas. About 90% of the production comes from the combined operations of 16 corporate groups which currently form the Canadian Sphagnum Peat Moss Association (CSPMA). About 10% of the total Canadian production of horticultural peat is sold on the domestic market. Peat produced in Canada is gradually capturing an increased market share in the United States. Imports in 1990 from Canada represented 44% of the United States market and continued growth is projected (Cantrell 1990).

3.2.2 Energy applications for peatlands in Canada

There have been numerous studies during the last twenty years concerning the potential role of peat in energy production. However, almost no area of peatland in Canada is currently used for commercial fuel energy purposes. At today's world prices for fossil fuels, peat as a possible energy source remains uneconomical in Canada. In rural areas of New Brunswick and Newfoundland, local residents continue to hand-cut small areas of peatland for home heating in a traditional use of peat. Energy use of peat is potentially highly consumptive of the resource and has been strongly opposed by environmental interests in Canada both from ecological and socio-economic perspectives.

Major peatlands in Quebec, Manitoba and Alberta have been flooded for hydro-electric reservoir construction. The total area of peatland affected to date is estimated to exceed 900,000 ha (Rubec 1991), with additional reservoir proposals projected to affect an additional 1 million ha of peatland or estuarine wetlands in Canada in the next decade. It is worth stressing that hydro-electric projects are affecting far more peatlands today in Canada than all urban development, peat harvesting and forestry operations combined.

In March 1992, the federal Cabinet announced *The Federal Policy on Wetlands Conservation* which applies to all federal agencies, programmes and project expenditures. Any federally-funded project that can be viewed by the environmental assessment process as significantly degrading the functions of peatlands or wetlands anywhere in Canada, especially if it involves federal lands, is likely be strongly scrutinised under this new Policy.

4 IMPACTS AND BENEFITS OF PEATLAND DEVELOPMENT

Development of peatlands involves numerous environmental issues. These include conservation of wildlife habitats, protection of rare or unusual species and release of stored carbon in relation to production of greenhouse gases. Issues reviewed in Keys (1992) include:

(i) wetland loss and degradation
(ii) wetland habitat impacts
(iii) impacts on threatened and endangered species and other biota
(iv) carbon release
(v) water quality and quantity impacts
(vi) maintenance of air quality.

Wetland loss has become acute in some regions of Canada and has become an issue of public concern. Agricultural development is the single greatest cause of wetland loss in Canada with over 17 million ha of wetlands converted to this sector since settlement (Environment Canada 1986). Wetland loss due to urban, industrial and agricultural development has been greatest in the marsh, swamp and shallow water wetland classes located largely in southern non-boreal regions of Canada. Only a low percentage of peatland bogs and fens have been affected by these factors. While horticultural peat developments are primarily found on bogs within the boreal wetland regions, their relative impact (affecting less than 16,000 ha of peatlands in Canada) remains relatively minor (Rubec 1991).

The development of particular peatlands can cause a loss of habitat locally for certain wildlife species which occupy a narrow ecological range. However, the relative level of impact must also be considered within a regional context in addition to site-specific factors.

The vegetation community which occurs on a typical peatland bog includes several species which are not common in mineral soil ecosystems. For example, pitcherplant (*Sarracenia* sp.), butterwort (*Pinguicula* spp.) and sundew (*Drosera* spp.), all of which can capture insects to provide nutrients, are considered unusual and unique in some areas (Warner 1992). Many of these species, however, are widely distributed throughout Canada's boreal wetland regions. Rare or endangered bird and mammal species that are known to use peatlands include the whooping crane (*Grus americana*), trumpeter swan (*Cygnus buccinator*), piping plover (*Charadrius melodus*) and wood bison (*Bison bison*). Peatlands are recognised as rich refugia for a wide range of other biological resources including invertebrate species. Some of the species now being found in Canadian peatlands are new to science.

Gorham (1991) assessed the impact of peatland development on the carbon cycle. The study indicates that on a global basis, combustion of peat as a fuel releases about three times the quantity of carbon as is released from drained peatlands. Drained peatlands for fuel peat production represent a large percentage of the total area of developed peatlands on a global basis, but not in Canada. The study notes that the release of methane from undisturbed peatlands has a far greater impact than the combined total impact from all peatland development areas. The current level of development of peatlands in Canada is low and none are used for peat energy. Areas in Canada used for horticultural peat production or other applications do not appear to impact significantly on the global carbon cycle or production of greenhouse gases.

The potential effect on downstream aquatic ecosystems of drainage waters from developed peatlands is a significant environmental issue. Environmentally-sensitive management of such sites in the development phase is required. Wind erosion of production areas and stockpiles is also a site-specific concern for horticultural peat developments. Harvesting and storage techniques that minimise surface exposure for extended periods and reduce wind erosion have been implemented in most peat harvesting operations in Canada.

4.1 PEATLAND RE-USE AND RESTORATION

Few harvested peatlands in Canada have reached the end of their production life; hence, few sites have been the focus of restoration efforts to date. In European countries such as Finland, Ireland and Germany, numerous peatland re-use projects reflect a long history of peatland use and the more frequent occurrence of peat deposits where the resource has been exhausted. There are several options for peatland re-use, including:

(a) afforestation
(b) agricultural production
(c) establishment of a wildlife habitat.

Revegetation of depleted Canadian peatlands with naturally occurring wetland vegetation is an option. A study by Nilsson et al. (1990) presents several case histories from eastern Canada and the northeastern United States for harvested peatlands which were abandoned and allowed to naturally revegetate. The rate of revegetation was found to be as short as a few years on minerotrophic sites. For large expanses of ombrotrophic bogs, vegetation cover by species identical to those found in pre-production conditions required as few as 15 to 20 years to become re-established.

5 PEATLAND POLICIES IN CANADA

The peat industry in Canada is encouraging the sustainable development of peatlands in accordance with environmentally sound practices. The Canadian Sphagnum Peat Moss Association has adopted a *Peatland Preservation and Reclamation Policy* (Canadian Sphagnum Peat Moss Association 1991) which encourages its member companies to: (i) reduce the impact of their operations on the environment, (ii) undertake ecological studies of sites representative of new development areas to provide benchmarks for restoration projects, (iii) leave areas of significant environmental interest undisturbed, (iv) co-operate with conservation bodies, and (v) co-operate with governments to designate protection areas. The industry has stated in this Policy that it is committed to site restoration and/or re-use It has initiated co-funding of research on appropriate restoration methods for harvested peatlands with major environmental organisations, research agencies and government regulatory bodies towards that end.

In February 1992, the CSPMA and government agencies also hosted a national workshop on peatland reclamation methods and guidelines. Specific recommendations for fostering research and appropriate technologies in support of the implementation of peatland reclamation and restoration were developed.

The Government of Canada has adopted *The Federal Policy on Wetland Conservation* (Government of Canada 1991). It includes recognition that ongoing development and research is fundamental to the achievement of wetland conservation and calls for sustainable, wise use of wetland resources. As outlined in Lynch-Stewart et al. (1993), this is one of eight provincial or federal governmental and several industry-based wetland policies now in place or under public discussion in Canada. About 65% of Canada's wetland resources are now encompassed by government-sector wetland conservation and sustainable resource use policies (Fig. 2). In Canada, provincial management agencies in most cases now regulate peatland development. Local decision processes at the municipal and regional level and public interest will be key factors in any future expansion of the peatland areas used by Canadian industries.

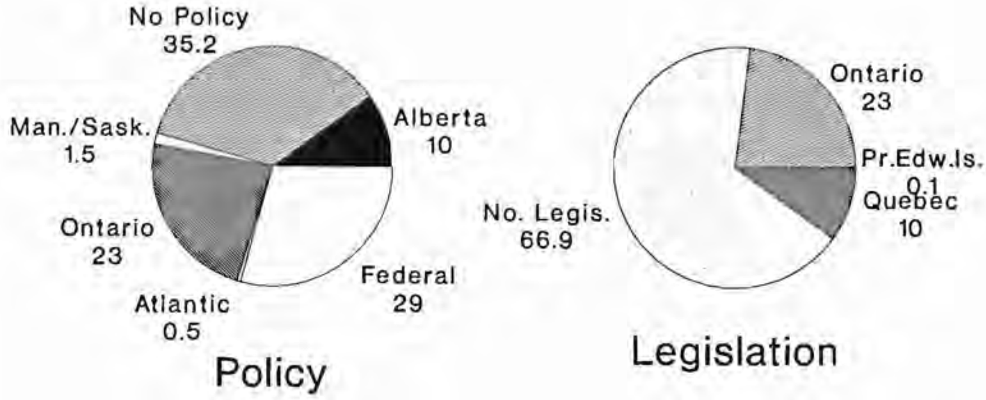

Fig. 2. Legislation and policy affecting Canadian wetlands by province. Atlantic = provinces of New Brunswick, Nova Scotia, Newfoundland and Prince Edward Island, Man/Sask. = Manitoba/Saskatchewan, Pr. Edw. Isl. = Prince Edward Island; values in % of total Canadian wetland areas.

6 CONCLUSIONS

Industry, government and environmental groups in Canada are working together to produce common strategies for peatland development considering and satisfying the wide range of interests and concerns. Canadian peatland resource users must conduct their business in a manner ensuring sustainability of the peat resources of Canada. Several environmental issues related to peatland development have been discussed in this paper. Major issues include the need for conservation of flora, fauna and other ecological values and functions of wetlands and peatlands. The potential for release of carbon and greenhouse gases due to Canadian peat harvesting is considered to be insignificant in relation to other issues at the present or projected levels of peatland development in Canada.

Re-use and restoration of peatlands after peat harvesting is essential; research into the best methods are being funded and undertaken jointly by the industry in co-operation and consultation with government and environmental groups. Restoration options are also being incorporated during the design and operational development of new peat harvesting areas.

Canada has extensive areas of peatlands in a natural state and has the opportunity to both select representative peatlands for conservation securement and practise total landscape management. Limited, future peatland development within the context of sustainable use of natural resources and continued responsible regulation can be expected. This opportunity has been lost in most

European countries where peat production has been practised for long periods. However, even in Canada, development pressures are high in some regions and for certain wetland forms. Co-operative efforts on a long-term basis between all levels of government, conservation groups and the peat industry will be required to attain a national network of secured wetlands and peatlands.

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Status of mires in Japan

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ABSTRACT

Iwakuma, T. 1995. Status of mires in Japan. *Gunneria 70*: 265-268.

The area of peatlands on Hokkaido Island has been estimated as 200,642 ha, about 62% of which has been modified by agricultural development and urbanisation. An accurate estimate of the peatland on the other islands of the Japanese archipelago is not available because people colonised them much earlier and most lowlands were subsequently changed to paddies. The Environment Agency recently surveyed wetlands larger than 1 ha. Most of the mires themselves have been protected, but the watersheds of some mires are excluded from legal protection. Only two of nine Japanese Ramsar sites are mires. Other Ramsar sites and also most candidate sites are shallow lakes and ponds, river mouths and coastal areas. Although more than 10,000 people visit the Ozegahara Mire daily during the blooming of the skunk cabbage, a symbolic plant growing on this mire, the importance of *Sphagnum* mosses is barely recognised. The lack of textbooks on mires or wetlands in Japan is also a significant problem.

1 INTRODUCTION

The next biannual symposium of the IMCG will be held in Japan in August/September 1996. It is therefore appropriate to take this opportunity of presenting the principal features of the mires of Japan. Since the meeting will be held on Hokkaido, most emphasis is placed on conditions on this island. The main content of this paper was presented at the 7th International Symposium on River and Lake Environments, at Matsumoto in Japan in October 1994.

2 AREA OF EXTANT AND EXTINCT PEATLANDS

The Japanese archipelago is located at the southern end of the global distribution of boreal peatlands (Gore 1983, Woleiko & Ito 1986). We have an accurate estimate of areas of peatlands and extant mires on northernmost Hokkaido Island, the second largest island in Japan, the area of which amounts to 22% of the country. The Hokkaido National Agricultural Experiment Station has completed a survey on the island involving drilling to a depth of 3 m at every horizontal grid point of 550 m by 270 m. From this work, the area of peatland on Hokkaido was estimated as 200,642 ha (Sakaguchi 1979).

It was possible to make such an estimation only because the island had been relatively undisturbed until the mass colonisation of people started last century. According to Sakaguchi (1979), 62% of the original peatland area on Hokkaido has been modified by agricultural development and urbanisation, i.e. about 76,000 ha of mire survive. People colonised the other islands much earlier and most lowlands were converted to paddies before accurate records began. It is therefore not possible to provide an accurate estimate of the former peatland area on these islands.

3 MIRE INVENTORY

The Environment Agency of the Prime Minister's Office made a survey of the vegetation in Japan in 1978 and 1984-1986. Wetland vegetation types were classed as *Vaccinium-Sphagnum* (cranberry-peat moss) vegetation, *Molinopsis* vegetation and *Phragmites* (reed) vegetation (Environment Agency 1980, 1988). Since geological information was not included in the survey, these vegetation areas did not necessarily correspond with peatland areas. In 1993, the Environment Agency made a detailed survey of wetlands (mire, spring, marsh, lake, mangrove, paddy, etc.) larger than 1 ha. The results will be published next year. However, about 70% of the nation's land area consists of mountainous areas covered with forests and grasslands, and such terrain makes it difficult to identify all the mires in these areas even in the latest survey.

4 MIRE PROTECTION

Several categories exist for the legal protection of mires. 1) National park (administered by the Environment Agency) and 2) Quasi-national park (administered by the prefectural governments under the supervision of the Environment Agency). Certain mires and their adjacent areas are designated as such parks, e.g. Kushiro, Ozegahara, Sarobetsu; these parks are, however, not "nature reserves" since the term "park" means that the area should be used for recreation. 3) Prefectural natural parks (designated for preservation by the prefectural governments). 4) Natural monuments and special natural monuments (designated for preservation by the Agency for Cultural Affairs at the Ministry of Education): some mires, e.g. Ozegahara, Kiritappu and Akaiyachi are designated as special natural monuments in nature protection districts. This is usually the category with the highest level of protection in Japan.

To date, many mires have been designated in one or more of the various categories of natural parks or monuments, but a considerable number of mires still have no legal protection. Furthermore, even for the protected mires, surrounding buffer zones are often excluded from the protected areas.

For example, Kushiro Mire has a vast unprotected catchment area that is mainly used for grazing.

5 WETLANDS AS RAMSAR SITES

So far nine Ramsar sites have been designated in Japan, but only two of these are mires, Kushiro and Kiritappu. The others are ponds, river mouths and paddies which fall within the wetland types defined by the Ramsar Convention. Nearly a hundred wetlands are listed by a non-governmental organisation, the Japanese Committee of the International Waterfowl and Wetlands Research Bureau (IWRB), as candidates for Ramsar sites (IWRB Japan Committee 1989). A few of these sites are mires distributed across Hokkaido. Again, the majority of the wetlands that are important habitats for waterfowl are shallow lakes and ponds, river mouths and coastal areas.

6 EDUCATION

Mires in Japan are not very important as habitats for waterfowl. As stated before, the Ozegahara Mire (760 ha) has been designated both as a national park and a special natural monument. It is a complex of bogs and fens. More than 10,000 people visit it daily at the peak of the tourist season, which coincides with the blooming along the streams of the skunk cabbage (*Lysichiton camtschatcense*), a symbolic plant growing on this mire. Many package tours are arranged for people to file along the walkboards looking at the white flower. Many colour guidebooks dealing with this mire are available, but only a few pages are given over to *Sphagnum* mosses. It is an urgent requirement that the vital role of *Sphagnum* mosses in creating and maintaining the bog ecosystem (and thus the skunk cabbage) be made more widely known to the general public, so that they can understand the importance of their conservation.

The lack of textbooks on mires or wetlands is a problem in Japan. For example, "Geology of Peatlands" (Sakaguchi 1974) is a comprehensive textbook on peatlands but has long been out of print and there is little to replace it.

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The golden flow: the changing world of international peat trade

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ABSTRACT

Joosten, J.H.J. 1995 The golden flow: the changing world of international peat trade. *Gunneria 70*: 269-292.

The use of peat is of major socio-economic significance. The annual, global extraction of peat for fuel may now exceed 30 million tonnes and for agriculture it may be as high as 150-200 million tonnes per year. International trade is largely confined to peat for horticultural purposes. In recent years, growing agricultural interest in horticulture has raised the demand for peat immensely. Campaigns against peat extraction have hardly affected the international peat trade. Alternatives to peat have not penetrated into the professional market for substrates, and no change is foreseen in the near future. Recent years have witnessed an organisational renewal of the peat industry, on both national and international levels. The industry considers conservational and environmental questions to be the major constraints to the expansion of peat consumption, a central issue being the (im-)balance between peat accumulation and extraction. Recent studies indicate that global peatland use is a major source of carbon and that restoration experiments have not yet shown satisfactory results. As a consequence, the global peatland carbon balance is shifting towards increasing net emissions. Declining domestic peat resources in western and central Europe and political changes in eastern Europe have resulted in a rapid increase in exports of horticultural peat from the former Soviet Union, especially the Baltic States A worldwide increase in the use of peat for fuel and horticulture may be expected in the near future. In the longer term, slightly humified peat may be replaced to some extent by (renewable) alternatives and by strongly humified peat.

1 INTRODUCTION

The ongoing destruction of mires in the world is largely caused by problems, needs and failures on a national scale. Reclamation of large areas of peatlands in Indonesia is in progress as part of the transmigration policy for the rapidly expanding population (Petterson 1994a). In Canada, projects to produce hydro-electricity are a greater threat to mires than all urban development, peat harvesting and forestry operations combined (Rubec 1993). Vast areas of peatlands in western Siberia are being destroyed as a result of oil recovery and transport (Chr. Geerling, pers. comm. 1993).

International mire conservation requires an international orientation on socio-economic developments that may influence the conservational perspectives of mires of international importance. Special attention must be paid to threats with an international dimension, including unwanted transboundary side-effects of human activities, non-extractive use for internationally orientated production, and extraction of peat for the international market.

Unwanted transboundary side-effects affecting mires and other peatlands include diffuse processes such as air pollution and climatic change. Destruction of mires, i.e. burning and oxidation of peat, contributes in some degree to these global problems (Immirzi & Maltby 1992).

Of direct importance is the deliberate destruction of mires for non-extractive use, such as the production of wood and agricultural products. Scandinavian countries promote their wood export by claiming that the area of forest annually planted in these countries exceeds the area that is annually felled. No mention is made of this "excess" being largely at the expense of virgin mires that have been drained extensively for afforestation (Eurola et al. 1988, Isomäki 1991). Also in southeast Asia, forestry operations in peat swamp forests (often for the Japanese market) result in severe habitat degradation (Immirzi & Maltby 1992).

The present rate of mire destruction for forestry in the world is estimated at 450,000 ha per year. This rate may be maintained if afforestation programmes are implemented to counter global carbon dioxide emissions. Long-term carbon releases resulting from drainage-induced peat oxidation will, however, often exceed carbon storage by afforestation (Immirzi & Maltby 1992).

Globally, the rate of draining mires for agriculture may have reached 100,000 ha per year (Immirzi & Maltby 1992). Only a small part of this agricultural production is destined for the international market. Regionally, however, these practices may raise conservational problems (e.g. oil palm plantations on peatlands in Malaysia, cf. Mutanen 1987).

Destruction of peatlands for forestry, agriculture and fuel peat extraction may be promoted by international subsidies (Fernandez Ruiz 1994), and by export of expertise and technology (Mutanen 1987). Recent examples of the latter include the development of peat extraction plants in Indonesia and Malaysia by the Finnish company Vapo Oy (Mutanen 1989, Vapo Oy 1992) and in Senegal by the Irish Bord na Mona (brochure Bord na Móna developing Ireland's peat resources).

The use of peat is of major socio-economic significance. In 1992, sales of peat products in the European Union and its applicant countries exceeded ECU 700 million and direct employment was over 10,000 person-years (Sopo 1994). This use involves substantial international trade. Imports of peat into the Netherlands in 1993 exceeded 1.6 million tonnes with an import value of ECU 50 million, approximately equalling the import of tropical hardwood (CBS Heerlen).

On a global scale, peat extraction is consuming only a small quantity of the available peat resources. Extraction, however, is not evenly distributed over the mire regions of the world. In Canada, it primarily occurs within the Atlantic Boreal and Low Boreal Wetland Regions, where high-quality peat for the horticultural market can be found (Keys 1992). A similar situation applies to Europe (Petterson 1994b). Areas and localities for peat extraction are selected by various criteria including climatic factors, available mire and peat types, presence and potentials of local infrastructure, and location in respect of markets and transport possibilities (Keys 1992, cf. De Zeeuw 1978). In contrast to this concentration of peat extraction is the use of peat, especially for horticulture, which extends to practically every country in the world (Petterson 1994b).

Peat extraction and consequent international trade may therefore seriously interfere with the conservation of mires. Those mire types and associated natural values are especially at risk that are limited to, or concentrated in, areas of existing and future interest for peat extraction. International mire conservation policy therefore has to pay attention to changing patterns of peatland exploitation in order to undertake adequate and timely action in case of threat to mire conservation values of international importance.

This paper surveys recent changes and future developments in the international peat trade.

2 METHODS

The data are largely derived from official statistics (Eurostat Luxembourg, Centraal Bureau voor de Statistiek Heerlen) and from published sources. Data for 1993 are mostly excluded, because definite figures are not available yet. Furthermore, the abolition of customs procedures within the European Union per 1 January 1993 presents methodological problems when comparing data.

The best statistical series available are presented in tonnes. Peat density, however, is to a large extent determined by moisture content, which is primarily a function of the extraction method. Differences in density are not taken into account in official statistics.

Import figures presented are the official figures of the importing country, export figures those of the exporting country. For several reasons, minor deviations may occur for identical traffic movements, dependent on the import or export point of view. These deviations, however, do not affect the general trends.

All data are expressed in metric tonnes (weight), m^3 (volume) or ECU (monetary value). The following standard figures may be useful for comparison:

1 m^3 of milled peat with 50% moisture content weighs ca. 330 kg, and contains 165 kg of dry substance. The energy value is ca. 0.8 MWh/m^3, or 2.5 MWh/tonne (i.e. 5.0 MWh/tonne Dry Substance (DS)). 1 m^3 of sod peat with a moisture content of 35% weighs ca. 400 kg and contains 260 kg of dry substance. The energy value is ca. 1.3 Mwh/m^3, or 3.4 MWh/tonne (i.e. 5.2 MWh/tonne DS) (Svenska Torvproducentföreningen undated).

Values have been standardised using 1 m^3 = 0.3 tonnes.

3 CHARACTERISTICS OF INTERNATIONAL PEAT TRADE

3.1 INTRODUCTION

Although the international peat trade is largely confined to peat for horticulture, some involves other purposes. The active carbon industry in the Netherlands, for example, imports peat from neighbouring German extraction sites (Robertson 1994). Sanitary towels incorporating Canadian Sphagnum peat moss are presently being marketed in the United States (Keys 1992). A recent development is the international trade in peat products for treating waste water and gases by bio-infiltration, and for oil-spill absorption (Bradley 1993, Butler 1993, Gill 1993). Actual volumes in international traffic for this kind of use are unknown, but probably limited. They are expected to increase in the near future because this diversification "is less demanding of the resource, adds far greater value and helps meet many real needs in the market" (O'Connor 1992).

3.2 FUEL PEAT

Peat is an important source of energy in several countries. Fuel peat is primarily used for centralised production of hot water and electricity, and to a minor extent for private consumption (peat briquettes and some private fuel production). Milled peat is chiefly utilised in large-scale power production, sod peat is favoured by smaller plants (Asplund 1994).

The volume of fuel peat being extracted annually worldwide may currently exceed 30 million tonnes, more than half of this being used in the countries of the former Soviet Union (18 million tonnes?, cf. Robertson 1994). Russia extracted 7.6 million tonnes of fuel peat in 1992 (Savelyev 1994). Ireland (6 million), Finland (5.5 million) and Sweden (2 million) also consume considerable volumes of peat for energy purposes (Prud'homme 1991, Nutek 1992, Fernandez Ruiz 1994). In Sweden and Finland, more than 150 municipal and industrial energy plants use peat as their main fuel (Robertson 1994). In Ireland, peat represents around 10% of the primary energy production (Fernandez Ruiz 1994), and a new 123 MW power plant, requiring one million tonnes of peat each year, is being planned (Schier 1994). Briquetting factories are operating in Russia, Belarus, Estonia, the Ukraine and Sweden, their total output exceeding 6 million tonnes per year (Asplund 1994).

Because of the unfavourable ratio between volume and energy content, the demand for peat for energy production is almost exclusively met by inland extraction. In Sweden, imports may cover a small percentage of the total fuel peat consumption, depending on weather conditions during the short production season (Nutek 1992).

Although energy crises promoted considerable interest for fuel peat during the mid-1970's and early 1980's, economic factors and the availability of other energy sources have so far prevented peat from becoming an attractive energy product in other countries (cf. pilot studies and projects in Brazil, Burundi, Canada and the United States: Kalmari & Leino 1985, Mutanen 1989, Cantrell 1991, Keys 1992, cf. Cantrell 1992). The competitiveness of peat depends greatly on the price of other fossil fuels. However, peat extraction technology is developing rapidly. The real price for peat fuel in Finland has decreased by 30% since 1981, thus encouraging a rapid growth in the use of peat for energy there (Asplund 1994). Asplund (1994) expects this trend to increase in the future due to environmental benefits (relatively low emissions of sulphur and nitrogen oxides), benefits to local (rural!) economies (cf. Hood 1994a), and because a further 30% decrease in production costs will be possible in the next ten years. The fastest increase in peat use in the 1990s will probably take place in the Baltic States, especially Latvia, where indigenous resources are extremely valuable (Asplund 1994).

3.3 AGRICULTURAL PEAT

Agricultural use is the main purpose of peat mining in the world, the annual extraction possibly being as high as 150-200 million tonnes. A more exact and reliable estimate is impossible because the (former) Soviet Union is/was responsible for over 95% of this volume, large-scale agricultural production on collective and state farms using enormous quantities of peat (Prud'homme 1991, Nutek 1992, Robertson 1994). Since 1989, peat extraction volumes have been hit by political restructuring (Cantrell 1991). In 1992, Russia extracted 53.6 million tonnes of peat for non-fuel purposes, primarily for agriculture (Savelyev 1994). Savelyev estimates that within a few years the annual peat extraction in Russia will equal the annual peat accumulation there, and he foresees a continuing increase in the volume extracted.

Because of the voluminous character of peat, international trade is largely confined to refined peat qualities for demanding and specialised agricultural markets, especially horticulture.

In recent years, various developments have affected the quantities of extracted peat and the pathways of international trade. These (interrelated) developments include:

* developments in horticulture
* declining domestic peat resources in western Europe
* local effects of anti-peat campaigns
* growing volumes of peat alternatives
* increased promotion of peat consumption by the peat industry
* geopolitical changes leading to the emergence of new, independent states.

4 RECENT CHANGES IN HORTICULTURE

4.1 INTRODUCTION

Drastic changes in peat consumption have taken place in the past decennium as a result of growing agricultural interest in horticulture coupled with new horticultural production techniques and new legislation. Early in the 1980's, the agricultural use of peat was still primarily in soil improvement and hobby gardening. This has rapidly changed, professional horticulture now being the major consumer. Over 60% of the peat extracted annually in Germany is now used for professional horticulture, against 25% for hobby gardening and soil improvement and 15% for industrial purposes (cokes, active coal) (Belka 1994).

4.2 EXPANSION OF HORTICULTURE

Horticulture is a rapidly expanding branch of agriculture in the world, especially for the production of luxury food crops and ornamental plants in urbanised regions. As various agricultural specialities are faced with surpluses (in Europe: milk, wine, sugar, cereals, meat), a tendency exists to turn to horticulture (Avermaete 1992). In Germany, the annual economic growth in horticulture has been 4% since 1985, while agriculture declined by 1.2% annually in the same period (Rhein 1994).

Horticultural production in 1991 amounted to ECU 7 milliard (10^9) in the former Western Germany, ECU 12 milliard in Italy, ECU 6 milliard in Spain and ECU 5 milliard in the Netherlands (Rhein 1994). Italy and Spain are now in a transitional phase from extensive horticulture (olives and citrus fruits) to intensive horticulture for the European market.

Severe competition and consumer demands for high-quality products have brought rapid technological developments. As a result, horticulture has become extremely capital intensive, the production value in modern greenhouses amounting to ECU 100 $m^{-2}.y^{-1}$! (Rhein 1994).

Modern horticulture is based on growing media, the materials on which plants grow. The most important requirements in horticulture are the uniformity, consistency and predictability of the final product. Growing uniform, high-quality plants at very high productivity levels demands media with the best possible features. Small deviations from the optimum may cause considerable financial losses to greenhouse operation. Professional growers will therefore not necessarily buy the cheapest product, since quality is their primary concern.

4.3 PEAT IN HORTICULTURE

The value of peat in horticulture lies in a unique combination of properties which enable it to retain large amounts of water, entrap large volumes of air and hold large quantities of plant nutrients in a readily available form. Peat is almost free from pathogens, pests, seeds and other plant propagules, is stable under storage, clean to handle and readily available in large quantities at a reasonable price. Furthermore, it has the advantage of low pH and nutrient contents, which facilitate the formulation of growing media for a wide range of applications by adding nutrients and other materials. It is biodegradable, although its important structural characteristics are long lasting even under intensive use. All these features make peat the ideal basic constituent for growing media (U.K. Peat Producers Association 1992, Schmilewski 1994). A weakly decomposed peat consisting mainly of Sphagnum mosses, with a minimal content of shrub or other plant remains, is the preferred base for production of growing media. More strongly humified Sphagnum peat is needed for production of compressed peat pots and pellets.

As a result of these developments, over 5 million tonnes of peat (15 million m^3) are processed annually for horticultural purposes in Europe (Schmilewski 1994) and almost 2 million tonnes in North America (Cantrell 1991, Nutek 1992, Gill 1993, Rubec 1993). In the past decennium, an increasing use of peat has been observable in almost every country. Countries with major peat resources extracted increasing volumes of peat, both for domestic horticulture and for export to countries with small resources.

The most conspicuous growth in peat import volumes is displayed by the Netherlands, with an increase of over one million tonnes in the past ten years. The Netherlands has a total area of greenhouses close to 10,000 ha and they lead the world in horticultural technology (Schmilewski 1994). Most of this peat is imported from Germany (Fig. 5), which exports over 50% of its domestic peat to the Netherlands. However, imports from the former Soviet Union, especially Estonia, have been growing markedly in the past few years.

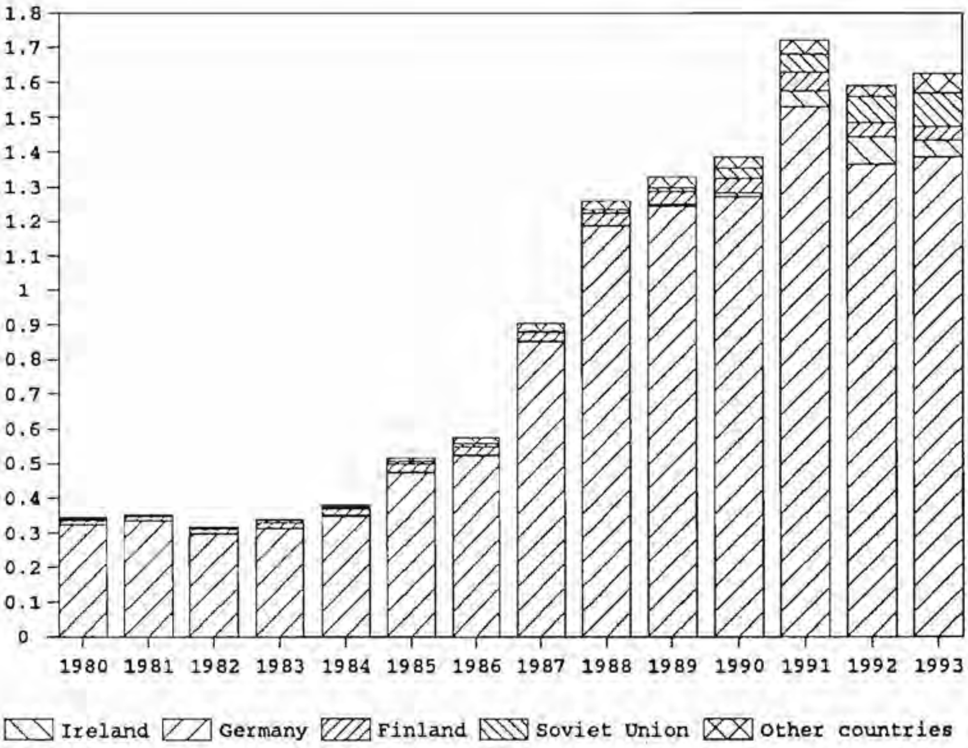

Fig. 5. Peat imports into the Netherlands (in 10^6 tonnes) (source: Eurostat Luxembourg, CBS Heerlen).

Canadian Sphagnum peat extraction has also been undergoing a steady growth over the past decade. The United States continues to represent 80 to 90% of the export market for peat extracted in Canada, while Japan consumes up to about 10% (Cantrell 1990, United States Department of the Interior 1991). Due to the high cost of shipping and competition from European peat, it is still not feasible for Canadian producers to export to Europe on a significant scale (Gill 1993).

Inland peat extraction in the United States is largely confined to reed-sedge or "Hypnum" peat. Although domestic Sphagnum peat extraction has increased in the last few years, it is still very small compared to imports from Canada. According to Gill (1993), it is unlikely that domestic production will ever constitute a significant threat to imports from Canada. United States horticultural peat applications are projected to grow at 3% per year during the 1990's, to over 1.7 million tonnes by the year 2000 (Cantrell 1992). The largest potential markets for professional-grade peat are the areas with the greatest concentration of greenhouses: the Atlantic seaboard (especially New York, New Jersey, Pennsylvania, North Carolina and Florida), the far west (California and, to a lesser extent, Oregon), the north central area (especially Michigan and Ohio), and Texas. The largest markets for consumer-grade peat are likely to be New England, the mid-Atlantic seaboard and east central states, because they have not only the greatest concentrations of population, but also the highest proportion of households purchasing soil amendments for their gardens (Gill 1993).

The main markets for peat in Asia, next to professional growers in Israel and Cyprus, are landscaping and agricultural land improvement in Saudi Arabia and adjacent oil states. The largest supplier to these countries is Germany. A study was undertaken recently into the feasibility of exporting peat from Canada to Saudi Arabia as a slurry in oil tankers. Since the tankers would otherwise be returning empty, transportation costs would be very low. The results of this study are not yet available (Gill 1993).

Japanese imports are also growing, from 10,000 tonnes in 1980 to 66,000 tonnes in 1992 (Thibault 1993). Most of this import derives from Canada, but the Canadian share has decreased from 94% in 1988 to 84% in 1991 (Gill 1993). Future market increases in Japan are expected to be in the range of 5% to 10% per year (Thibault 1993).

Small, but increasing, peat imports indicate that South Korea, Taiwan and other "emergent markets" could also emerge as significant markets for peat, once they reach income levels similar to those found in Japan today (Gill 1993).

Transportation costs represent a high proportion of the delivery price in eastern Asia, because of the long distances involved and the multi-modal nature of the movement. Transportation is estimated to represent in excess of 60% of the landed value of peat in Japan (Thibault 1993). In China, a joint Chinese-American company is producing horticultural peat for the Far Eastern markets (Lappalainen & Sopo 1994).

On the African continent, Morocco (cf. Spain) is the major consumer of peat, most of it being imported from Germany. Growing consumption is foreseen in South Africa, possibly based on peat imported from New Zealand (Gill 1993).

New Zealand, next to Germany, also provides Australia with some Sphagnum peat. Australia itself extracts a small amount of Sphagnum moss peat for domestic consumption. Imports from New Zealand may grow (Gill 1993).

4.5 ENVIRONMENTAL LEGISLATION

Growth of peat consumption in horticulture is not only resulting from expanding output and increasing quality demands, but also from environmental legislation. For logistic purposes, horticulture takes place in concentrated areas. Consequently, these areas are often subject to considerable environmental pollution from nutrients and pesticides.

In the Netherlands, new legislation will require that in the year 2000 all horticultural crops must be container grown in order to reduce the effects of effluents on soils, surface- and groundwater quality. Dutch growers have estimated that this will double their requirements for peat-based growing media by the end of the decade (U.K. Peat Producers Association 1992, Van Schie 1992). Other countries may in future be expected to follow the example of this trendsetter in horticulture.

5 DECLINING DOMESTIC PEAT RESOURCES

Western and central Europe has been a major peat consuming area for several centuries. As a consequence, hardly any virgin mires are left in countries like the Netherlands and Germany, where domestic peat resources used to be abundant. In the Netherlands, formerly a major net exporting nation, peat extraction came to an end in 1992 (Joosten 1994) and all peat now has to be imported (Van Schie 1992).

The situation in Germany is similar. Because of diminished resources and the demands of nature conservation, peat extraction increasingly has to concentrate on peat deposits formerly in agricultural use ("Deutsche Hochmoorkultur") and yielding lower peat qualities. Especially the slightly humified Sphagnum peat is becoming rare. Although peat is still a major German export product (Fig. 6), high-quality peats have to be imported in increasing quantities (Belka 1994) (Fig. 7).

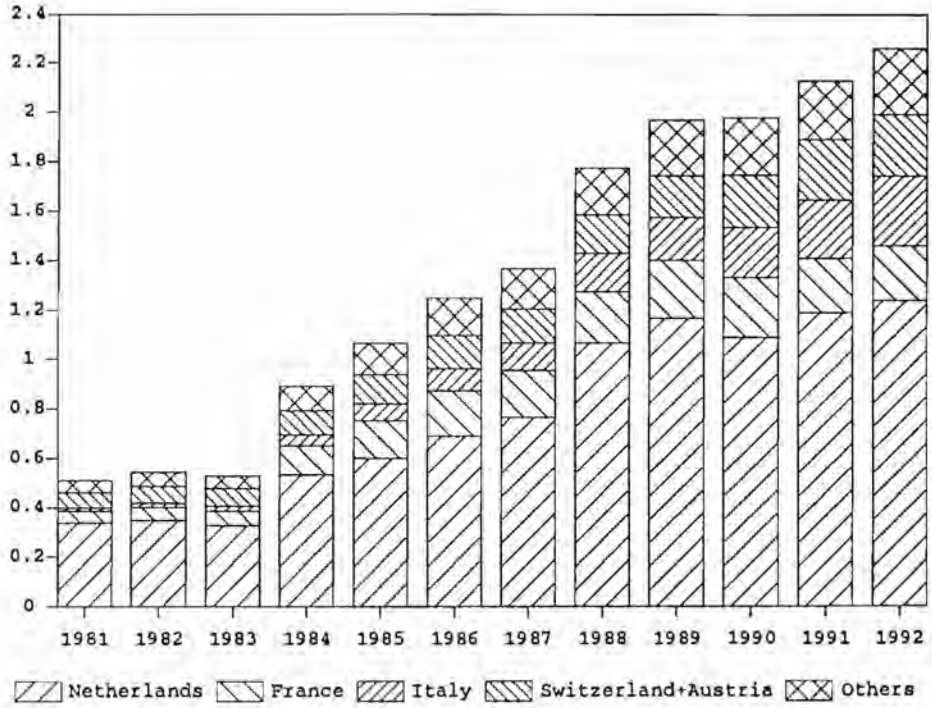

Fig. 6. Peat exports from Germany (in 10^6 tonnes) (source: Eurostat Luxembourg).

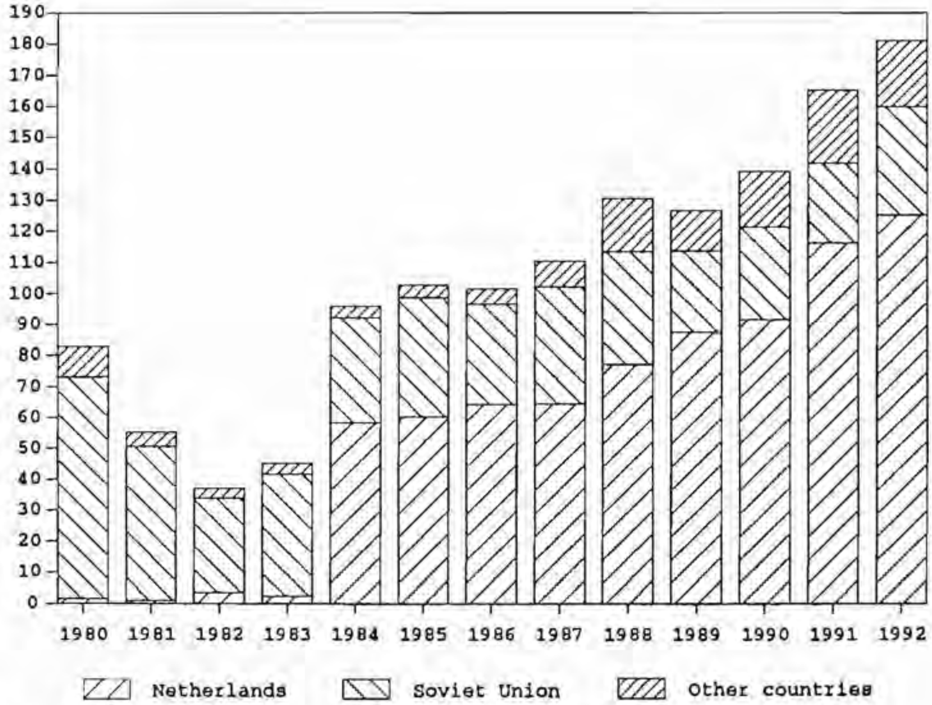

Fig. 7. Peat imports into Germany (in 10^3 tonnes) (source: Eurostat Luxembourg).

The Netherlands has recently developed into the prime redistributor of peat in the world, because of its historical roots in peat commerce and its export of horticultural expertise. Special seaport terminals have been built to provide cheap peat transport facilities. Figure 5 shows the increasing import figures, but Dutch exports have also been growing rapidly (Fig. 8); after Germany and Canada, the Netherlands is now the main peat exporter in the world, volumes being almost twice as high as exports from Ireland! In 1993, the Netherlands imported 1,625,284 tonnes of peat from 19 different countries, including Germany (1,386,549 tonnes), Estonia (62,738 tonnes), Ireland (47,768 tonnes), Finland (41,476 tonnes) and Lithuania (27,149 tonnes). In the same year, 717,966 tonnes of peat were exported from the Netherlands to 53 countries all over the world. Exports were primarily focused on Belgium and Luxembourg (275,762 tonnes), France (167,249 tonnes), Germany (142,955 tonnes), Italy (54,701 tonnes) and Spain (31,999 tonnes). Germany forms both a major peat exporting and importing country for the Netherlands, an indication of different peat qualities moving across national boundaries.

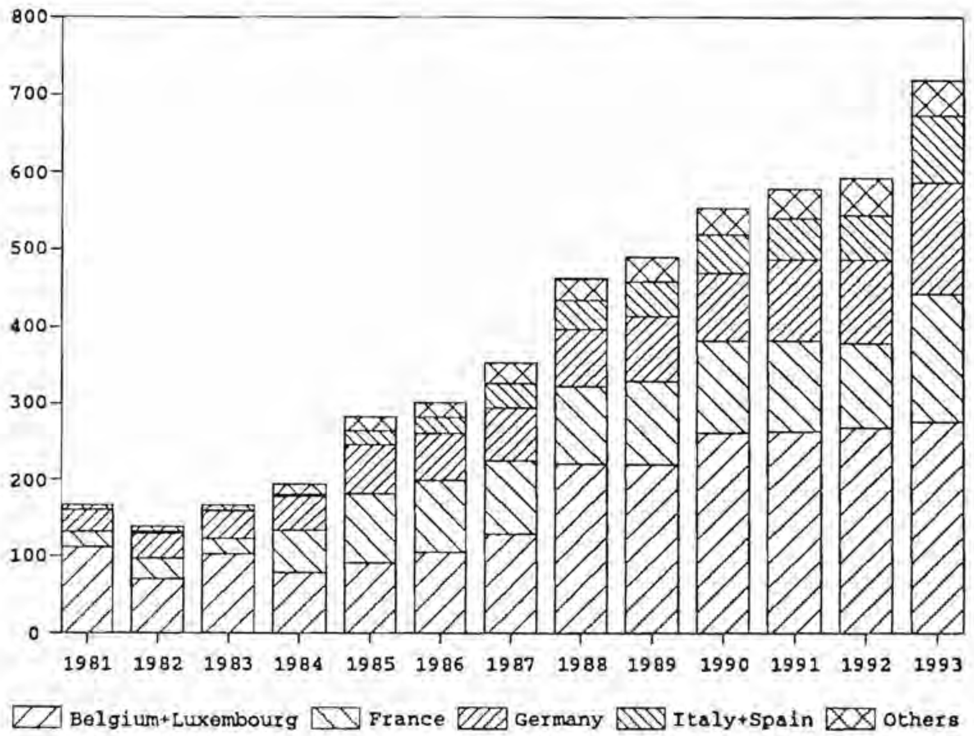

Fig. 8. Peat exports from the Netherlands (in 10^3 tonnes) (source: Eurostat Luxembourg, CBS Heerlen).

6 LOCAL EFFECTS OF ANTI-PEAT CAMPAIGNS

The end of the 1980's witnessed a growth in anti-peat campaigns in Europe, primarily in the United Kingdom. In March 1990, British and Irish environmental and conservation groups joined forces in the Peatland Campaign. This campaign was aimed at persuading members of the general public, and users in the horticultural trade, to discontinue their use of Sphagnum peat, thereby reducing the threat to and pressure on particularly the raised bogs of Britain. The campaign was supported by many prominent persons, including gardening celebrities and the Prince of Wales (Peatland Campaign Newsletter 1991, IPCC Peatland News 17, spring 1994). Figure 9 illustrates some changes on the British peat market. Imports reached their maximum in 1988, followed by a marked reduction during 1989-1991. Since the United Kingdom is the major export market for Ireland, total Irish exports dropped simultaneously. In 1992, peat imports into the UK started to rise again, while Ireland succeeded in turning back the downward export trend already in 1991 by covering new markets outside the UK. In the meantime, British exports were influenced to a lesser degree (Fig. 10), illustrating that the "Peatland Campaign" primarily affected domestic peat use inside the UK.

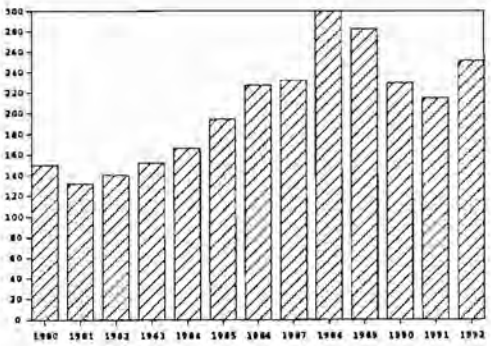

Fig. 9. Peat imports into the United Kingdom (in 10^3 tonnes) (source: Eurostat Luxembourg).

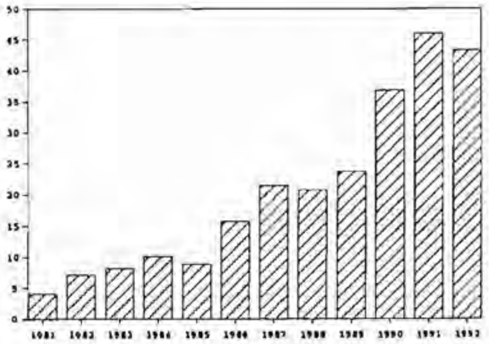

Fig. 10. Peat exports from the United Kingdom (in 10^3 tonnes) (source: Eurostat Luxembourg).

7 ALTERNATIVES TO PEAT

One way in which the British Peatland Campaign reduced the demand for peat was to promote substitutes. These products, based on bark, spent mushroom compost, straw, vegetable remains, wood products and a range of more novel materials, can provide an alternative to peat, particularly for less demanding purposes such as soil improvement, mulching, tree or shrub planting and hydroponics systems. As a result, the peat extraction industry has increased the production and marketing of these alternatives (Knight 1991).

Since most alternatives are more expensive and some raise new environmental concerns, peat remains the most important basic constituent for growing media for high-value crops and for the propagation of vegetable plants. It is expected to take considerable time before safe, reliable, readily available and cost-effective alternatives are produced in sufficient quantities to match the current demand for peat-based products (UK Peat Producers Association 1992).

An often mentioned alternative to peat is compost. In the relation between peat and composts, two opposite developments are observable. In Canada, home gardeners are pressed by the peat industry to change from composts to the better peat material (Gill 1993). In Germany, the peat industry, being actively involved in composting organic waste, stimulates the use of compost by home gardeners to save the better peat for professional horticulture. European countries increasingly prescribe the composting of organic waste (especially household refuse), leading to growing volumes of compost. Germany expects to produce 5-6 million m^3 of compost in 2000, against 1 million m^3 in 1993 (Perschl 1993). This compost interferes with peat-marketing policies in various ways. Compost increases the pressure on the less exacting markets, such as hobby gardening and soil improvement. Its price is completely artificial as processing of household refuse is paid for by the citizens. Furthermore, since compost production takes place locally, transport costs are low in comparison to peat. As a result, peat is being ousted from the market to some degree.

Volumes, however, are expected to increase to such an extent that a consuming market is foreseen for only part of the compost in the European Union (Belka 1994). To overcome this stagnant situation, the peat industry proposes to improve the properties of compost by blending it with peat. This was a major argument in the discussion about establishing an ecolabel for peat (Schmilewski 1994). The European Union member states, however, agreed in 1994 that soil improvers containing peat will not be eligible for the European ecolabel.

8 PROMOTION OF PEAT CONSUMPTION

8.1 ORGANISATIONAL RENEWAL OF THE PEAT INDUSTRY

One effect of anti-peat campaigns was an organisational renewal of the peat industry, on both national and international levels.

The Canadian Sphagnum Peat Moss Association (CPSMA), founded in November 1988, initiated discussions with Canadian government and public environmental groups to create policies under which the peat industry can conduct business while safeguarding wetlands for future generations. This resulted in the CSPMA Preservation and Reclamation Policy (January 1991), urging CSPMA members to "Reduce the impact of their operations on the environment and strive for maximum land restoration to the continuing benefit of the community" (Lynch-Stewart et al. 1993). Consequently, the Canadian peat industry started to support and fund research into techniques for restoring bogs and peatlands (Hood 1994b, Rochefort 1994). Simultaneously, the CSPMA began a solid publicity programme to promote sales of Sphagnum peat (Canadian Sphagnum Peat Moss Newsletter 4/1, spring 1994).

Canada is not representative for most countries since it has enormous tracts of mire and very few mires are used for peat extraction. Extraction is estimated to be 1-2% of the annual peat accumulation (Keys 1992), suggesting a sustainable yield and resulting in an absence of major environmental conflicts.

The Canadian example of coupling peat extraction more aggressively with environmental questions is being followed by various other countries. In Germany, extraction is promoted with the slogan "Torfabbau lässt Moore leben" ("Peat extraction revives mires", Zentrale Informationsstelle Torf und Umwelt/ZIT, Wachenheim). Members of the UK Peat Producers Association commissioned research on restoration of cut-over peatlands, e.g. Fisons with the University of Sheffield (Knight 1991).

Following the example of the CSPMA, the International Peat Producers Association (IPPA) was founded in Uppsala in June 1992. This is a co-operative group of peat extractors that carries out its operations within the framework of Commission II (Industry) of the International Peat Society (IPS). It funds the IPS substantially; in 1993, some 40% of the total IPS income was derived from the IPPA. The IPPA recognises conservational and environmental problems as major constraints for the expansion of peat extraction and consumption in the world. It has therefore initiated an IPS project to make an up-to-date inventory of the peat and peatland resources in the world (Lappalainen 1994).

The most important global environmental issue is the (im-)balance between peat accumulation and extraction, and the associated question of sustainability. The outcome of this discussion may have severe economic implications regarding ecolabelling and carbon dioxide taxes on fossil fuels. To deal with these aspects, the IPPA formed working groups on Eco-labelling, Global Warming, and Strategic Planning (IPS Bulletin 24, 1993). Another working group organised the International Peat Conference (Brussels, March 1994) to inform European Union officials (IPS Newsletter 2, April 1994).

8.2 SUSTAINABILITY AND RENEWABILITY

The IPS and IPPA are increasingly arguing that "peat is a sustainable and renewable natural resource and it should be classified as a bio-fuel" (Petterson 1994b, IPS sircular February 1994). The sustainability is motivated by pointing to the carbon accumulation capacity of remaining mires, counteracting carbon emissions from ongoing peat extraction. From a carbon balance point of view, the statement is supported by poor data (cf. Peat Producers Association 1993) and questionable reasoning (cf. O'Connor 1994, Robertson 1994). An illustrative example of the latter is given by Robertson (1994): "current annual capture of carbon by peatlands within the (European) Union is 1.1 million tonnes as against 2.8 million tonnes released by the peat industry. Future expansion of the Union, through the accession of Finland, Sweden, Norway and Austria, will greatly increase the peatland area and reduce the proportion utilised for peat production from 3% at present to less than 1%, *resulting in a more favourable balance between carbon capture and emission*" (my italics).

Claiming carbon accumulation in virgin mires exclusively for the counterbalance of carbon emissions by peat extraction is unjustifiable in view of emissions from other types of peatland use and other carbon dioxide sources in society. Mires should be considered and treated as global commons in the carbon household of the world.

Recent inventories indicate that annual global carbon emission from extracted peat is of the same order of magnitude as carbon accumulation in the remaining peat-accumulating mires. Immirzi & Maltby (1992) estimated a global accumulation rate in mires of approximately 100 million tonnes of carbon per year. Peat is extracted at a rate of approximately 200 million tonnes per year (see above). Assuming a (conservative) moisture content of 50% and a carbon percentage of 55% of the organic matter, it may be calculated that 55 million tonnes of carbon are being released (or made releasable) from the extracted peat annually. Carbon emissions from continuing peat oxidation in cut-over, but insufficiently rewetted peatlands, and agricultural and forestry activities on peatlands may amount to a further 100-200 million tonnes of carbon emitted annually (Immirzi & Maltby 1992), indicating that global peatland use is a major source of carbon in the world (cf. Armentano & Menges 1986).

The "renewability" of peat must also be seriously questioned (Schmilewski 1990), as the peat industry itself does: "Taking into account the relative insignificance of annual increment of peat layer, especially in northern regions, and also the fact, that peat accumulation process stops on drained deposits, it should be stressed that the reproduction ability of peat reserves has significance predominantly from the geological point of view rather than from the nearest industrial perspective." (Savelyev 1994).

Restoration experiments on large, cut-over bogs have so far not produced satisfactory results (Joosten 1995). Moreover, although some studies suggest that horticultural peat might be "grown" on a commercial scale (Joosten 1995), sustainable peat "production" has not yet been studied, let alone practised (cf. Elling & Knighton 1984). Peat extraction in the world is therefore not "harvesting" a sustainable yield, but increasingly destroying living mires. Because of the ongoing destruction of these natural peat producing "factories", and their insufficient rewetting and unsuccessful restoration, the global peatland carbon balance is shifting more and more towards increasing net emissions.

9 RECENT GEOPOLITICAL CHANGES

Because of rapidly declining domestic peat resources, the peat industry in western and central Europe has been eagerly looking for new sources. These have been provided by the recent political changes in eastern Europe. Since 1991, exports of horticultural peat from the newly independent states of the former Soviet Union to western, central and southern Europe have increased rapidly, not least from the Baltic States (Fig. 11). Peat has become a more important element in their economy, and horticultural peat is now a major export product (Veski 1993). The significance of fuel peat in national energy policies has increased and will increase further in lessening the dependence on imported fuels. The European Bank for Reconstruction and Development and the World Bank are presently funding boiler conversion projects in Estonia to change from oil-fired to peat-fired plants (Tammemägi 1993).

10 FUTURE DEVELOPMENTS IN INTERNATIONAL PEAT TRADE

In the near future, a rapid increase may be expected in the extraction and use of horticultural peat, resulting from higher demands and higher prosperity. Extraction will focus on countries where high-quality peat is easily available, including Canada, the Baltic States and possibly southeast Asia for Far Eastern markets.

Preparation of horticultural substrates may either occur near the peat deposits or near the consumers (Netherlands, France, Italy, Spain, the USA, Japan). The latter will be more probable because it will enable rapid production of many different and specialised substrates to demand (Belka 1994).

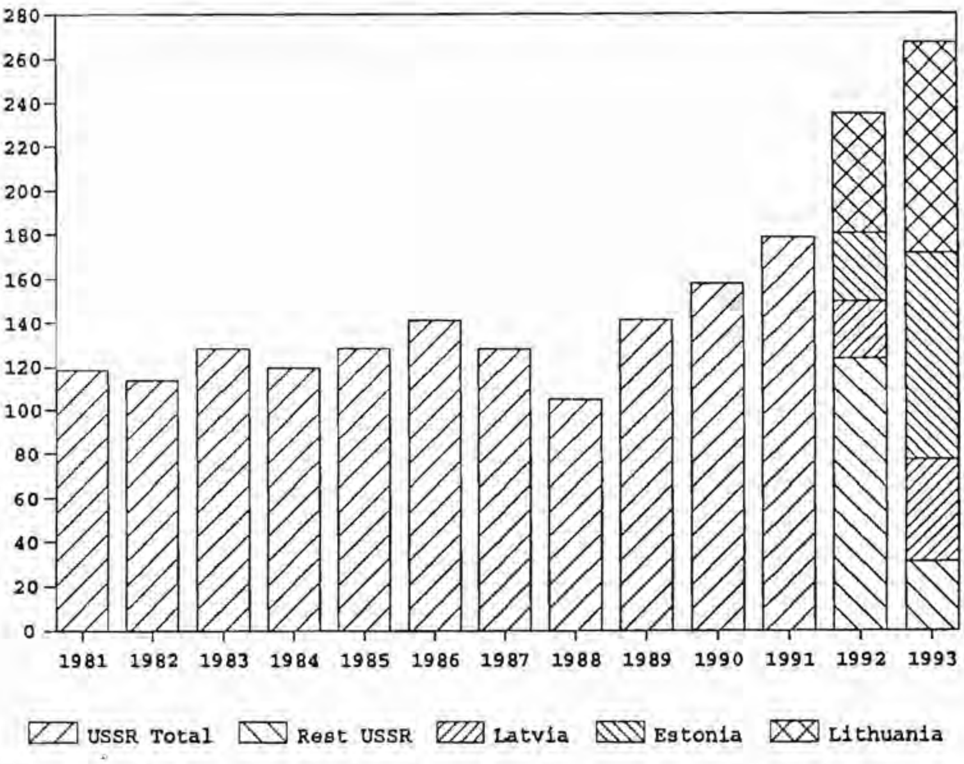

Fig. 11. Export from (former) Soviet States to the European Union (in 10^3 tonnes) (source: Eurostat Luxembourg).

In the longer term, decreasing resources may result in slightly humified peat being partially replaced by strongly humified peat and (renewable) alternatives like bark, wood fibres, cocos (coir), rice chaff, etc. This will mean poorer quality growing media, leading to a further differentiation of substrates according to the requirements of the various consumers.

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The 1992 International Mire Conservation Group symposium in Switzerland: a review of the issues and the formal resolutions

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ABSTRACT

Grünig, A. 1995. The 1992 International Mire Conservation Group symposium in Switzerland: a review of the issues and the formal resolutions. *Gunneria 70*: 293-302.

In 1992, the 5th IMCG field excursion and symposium took place in Switzerland. The meeting was the largest so far and was attended by 40 mire conservationists from 18 countries, including representatives from Canada, Estonia, Germany (former GDR), Japan, Poland, Russia and the USA. The event was a two-week study tour of bogs, fens and mire landscapes in almost every region of the country.

1 AIM OF THE EXCURSION

The aim of the excursion was to introduce the principal Swiss peatland types. The delegates were immediately struck by both the diversity and the beauty of the mires. It became evident that this country has a particularly important part to play in conserving some of Europe's outstanding high-altitude mire habitats. IMCG members had an opportunity to see the basic problems involved in the conservation of mire habitats in a small, mountainous, yet densely populated country which has already lost up to 90% of its natural peatland heritage. The participants learned of the difficulties of implementing the Rothenthurm amendment to the Swiss Constitution. The problems of conserving mire habitats and mire landscapes were discussed. The group also tried to understand how land-use conflicts had been resolved by negotiation and agreement, and how positive mire habitat management stipulated by agreements can promote rehabilitation of damaged peatlands.

2 POLITICAL DEBATE ON THE PROTECTION OF MIRES IN SWITZERLAND

By coincidence, the political debate on the protection of mire habitats and mire landscapes reached its climax at the time of the symposium. Throughout the country, press coverage of the issue reached as many as 300 to 400 newspaper articles per month. IMCG members regretted that the most common objections to the proposed mire conservation law and decree were that the sites were too large and that the law was too restrictive in its interpretation of the constitutional amendment. The lesson to be learned was: mire conservation will always remain difficult, even when there are specific laws and decrees which are among the most advanced in the world.

3 INTERNATIONAL OUTLOOK

At evening lectures and presentations, IMCG members had the opportunity to report on conservation issues in their own countries; specific problems were discussed and resolutions formulated. In the middle of the excursion the traditional IMCG symposium conference was held in Berne, keynote lectures being delivered on mire conservation, peatland monitoring, and the effect of climate change on peatland development. Comparisons were also made between the situation in Switzerland and other densely populated countries, such as Austria, the Netherlands and Britain. The details of the excursion, additional information about Switzerland, the proceedings of the symposium and parts of the evening lectures were published together with the 1992 IMCG resolutions in Grünig (1994).

4 FORMAL RESOLUTIONS

During the excursion, the IMCG prepared formal resolutions which were sent to the central governments of 13 countries and to 58 local governments and non-governmental organisations. Finland, France, Japan, Poland and Russia did not reply; the remaining 8 countries expressed positive attitudes towards the concept of mire conservation. The resolutions and replies regarding these 8 countries are briefly examined here; the situation in Poland is also dealt with. Further information, including the full text of resolutions and replies, is given elsewhere (Grünig 1994: 351-366; IMCG 1993).

4.1 AUSTRIA

Taking into account the federal organisation of nature conservation in Austria, the IMCG issued two resolutions on specific mire conservation problems in two federal states (= Bundesländer).

One of these called on the government of Styria to prevent planned extraction of peat for balneological use from the Schrenkenbichl mire. This site is of great value and forms an integral part of the Überling mire. The 1990 IMCG resolution for Austria requested that part of this area, the Bundesland Salzburg, be declared a World Heritage Site (cf. Foss 1991).

The reply from Dr Hannes Zebinger, on behalf of Mr Franz Hasiba, the proxy of the Styrian Landeshauptmann Dr Josef Krainer, stated that the Styrian Nature Conservation Act of 1976 lacks powers to prevent peat extraction from the Schrenkenbichl mire. However, the nature conservation authority, aware of the value of the site, has opened negotiations with the potential exploiters of the peat. The outcome of these discussions was still not clear in December 1992. Dr Zebinger, furthermore, reported that a new nature conservation bill was being prepared, which provides universal protection for mire sites in Styria.

4.2 ESTONIA

In the resolution for Estonia, the IMCG acknowledged the excellent achievements of the last two decades in relation to mire conservation with some 70% of Estonian mires still being in a virgin state and about 13% being formally protected in 1992. However, the IMCG felt that there was still an urgent need for further action to ensure that examples of the full range of mires in Estonia are represented in the conservation programme. Concern was expressed that sites which are already protected may not retain this status after the current privatisation programme has been completed. Bearing in mind the western European experience of the peat industry, the IMCG also suggested the establishment of a long-term mire conservation strategy, in which "conservation" means "wise and sustainable use" as well as "protection and rehabilitation".

Mr Andres Tarand, the Estonian Minister for the Environment, stated that 69 mires had been protected by November 1992. These sites covered an area of 156,500 ha, corresponding to 14.9% of the total mire area (which is about 1,050,000 ha), or 3% of the country. The Group was also pleased that the state authority, in full concurrence with the suggestions of the IMCG resolution, has appointed a working group of officials and scientists to establish a national mire conservation programme. Important issues should include fens which have rare plants, mires which guarantee protection of water resources, peatlands with unique peat layers and a plan to inform and educate people about mire conservation issues. The IMCG will watch these developments with interest.

4.3 GERMANY

The German resolution was sent to both the national government of the Federal Republic of Germany (FRG) and the regional governments of the 16 states (Bundesländer). It urged each State Authority to compile a catalogue of mire sites, provide additional legislation for the establishment of mire landscape reserves and develop a rehabilitation programme for all disturbed mire sites which retain conservation value. For the vast lowlands of eastern Germany (the New Countries), which have been drained for intensive agriculture, the IMCG urged national and regional governments to intervene to stabilise the groundwater regime, and thus avoid further loss of organic matter into the atmosphere as carbon dioxide.

In his reply, Dr Dieterich, on behalf of the Bundesminister für Umwelt, Naturschutz und Reaktorsicherheit, Professor Töpfer, welcomed the activities of the IMCG, which were considered to be congruent with similar efforts of the Federal Republic of Germany. According to the Federal Act on Nature Conservation, mires are universally protected; any operations infringing protection aims are prohibited. However, the reply emphasised that the individual states are responsible for implementing mire conservation. The reply also stated that the Telma project recognised 14 mire sites of international importance within the borders of the FRG. Each of these had been declared a nature reserve, at least partially.

Of the 16 regional governments, only the authorities of Berlin, Rheinland-Pfalz, Sachsen-Anhalt and Schleswig-Holstein replied. However, all the replies were in favour of better and sustainable mire conservation.

4.4 GREAT BRITAIN

The IMCG, recognising that Britain is one of the most important countries in Europe for Atlantic raised bogs, which have suffered extensive losses, requested the authorities to:

- urgently implement measures which will stop all commercial peat extraction from protected sites
- ensure that legal protection is given to all raised bogs which retain primary surfaces, or have the potential for rehabilitation to ombrotrophic conditions
- provide sufficient resources, both staff and material, for the necessary positive conservation management to be carried out on all these sites
- provide sufficient resources for the National Peatland Resource Inventory to enter the next phase of its programme, which will supply the British government with a continuing programme of environmental audit which then can be used to monitor the success, or otherwise, of these conservation measures.

The IMCG hoped to learn at its 6th Symposium in Norway in 1994 that Britain had made real progress on these important questions.

Miss A E Ward of the Department of the Environment, who was asked to reply by the Secretary of State for the Environment and on behalf of the Prime Minister, indicated that the British government is aware of the importance of protecting raised bog habitats. It also recognises the obligations which it has for implementing the EC Habitats Directive [92/43/EEC], in which active raised bogs are listed as a priority habitat. Miss Ward also pointed out that the Department and its statutory nature conservation advisors are taking steps in recognition of these obligations. The peat extraction industry is also co-operating. It is expected that by the time of the IMCG's next symposium in Norway considerable progress will have been made on the matters set out in the "Resolution for Great Britain".

In the Welsh reply, Mrs G Duncliffe, on behalf of the Secretary of State for Wales, wrote that the importance for nature conservation of raised bogs in Wales has long been recognised. Several outstanding sites are protected and managed as National Nature Reserves. With one notable exception, the Fenns and Whixhall Site of Special Scientific Interest (SSSI), Welsh raised bogs have not been subjected to recent large-scale peat removal. The Government's statutory nature conservation advisors purchased, for a substantial sum, the leasehold on 263 ha of that site from a commercial peat extractor.

No specific reply was received from the Scottish Secretary of State. Bearing in mind the valuable concentrations of high-quality peatlands, both raised bog and blanket bog, which occur there and which were seen by IMCG members in 1986, the group would welcome a statement from the Scottish perspective.

4.5 IRELAND

The IMCG has noted that the Irish government's Conservation Commitment to conserve 10,000 ha of raised bog and 40,000 ha of blanket bog predicted for 1997 has only been met in part, with 22% of raised bog and 40% of blanket bog targets actually conserved by 1992. The IMCG resolution therefore urged the Irish government to make specific financial efforts to attain the target before the extinction of the remaining bog habitats, particularly at a time when the EC has made a commitment to increased funding through the Life Regulations of the Habitats Directive. The IMCG estimated that a realistic government budget of IR£ 850,000 needs to be assigned annually if peatland conservation targets are to be achieved.

The IMCG was pleased to learn from the Irish reply, that the Taoiseach appreciated the contribution of groups such as the Irish Peatland Conservation Council and the International Mire Conservation Group, but indicated that financial considerations influenced the rate at which sites could be conserved. The IMCG is hopeful that the Irish government will continue the 1993 scale of peatland purchase of 2000 ha acquired for conservation, until the national peatland conservation target is achieved.

4.6 POLAND

The IMCG has learnt that no comprehensive mire inventory is available for Poland, although more than 45,000 individual mire sites have been catalogued. In the resolution for Poland, considering the fact that within Europe the Polish mires represent a considerable natural resource with important implications for wildlife and landscape conservation, the IMCG recommended that the Polish government develop a plan to protect the remaining examples of Poland's natural mire systems. The IMCG placed particular emphasis on the proposed Biebrza National Park in northeastern Poland.

The Polish government did not reply to the 1992 IMCG resolution. However, the IMCG is pleased to learn from journals that the Polish authorities have designated the southern and central basins of the Biebrza valley for conservation. The protected area of the new Biebrzanski National Park comprises around 60,000 ha and this is the largest of Poland's national parks. The site is not only famous for its rich bird life, but is also the finest and most extensive contiguous wetland area in central-eastern Europe.

4.7 SWEDEN

The Swedish resolution was sent to both the Swedish Prime Minister (= Statsminister) and all 24 County Boards (= Länsstyrelsen). The IMCG urged the authorities:

- to complete the Swedish Wetland Inventory (VMI) by adding the county of Norrbotten
- to ensure that sufficient financial and personnel resources were made available to:
  protect all mires listed in the Swedish Mire Protection Plan within 10 years
  carry out essential conservation work - for example, mowing or grazing
  rehabilitate protected areas where they have been damaged - for example, blocking ditches to restore the hydrology of a drained site
- to recognise the need for proper buffer zones around mire sites
- to increase applied scientific research
- to establish a comprehensive monitoring programme for mire sites

- to recognise that the Komosse and Blaikfjället mire sites are of international standing and fully merit national park status.

Mr Olof Johansson, head of the Department for Nature Resources and Sites, who was asked to reply by the Swedish Prime Minister, said he had taken note of the resolution. He also noted that the representatives of the Swedish National Environmental Protection Agency did not sign the resolution, although they participated at the meeting.

Of the 24 county boards, only those of Älvsborgs län, Dalarna and Västmanlands län replied. However, the IMCG was pleased to learn from the county board for Älvsborg that the mire complex of Komosse has been protected as a nature reserve. All three replies from the county boards were in favour of better and sustainable mire conservation. They commented that in the decade to come a major task for the county boards will be the protection of the sites listed in the Swedish national mire conservation plan.

4.8 SWITZERLAND

In the resolution for Switzerland, the IMCG urged the Swiss Federal Council, the cantonal governments, and the federal and cantonal parliaments to ensure:

1. that they will permit no major changes to the proposed decree concerning the conservation of the nationally important fenland sites and permit no fundamental alterations to the proposed decree concerning the protection of mire landscapes
2. that national standard guidelines be established to ensure that the various mire protection programmes are implemented consistently and effectively
3. that co-operation between the whole range of federal ministries and offices will be encouraged in relation to the mire protection programmes; in particular, where the Confederation is the landowner of a nationally important mire, the IMCG urges that it should protect and manage these sites in an exemplary way
4. that the budgets of the cantons and the Confederation be adjusted to provide sufficient funds to meet all the costs relating to management incurred by owners or users of the protected mire systems
5. that monitoring of both mire habitats and mire landscapes is recognised as an essential element in the implementation of mire protection programmes to provide the necessary evidence of success or failure of each of these programmes on individual sites; adequate resources should be provided for this work

6. that research be urgently promoted to investigate the ecological requirements of natural and disturbed mire biotopes and suitable management methods for them, because there are still significant gaps in scientific knowledge about mire ecology.

In his reply, Dr Philippe Roch, Director of the Federal Office of Environment, Forests and Landscape, was delighted at the interest of the IMCG concerning mire conservation in Switzerland. The IMCG is pleased to learn from Dr Roch that mire conservation in Switzerland is largely uncontested and that some progress has been made. This is the result of both the popular initiative "Protection of Mires - the Rothenthurm Initiative" and efforts by the Office of Environment, Forests and Landscape. However, further major efforts are needed to reach the target set by the Federal Constitution. It had been planned to implement the decree on the inventory of fenlands of national importance in 1993. In contrast to the mire habitats, the protection of which is not questioned in principle, the situation of the mire landscapes is quite different. As mire landscapes are usually substantially larger than the mire habitats within them, land-use conflicts become more important. In the case of mire landscapes, Switzerland is taking a decisive step towards a more comprehensive conservation of the countryside. A revision of the Federal Act on Wildlife, Countryside and National Heritage Protection is therefore needed, and this is currently being discussed in parliament. The same is true for the allocation of financial resources. The completion of the inventory of mire landscapes will take time. To gain wide acceptance for it, the Federal Office wants to proceed cautiously. It also approves of the idea of promoting monitoring and scientific research to measure the success of all the protection efforts made, but considers that the resources for this task are limited.

4.9 UNITED STATES OF AMERICA

In the resolution for the United States of America, the IMCG expressed its concern that 1) the new definition of wetlands, proposed in 1991 by the US government, is excessively restrictive, apparently excluding a number of wetland types that obviously have wetland functions, and 2) "mitigation banking" would lead to a net loss of wetland functions as it would permit the replacement of a given wetland by an entirely different kind of wetland.

In his reply, Mr David G. Davis, Deputy Director, Office of Wetlands, Oceans and Watersheds of the United States Environmental Protection Agency, appreciates the interest and concern expressed by the IMCG in the protection of the valuable wetland resources of the USA. Mr Davis shares the concerns of the IMCG about the potential effects of the proposed revisions to the Federal Manual for Identifying and Delineating Jurisdictional Wetland of August 14, 1991. Field testing has demonstrated that the proposal could cause a significant reduction in the geographical scope of the wetlands protection programme. Therefore, in 1992, his office was working with other Federal agencies to produce a more workable, scientifically defensible wetlands delineation manual. Mr Davis also expressed his concern about the potential misuse of mitigation banks. Although he was optimistic about their use, Mr Davis assured the IMCG that the Office would be proceeding cautiously in exploring the utility of mitigation banks as a means of providing compensation in situations where the degradation or destruction of wetlands is unavoidable.

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European mires, distribution, threats and conservation - an IMCG project

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ABSTRACT

Löfroth, M. 1995. European mires; distribution, threats and conservation - an IMCG project. *Gunneria 70*: 303-306.

In recent decades, vast tracts of mire landscapes have vanished throughout Europe; for instance, all natural mires have been lost in the Netherlands. In other European countries, such as Russia, Norway and Sweden, large areas of mire are still intact. This paper describes a project started in 1990 and planned to end in 1996 to produce an expert report on the distribution, exploitation, management and conservation of mires in Europe.

1 INTRODUCTION

Most of the mires in Europe have been used by man. Peat extraction has destroyed many mires and is still a threat in countries like Ireland, the United Kingdom, Estonia, Finland, Belarus and Russia. Millions of hectares of mire ecosystems have vanished through agricultural activities such as drainage, fertilising and grazing. Also the peat itself, the natural substrate of a mire, disappears by oxidation when these measures are carried out. Countries with great losses of this kind are, for example, Poland, Belarus, the Czech Republic, Slovakia and Germany. Afforestation, usually combined with drainage, causes extinction of the mire systems in many countries, for example Ireland, the United Kingdom, Norway, Sweden and Finland. Other threats to the mires of Europe include aerial deposition of nutrients, abandonment of mowing or grazing and development of infrastructure. In the Netherlands, more than 95% of the original mire area of 1.5 million ha has disappeared through one cause or another, and not a single natural mire remains.

Although mires still exist in nearly every European country, most of them are affected by the activities mentioned above. Their natural vegetation has therefore changed or is changing due to slow drying-out, eutrophication and, in some formerly rich fens, acid precipitation.

For the first time, the IMCG is able to produce a detailed report about European mires based on the first-hand knowledge of its members throughout Europe. The last attempt to do this was when Goodwillie (1980) produced a report for the Council of Europe. This, however, covered only western Europe and was a desk study which recent data have shown was inaccurate with regard to, for example, the distribution of certain mire types.

The recent political changes in eastern Europe have meant that mire experts are able, and are allowed, to exchange information and experience on mires throughout Europe. This has not been possible for 40 years. This situation has presented us with a good opportunity to produce a report for the whole of Europe, thus extending the scope of Roger Goodwillie's report.

After that report was published, mire and wetland inventories have been carried out in several European countries, including Britain, Ireland and Sweden. Detailed mapping of mires and, in particular, research on mire ecology has also taken place in other countries, for example Austria and Germany. These are further good reasons for updating the original report.

2 AIMS OF THE REPORT

1. An overview of the distribution of the different mire types will hopefully help us to achieve a better understanding of the mechanism of mire genesis, including climate, soils, precipitation, degree of oceanic influence, etc.
2. To date, European countries have produced their information about mires in many languages, making it difficult to present it to a wider public. Furthermore, many different terminologies have been used to describe mires. Different parameters have also been used, for example hydrology, morphology, water chemistry, genesis and structures. A general description of the mires and their status, using a common language and defined sets of terminology, will allow us to select mires for conservation on a sound scientific basis and make the whole European picture more understandable to a wider audience.
3. Many publications from different countries are written in a complex scientific language, thus making it difficult to explain to a member of the general public or a politician why it is important to protect mires and understand these habitats. Our report intends to provide an easily understandable, comprehensive, summary of the status of European mires.
4. When mires are being chosen for conservation, they should be selectable on the basis of their regional distribution rather than just in relation to their occurrence within national borders. However, in many regions all reasonably intact mire sites have to be accepted for conservation.

5. The information we are collecting on the original distribution, decline and threats to the different European mire types will allow the IMCG to formulate strategies to ensure that the most representative mires of conservation value are protected, and that the scale and pattern of threats is clearly understood.

3 THE PROJECT

The project started in 1990 in Dublin, Ireland. The aim was that European members of the IMCG (at that time representing 10 western European countries) should describe the status of mires in their own country. This information would be the subject of an IMCG report. After a time, in connection with the changed political situation in eastern Europe, interest grew to include the whole of Europe. I began contacting some of these countries, for example Estonia, Russia, Latvia and Poland, as well as western countries that are still not represented in the IMCG, such as Iceland, Denmark, Italy and Spain. The IMCG meeting in Switzerland opened up possibilities for contacts and it became possible to include additional countries, such as Portugal, Belarus and Czechoslovakia.

Texts from the following countries were included in the draft report prepared for the IMCG conference in Norway (Löfroth & Moen 1994): Austria, Belarus, Belgium, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Iceland, Ireland, Italy, Latvia, the Netherlands, Norway, Poland, Portugal, Russia, Spain, Sweden, Switzerland and the United Kingdom. I hope to receive texts from Lithuania, the Ukraine, Hungary, Slovakia and Slovenia before the book is printed. Since it must be printed soon, otherwise its topicality will be lost, time is too short to try to contact experts from southeastern Europe, countries like Albania, Bulgaria, Greece, Romania, Turkey and parts of the former Yugoslavia. However, mires are rather rare in this region.

The report will be published in 1996.

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Concluding comments on the 6th IMCG conference

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1 INTRODUCTION

This conference has a single unifying thread, a theme which runs through all the presentations binding them together into a composite picture. The theme - regional variation displayed by mire systems and the significance of this variation for conservation - is particularly appropriate for an IMCG conference. This is because one of the primary objectives of the IMCG network is to provide a particularly good opportunity for each one of us to see beyond the narrow confines of our own region or specialist area, thus enabling us to understand the broader context within which we are all working.

Ivanov (1981) observed that: "Mires are a zonal phenomenon. As biogenic formations on the surface of mineral strata, they are affected by local differences in natural conditions, among which climate and relief play a leading part." Classic publications such as Ruuhijärvi (1960) and Wetlands of Canada (National Wetlands Working Group 1980) have demonstrated the major zonal differences which can be observed within their respective countries, while Sjörs (1948) examined, amongst other things, the smaller-scale zonal variation which can be found within a single site. The recent history of blanket mire conservation in Britain is a typical example of the benefits which come from a wider perspective than that provided by these classic works, a perspective which goes beyond national boundaries into the realm of the IMCG network.

With more than 1,400,000 ha of blanket mire in Britain, and more than two-thirds of this in Scotland, the perception for generations, particularly in Scotland, has been that there was little remarkable about these vast treeless landscapes of peaty soils which dominate so much of upland Britain. A similar attitude prevailed within the conservation community until the early 1980s, when Gore (1983) revealed that a peat landscape of that particular type was remarkably restricted on a global scale. The IMCG network visited Scotland in 1986 to provide its collective opinion about the rarity or otherwise of the Scottish blanket mires. As a result, and following two reports (Stroud et al. 1987, Lindsay et al. 1988) which summarised the importance ornithologically, botanically and internationally of one of the largest expanses of blanket bog in Scotland, major conservation attention has been focused on the habitat since then, and very large areas have been protected. Such a shift in perception could never have been achieved without the wider international perspective provided by the IMCG network, supported by publications such as Gore (1983).

Regional variation is not, however, restricted to differences in the ecological characteristics of mires from different regions. What is clear from the papers presented at this conference is that differences exist in relation to the reasons and pattern of land-use change, mechanisms adopted to protect mires, and the degrees of success achieved by these various conservation measures. Indeed six distinct stages can be identified in most conservation programmes, and examples from each stage have been presented during the course of the conference. These stages can be posed in terms of six questions.

2 WHAT DO WE HAVE?

Before we can decide what is valuable and merits conservation action, it is essential to establish the full range of natural and anthropogenic diversity displayed by the habitat and its associated species. This is because conservation is based on the concept of "value". Only if something is perceived to have value of some sort will action be taken by someone or some authority to protect it, and such value is most commonly associated with concepts such as "rarity", "fragility", or "typicalness" (Ratcliffe 1977). By and large these are concepts derived from the context of the habitat or species within the landscape as a whole (be it the local, regional or global landscape) and thus it is important to be able to demonstrate that what is proposed for conservation is the rarest or most fragile example because of widespread habitat loss, or else the most typical. Very rarely in official conservation activities will "intrinsic appeal" (Ratcliffe 1977) feature as a reason for protection, because this is generally regarded by government officials and ministers as wholly subjective and thus highly suspect. In practice, intrinsic appeal is often what mobilises widespread public concern over an issue, but usually the case for some other more "objective" value will nevertheless be required to form an integral part of any successful conservation action on which governments will act.

Good inventory information for the resource is thus of prime importance. All subsequent conservation actions and decisions will flow from this foundation of knowledge. However, certain key requirements for inventory must be met if the accumulating knowledge-base is to be of maximum possible value or, more importantly, not to descend into irreconcilable anarchy.

A harmonised system of classification is critical. Just as taxonomists prior to Linnaeus found that their task was impossible as long as a multitude of differing systems of description proliferated, so increasingly it is becoming clear that those responsible for biotope conservation often encounter significant difficulties when attempting to compare the results of their own inventory work with that of others from different regions or different countries.

Phytosociology has become firmly established as the favoured tool for describing the vegetation of central Europe, but in much of the rest of the world a whole series of regional or national systems are used. Thus, one system currently favoured in Britain is the National Vegetation Classification (Rodwell 1991), although even this, despite its intended purpose as the standard descriptive system, is far from universally applied. However, vegetation forms only one part of a peatland system the hydromorphology, range of surface features, type of peat, and a great many other factors, continue to be used to classify peatlands.

It is thus difficult, for example, to determine from published literature what the distribution of "surviving raised bog" habitat is in Europe despite the fact that "raised bog" is one of the oldest and most widely recognised concepts in peatland ecology. This problem arises because across Europe different interpretations exist for the original definition of raised bog, and concepts of what constitutes "surviving" vary widely (i.e. wholly natural, or still present in some form, or that which is protected?).

Without a harmonised classification system for peatlands, how is it ever going to be possible to describe and measure biodiversity consistently between sites, regions and countries? The need for such a harmonised system has been recognised by IMCG members, and it is one of the primary objectives of this conference and field symposium that significant progress will be made in moving towards agreement on many terms and concepts.

Inventory programmes should recognise that important information exists in all parts of the biotope. Much of the discussion above focused on aspects such as vegetation or broad hydromorphological descriptors for peatland systems, and these certainly tend to form the basis of much inventory work. This is partly because such factors are relatively simple to describe and map and are not season- or weather-dependent to the same degree that many other possible inventory topics tend to be. Nevertheless, simplicity of inventory technique is not necessarily an effective way of selecting those features which are going to be of most value in measuring conservation value, nor of evaluating conservation success. Invertebrate populations, for example, may prove far more sensitive than vegetation to past management activities and thus may give a deeper insight into the current dynamics of the ecosystem. It is thus important to recognise that the relatively easy option for inventory may not be the best or most appropriate for long-term conservation success.

It is clear that the majority of countries and regions represented at this conference are committed to various degrees of inventory. Some can provide detailed descriptions of virtually every site and are now putting into place long-term monitoring programmes (e.g. Switzerland), whereas other countries are just beginning, or are seeking funding to begin, their conservation inventory programmes (e.g. Latvia).

Nevertheless, there is obviously still a great need for continued effort to be devoted to inventory because the majority of national programmes are still at the stage of preliminary cataloguing rather than being capable of providing comprehensive descriptions of biodiversity for the peatland habitat. Furthermore, it seems likely that significant gaps exist in the global picture of inventory. To what extent, for example, are tropical and southern hemisphere peats catalogued? This is a particular area which IMCG should pursue between now and the next symposium in 1996.

3 WHAT HAS BEEN LOST?

Although much inventory work is concerned with what exists now, in the present, this tells only part of the story. For conservation purposes it is often important to know what also existed in the past - for example, how much more extensive was the habitat 30 years ago, or what was the species diversity of the site when it was in its original, natural state? This type of information, if it can be used, is extremely valuable in placing the resource, or aspects of the resource, into a historical context from which it is often possible to identify particular trends, or rates of change.

Such retrospective inventory, in some form or other, is often made possible by the existence of old records, or perhaps the presence of particular material in the peat archive. In Britain, the National Peatland Resource Inventory (NPRI) has been able to use geological drift maps to identify the original extent of peat throughout England, Scotland and Wales because peat deposits are marked on the drift maps simply as a superficial deposit, whether or not they still support peatland vegetation. Consequently, it has been possible to make some estimate of the degree to which the habitat has declined from its original extent.

Obviously some information set must be available which can be used to provide information about past conditions; without this, retrospective inventory is impossible. For certain areas of interest, however, the value of measuring particular parameters has only become apparent in recent years. Consequently, it is impossible in such cases to find data sets which go back in time much more than a few years. This reliance on the chance existence of past data sets emphasises the importance, now, of establishing baseline data sets which can then be used by future generations.

Comparisons between data sets will only be as good as the lowest common factors. The difference between a historical data set and one which is being collected today is that the modern inventory can be added to as required, while the historical data set is immutable. This emphasises the need to ensure that modern inventory programmes are established at least in part as baseline studies, and that the scope and quality of their recording is of a standard which is sufficiently high to meet the possible demands of retrospective analysis ten, twenty or more years hence.

4 HOW/WHY HAS THE RESOURCE BEEN LOST?

The reasons for mire habitat loss have not formed a major part of the discussions at this conference, but, despite this, some important common issues in relation to such losses have emerged.

A number of causes of land-use change on peatland ecosystems are, if not universal, then at least extremely widespread. Under such circumstances it is valuable to combine information across national boundaries in order to obtain a more comprehensive and clearer view of the threat. In doing so, and by sharing experiences, conservation bodies are more likely to present multinational developers with a degree of consistency and unity, thereby making it difficult for them to play off one conservation organisation, or national body, against another during negotiations or as part of a corporate strategy. International co-operation in terms of information exchange also raises the possibility of reacting to such development pressures through co-ordinated actions.

Some causes of habitat change arise from activities which are highly localised in their nature and call for specialised local knowledge. Where this is the case it is important that any supporting conservation actions should be guided by those closest to the issue, rather than attempting to introduce broad, very generalised conservation measures which might or might not apply in these particular cases.

When dealing with conservation issues it is all too easy to feel that one's own area of interest is under extreme pressure and being attacked from all sides. However, it can sometimes be a sobering experience to learn what colleagues in other territories or countries are experiencing. By taking this broader viewpoint it is easier to highlight those areas or regions where urgent action is genuinely needed. Unless this is done, there is a real danger that time and resources will be spent on issues of relatively minor significance instead of being focused on those areas where the need is greatest. The problems of Ukraine and Belarus, as we have heard, are very serious and merit significant international support for their respective peatland conservation programmes, whereas until now they have received scant support from the peatland world at large.

The causes of loss are well-documented for many countries, largely as a result of recent inventory programmes. However, whereas the International Peat Society provides a formal and useful forum for the peat industry to synthesise information of value to the industry, no such mechanism exists at present to co-ordinate the results of the various ecological and impact reviews into a holistic view of land-use impacts on peatlands. This is an area where the IMCG could make a particularly valuable contribution, and has indeed made a start with the European Peatlands Review presented in draft form at this conference (Löfroth & Moen 1994).

5 WHY CONSERVE MIRES?

More so than many other habitats, mires have long been regarded as wastelands or hazardous places within the landscape and thus a cultural imperative to "develop" or eradicate mire landscapes has existed for more than a thousand years. As a result it is now necessary to use particularly convincing arguments, more so than is usually necessary for habitats or species having evident "intrinsic appeal", in order to persuade local people, government officials or politicians of the need to protect and conserve mire systems.

From the number of references to functional benefits made by contributors to this conference it is evident that the importance of such aspects to conservation is widely recognised. Sadly, but perhaps inevitably given the complexity of many of the ecological and hydrological processes involved, research into the benefits which society obtains from mire systems has lagged significantly behind more descriptive ecological work. However, long-term conservation and wise use of mires will certainly come to depend increasingly on the evidence of the function that mire systems play within the landscape; countering individual threats and new initiatives from peat developers and land-users will be an endless tactical battle. This is because new uses can always be dreamed up, whereas once there is general acceptance of the value that mires provide in their natural or wise-use state, a potential developer is first faced with having to construct a case for the greater benefits which will flow from the new proposal. At present, a developer merely has to observe that the proposed scheme is better than leaving the mire in its natural but economically useless state.

A number of publications have brought together what is known and understood about functional benefits and values (e.g. Greeson et al. 1979, Maltby 1986, Williams 1990), and work continues through various institutions, but a very great deal of research still needs to be carried out before a case for the functional benefits of a mire system can be defined to the same degree of detail as is currently expected when describing the physical or botanical nature of the mire.

An increasing number of international treaties and conventions, and examples of domestic legislation in various countries, are explicitly embracing the concepts of "sustainable use" or "wise use". While this is something to be welcomed, it raises the question of what exactly is meant by these concepts when applied to mire systems. Often the concept will be closely linked to that of functional benefits, but, as discussed above, this area of research is still in its infancy. This lack of any clear definition for "sustainability and wise use" in relation to mire systems needs to be addressed because the various treaties and elements of legislation require some clear actions in relation to such topics. It is important therefore that, imperfect though the definitions may be, encouragement should be given both for the development of working descriptions of "sustainability and wise use" by those involved with the conservation of mire systems, and for the subsequent adoption of these by the competent authorities.

There is a useful adjunct to this consistent appearance of "sustainability" in various forms of national and international legislation. Politicians, when faced with legal obligations, will increasingly be seeking answers to questions about sustainability and wise use. If ministers can be persuaded that this is an area where political and legal requirements are ahead of the available scientific research, it may prove possible to unlock funds for research into sustainability and functional values.

This is an area which has not played a major part in IMCG discussions in the past, but which will increasingly, one suspects, form a central theme of the organisation's activities. In the meantime, it is important that IMCG members work together as much as possible to ensure that the definition and adoption of concepts such as "sustainability" as they refer to mires are acceptable for conservation purposes.

6 HOW SHOULD MIRES BE CONSERVED?

A successful campaign to persuade local people, government officials and ministers to protect mire systems will ultimately be faced with the question of practical strategies for providing the required protection, and will either have to define these itself, or decide whether the proposed measures put forward by others are acceptable.

Arguably one of the failures of the otherwise successful campaign to protect the Flow Country of northern Scotland during the late 1980s was that a great deal of effort went into describing the importance of the area and the threat posed by afforestation, but very little thought was given to the question of what to do if the campaign was successful. By the time the conservation campaign had built up a large following, such a large degree of commercial interest had established itself in the area that simply halting all forestry was not going to be a practicable solution; a conservation strategy should have been drawn up to suggest a range of ways whereby the area could be protected while still supporting the local economy. As it was, the forestry incentives were removed overnight, causing much resentment, and the existing form of statutory protection for sites was offered by the government as the only way forward, thereby causing even more resentment in the local area because such legislation has traditionally been regarded as unduly restrictive by local people. Only now, nearly ten years on, is a scheme being introduced, partly through European Union funding and partly through the Scottish statutory conservation agency, which provides a more acceptable, positive face to the conservation programme in the eyes of the local people. It was a lesson painfully learned.

Legislation is generally seen as the primary means of conservation but, as described above, it may not always be the most appropriate solution. Equally, it may not be the effective option if the quality of the legislation is poor, or there is little political will to enforce it.

Several papers at this conference have described successful conservation actions where partnership and co-operation have played important roles. It is always more effective to have the other partner convinced in their own mind that conservation is a wise thing, rather than having it imposed by authority or force of argument. At the same time, it is important to recognise the difference between a successful partnership and an uneasy truce where the site, or resource, is in effect merely under a stay of execution rather than being genuinely protected.

It is important that conservation programmes, be they statutory or voluntary, are sufficiently well linked to the ever-changing scientific understanding about mire systems that they can be underpinned by this science-base but also retain sufficient flexibility to be modified when new insights and understanding are obtained from ongoing research. Conservation programmes should have clear objectives, but only through the application of scientific understanding will it be possible to have confidence that the approaches adopted will achieve these objectives.

A number of models for mire protection have been described during this conference, particularly for East European countries, and the majority of IMCG members are involved in their own domestic conservation programmes. However, although the International Peat Society (IPS) is actively exploring strategic approaches to mire development in a number of topic areas, there has been little discussion so far during IMCG's activities about more strategic approaches to mire conservation. This area deserves much more attention and must form a key part of any future IMCG activities.

7 HAVE WE SUCCEEDED?

"Success" in conservation terms is often equated with the successful protection of a site from a particular development threat. This may be a major step forward but it is usually only the first step of many, because, having saved the site from immediate destruction, it is usually necessary to decide what is needed for its long-term maintenance. This is particularly so in the European Union, where the concept of long-term protection of the biotic interest is written into EC legislation.

Such long-term commitment is inevitably (or usually) expensive, whether in terms of state funds, private donations, human resources or social consequences. There is thus generally considerable pressure to demonstrate that these programmes have succeeded and been worth the costs involved. In one form or another, such a commitment represents a monitoring programme. In its own way, monitoring can be as difficult and complex, and is certainly of a longer duration, than any campaign to protect the site in the first place, yet it is often given the least amount of thought and commitment. Various types of monitoring can be adopted:

- **Resource monitoring**
  This is concerned with evaluation of the continued distribution and health of part or all of a resource, perhaps across national boundaries. For this to provide useful composite information beyond the limits of any particular monitoring programme, it is essential that harmonised and consistent classification systems are employed.

- **Site monitoring**
  This focuses on events and features within particular sites, but if any comparisons are to be made between sites, again a consistent classification system must be involved.

- **Species monitoring**
  This is important where particular species are valued, but can also play an important part in both resource and site monitoring when individual species are used as biological indicators of success or failure.

- **Legislation**
  It is important to monitor the success or failure of legislation, because if the biotope continues to be lost despite statutory protection, or the legal system becomes overloaded with disputes, it suggests that there is something wrong with the law as it is drafted. No law is perfect, but some are less perfect than others and it is important to recognise and highlight these.

- **Progress**
  Long-term monitoring is an enormous issue which has the potential to swallow huge amounts of resources in the future. While harmonised classification systems are an important part of monitoring, they are only one part of a larger question, and it seems likely that IMCG will need to devote an entire working session at some time in the not too distant future to discuss the monitoring of mire systems.

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INTERNATIONAL MIRE CONSERVATION GROUP

Appendix 1. Formal resolutions of the International Mire Conservation Group

The Trondheim Declaration

An International Statement on the Global Conservation of Mires and Peatlands

Preamble

Mires and peatlands are among the world's most endangered ecosystems. These peat-forming environments are found throughout the world, occurring in subarctic and boreal regions of North America, northern Europe and Siberia, in the tropical rainforest regions of, for example, Costa Rica, Zaire and Indonesia, and dominating the lowlands of Tierra del Fuego on the southernmost edge of South America. In some nations, as much as 90% or more of these important areas have been destroyed or significantly degraded, resulting in a serious loss of the rich biodiversity and natural resources they provide. On a global scale, the World Conservation Union (IUCN) has recently estimated that 50% of these ecosystems have vanished from the face of the Earth. Destruction of mires and peatlands continues at an increasing and alarming rate in all regions.

Wetlands cover about 5% of the terrestrial and freshwater surfaces of the world. Of this wetland area, up to 60% is dominated by environments favouring peat-forming processes. Where these processes have not been completely destroyed, these ecosystems are commonly referred to as "mires", although they are also known by many other names around the world. Mires provide many of the critical functions of the world's wetland systems. These functions include provision of rich biodiversity and habitats; major contributions to the maintenance of water quantity and quality; ensuring provision of food, fibre and livelihood to peoples around the world who are dependent on natural resource-use; forming a major component in carbon cycling and long-term storage - perhaps even more important than the tropical rainforests in this respect; as well as providing an archive and record of cultural, climatic and environmental change.

However, to date, the activities of the World Community with regard to wetland conservation have been focused on non-peatland habitats with little direct attention given to mire systems. Global and national Mire Conservation Action Plans are urgently needed to promote conservation of mire ecosystems through nature protection, sustainable wise-use, and management practices.

The Ramsar Convention on Wetlands of International Importance is one of the international instruments available to promote mire conservation. Since 1971, over 80 nations have become Contracting Parties to this convention. The Wise Use Principles of the Convention call on its Contracting Parties to develop comprehensive wetland conservation policies and programmes for the full range of types and functions that wetlands provide. While few nations have nominated Ramsar sites exclusively because they are mires, many of the wetlands of international importance are in fact wholly, or in part, mire ecosystems. Hence, designation of mires as Ramsar sites is both consistent with, and should be considered a commitment of, the Contracting Parties to the Ramsar Convention.

In addition, a wide range of mire conservation opportunities have evolved through the implementation of other international conventions, treaties and regulations. The

Biodiversity Convention in particular is emerging as the most prominent tool for implementation of sustainable development and the conservation of regional diversity.

For the last decade, an international network of mire and wetland scientists has been evaluating the ecological values, characteristics and status of mires throughout the world. At the July 1994 Sixth International Conference on Mire Conservation held in Norway, the following declaration was developed for consideration by national governments and concerned organisations or agencies having an international focus. The participants in this Conference, drawn from 23 countries, are prominent representatives of national wetland, mire and/or nature management programmes, as well as universities and research institutions.

Declaration

The following declaration, hereafter to be referred to as "The Trondheim Declaration", was adopted by the parties to the Sixth International Conference on Mire Conservation hosted by the Norwegian Directorate for Nature Management, the University of Trondheim, and the International Mire Conservation Group (IMCG) at Trondheim, Norway, from July 4-15, 1994.

Representing the global mire-wetland conservation, science and habitat management community, the parties to this international conference:

RECOGNISING the serious degree of risk to global mire resources and their integrity;

AWARE OF the major commitments made by the world's nations (particularly Contracting Parties to the Ramsar Convention and the Biodiversity Convention) to creation and effective implementation of conservation policies and programmes for all ecosystems including mires;

AWARE OF the significant potential for mire conservation initiatives through programmes under the International Biodiversity Convention; the Ramsar Convention; the Global Convention on Climate Change; the Bonn Convention; the Berne Convention; the European Union's Birds Directive and Habitats and Species Directive; the IUCN Wetland Programme; the International Peat Society Commission on Land Use Planning and Environment; the wetland initiatives of the World Wide Fund for Nature; the Agreement on Conservation of Arctic Flora and Fauna; the UNESCO Biosphere Reserves Programme; and the joint actions of the International Waterfowl and Wetlands Research Bureau, Wetlands for the Americas, and Asian Wetland Bureau; and

CONCERNED FOR the future of wetland and mire programmes in the nations of Europe with economies in transition, in Tropical Regions, in Asia, in North America, and in the Southern Hemisphere; and

WELCOMING the leadership towards global conservation of biodiversity particularly in mire ecosystems as displayed by the Norwegian Directorate for Nature Management, the University of Trondheim, and the International Mire Conservation Group in supporting the Sixth International Conference on Mire Conservation;

RECOMMEND THAT:

- An international coordination office and function should be established to facilitate global mire conservation, to be housed with a major international wetland agency based in Europe. This should be funded and undertaken in co-operation with partner agencies and organisations and Contracting Parties to the Ramsar and Biodiversity conventions that have significant mire systems.
- A series of informative publications should be produced for international distribution on the status of inventory, protection, and management of mires throughout the world. Such regional reports might include: Europe, particularly for countries with economies in transition, as well as tropical regions, Asia, North America and the Southern Hemisphere.
- Partner agencies and organisations should proceed with development of global and national Mire Conservation Action Plans. A particular focus area should be European countries with economies in transition. Implementation of the components of these Action Plans should be funded by nations and economic sectors that have historically benefited from mire resource-use. The overall objectives of such Action Plans should include:
  - (i) promoting the conservation and sustainability of mire functions and values through the implementation of global biodiversity objectives; and
  - (ii) facilitating mire conservation commitments made by the nations of the world through their implementation of international and multilateral conventions, treaties and regulations.
- Ramsar Contracting Parties should ensure that international mire conservation is a focus issue for discussion at, and the resolutions prepared for, the 1996 Sixth Meeting of the Conference of the Parties to the Ramsar Convention as well as forthcoming meetings of the Contracting Parties to the Biodiversity Convention.
- Other international conventions, agreements and regulations be used effectively to support international mire conservation and management wherever opportunities arise.
- Further strengthening of effective international co-operation and information exchange between those involved in mire conservation and resource-use issues should be actively supported.
- A key aspect of the conservation of the biodiversity of the world's mires is proper and thorough understanding of their ecology. Universities and governments worldwide should establish centres of excellence and ensure significant expansion of training experience for development of future generations of experts in all aspects of mire ecology and science.
- The International Mire Conservation Group (IMCG) should be recognised as an appropriate expert group and international lead organisation for the provision of scientific and management advice on the world's mire ecosystems. The IMCG should, furthermore, work actively to promote and support international and national implementation of mire conservation programmes.

National resolutions

Resolution for Belarus

The International Mire Conservation Group (IMCG) is a worldwide organisation of mire (peatland) specialists who have a particular interest in the conservation of peatland habitats. The IMCG willingly places its advice and expertise at the disposal of any government seeking to establish or maintain mire conservation programmes.

The IMCG held its 6th Biennial Field Symposium in Norway in July 1994, looking at the particular issues of Norwegian mire conservation. During the symposium, considerable discussion and debate was devoted to the issues of mire conservation in other countries represented at the meeting. A number of resolutions were drawn up for the countries represented, as a means of indicating various ways in which each national government could make a positive contribution to the internationally important issue of mire protection.

The IMCG is aware of the work achieved during the last two decades in relation to the protection of mires in Belarus. The Group has also learned that over 60% of Belarussian mires are still in a virgin state, and about 16% are now protected. Other sites, currently under negotiation, comprise another 13%. Thus, it is expected that in Belarus about 29% of mires will be under legal protection and in their natural state.

Nevertheless, despite this excellent record, there is an urgent need for further action to ensure that examples of the full range of mires in Belarus are represented within the mire conservation programme.

The following resolutions have thus been endorsed by the members of the IMCG:

- It is vital that sites which are currently protected should retain their protected status after the privatisation programme in Belarus has been completed.

- Although the inventory of Belarus' peat resources is largely complete and comprehensive, there is an urgent need for an equivalent inventory of the ecological and hydrological condition of this resource.

- Mires and other wetlands possess significant biospherical properties, including atmosphere and soil groundwater purification from pollution, and biodiversity conservation. Consequently, reduced incentives for the destruction of mires and, in certain areas, greater incentives for the restoration of mire systems are required.

- Since, in several European countries, the natural peat resources have been completely destroyed, the peat industry is increasingly looking to the possibilities of expansion within countries that still possess significant peat resources, including Belarus. Bearing in mind the western European experience of the peat industry, the IMCG considers that Belarus urgently needs to establish a long-term conservation strategy for peatlands in which *conservation* means wise and sustainable use as well as protection and rehabilitation, thus ensuring a purposeful activity allowing mire resource utilisation that is compatible with its importance in the biosphere.

The IMCG will assist in any way it can to help develop such a strategy.

The IMCG hopes that the Government of Belarus will consider these observations to be helpful, and that it will be possible to report positive progress at the next Biennial IMCG Symposium.

Resolution for the Czech Republic

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The IMCG held its 6th Biennial Field Symposium in Norway in July 1994, looking at the particular problems of Norwegian mire (peatland) conservation. During the symposium, considerable discussion and debate was devoted to the issues of mire conservation in other countries represented at the meeting. A number of resolutions were drawn up for the countries represented as a means of indicating various ways in which each national government could make a positive contribution to the internationally important issue of mire protection.

The IMCG has learnt that mires form a small part of the Czech landscape. As such they have a high ecological and scientific value and, consequently, require a high degree of protection. The IMCG, therefore, strongly recommends that the responsible state authorities should undertake the following actions:

- that financial support be provided to compile an inventory of all remaining unprotected and intact or functioning mire ecosystems, with emphasis given to the highly endangered minerogenic fens, which are usually situated in intensive agricultural landscapes;

- that a National Mire Protection Programme be drawn up which establishes National Nature Reserves and/or Nature Reserves for mires and includes plans for their optimal management and sustainable use;

- that the necessary legislative framework be enacted to prevent uncontrolled drainage, reclamation and peat extraction on mires which are owned privately or by the state, municipalities, co-operatives and other institutions; and

- that support be given to all types of research institutions which conduct research concerning the ecology, functionality, management and possible restoration of mire ecosystems.

The IMCG hopes that the Government of the Czech Republic will consider these observations to be helpful, and that it will be possible to report positive progress at the next Biennial IMCG Symposium.

Resolution for Estonia

The International Mire Conservation Group (IMCG) is a worldwide organisation of peatland (mire) specialists who have a particular interest in the conservation of peatland habitats. The IMCG willingly places its advice and expertise at the disposal of any government seeking to establish or maintain mire conservation programmes.

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About 170,000 ha of mires, mostly raised bogs, are conserved in Estonia. Since 1992, when the IMCG Symposium was held in Switzerland, considerable progress has been made in Estonia in mire conservation. The Soomaa National Park, containing several mire conservation areas, was established. A recently signed protocol for the Alam-Pedja Nature Conservation Area has helped to protect additional mire sites.

We have learned that Estonia is adopting a new Energy Programme. One of the most important aims of the Programme is the re-introduction of district schemes for domestic heating which will be less dependent on imported oil, coal and natural gas. This will involve the use of local fuels such as peat and wood-chips.

The IMCG notes that some 70% of Estonian mires have been drained for agriculture, peat extraction and forest plantation. The most threatened mire biotopes are minerotrophic fens, of which only 10% are still intact.

Following the Rio Declaration, Ramsar Convention and EU Habitats Directive, the important role of mires in maintaining biodiversity, in stabilising global climate, in water purification and in other ecological functions has been recognised.

The IMCG therefore calls on the Estonian Government and the district governments to ensure:

- that virgin peatlands should not be exploited, since there are important peat resources on already heavily-drained peatlands and the demand for peatland reclamation for agriculture is in decline;

- that priority be given to conservation of minerotrophic mire sites;

- that ecological inventory of mire biotopes be undertaken to allow the scale of the resource to be evaluated and the range of biodiversity and habitat to be quantified;

- that urgent research should be promoted into the ecological and management requirements of mire biotopes, both in their natural and disturbed states, since significant gaps in scientific knowledge of these topics still exist: only by further research will it be possible to achieve the ultimate objective expressed by the Estonian people, namely, the survival of Estonian mires for further generations.

Resolution to the European Commission

The International Mire Conservation Group (IMCG) is a worldwide organisation of mire (peatland) specialists who have a particular interest in the conservation of mire habitats. The IMCG willingly places its advice and expertise at the disposal of any government seeking to establish or maintain mire conservation programmes. The IMCG held its 6th Biennial Field Symposium in Norway in July 1994, looking at the particular issues of Norwegian mire conservation. During the symposium, considerable discussion and debate was devoted to the issues of mire conservation in other countries represented at the meeting.

The 10 years of close collaboration between mire specialists within the IMCG has resulted in a better international understanding of mire types. Consequently, the IMCG devoted its 6th biannual conference (Trondheim, Norway July 1994) to "Classification of Mires".

IMCG recognises the importance that the European Union gives to conserving mires, as demonstrated in the Habitats and Species Directive, the Birds Directive, the LIFE-Regulation, and the role of the EEA-Biotope Centre. In view of the effective use of these Union instruments and the enlargement of the Union to include Austria, and potentially Norway, Sweden and Finland, the IMCG kindly asks you to take the following points into consideration:

- <u>Involvement of the IMCG to improve the existing CORINE classification</u>
  The IMCG has the expertise of networking between national experts already involved in the classification and mapping of mires in their respective countries. The CORINE classification gives a good overview of mire types in the 12 Member States of the Union, but will be found to have significant omissions as the Union is enlarged. Furthermore, the CORINE system is, in part, incoherent or confusing for mire classification in several aspects. Since the CORINE biotope classification is used as the basis for mapping of natural areas in Europe, both inside and outside the Union (e.g. the Baltic countries), the IMCG willingly offers its expertise for adapting the CORINE classification system for mires.

- <u>Attach greater importance to threatened mire types</u>
  Annex I of the Habitats Directive does not list "alkaline fens" as a priority habitat type. Nevertheless, these fens have become extremely rare due to their conversion into agricultural land and are still under intense threat. It is regrettable that alkaline fens are not given priority status as financial support through LIFE funding is not possible for the restoration and protection of these mires. Management or conservation actions are urgently required and are highly appropriate for this biotope type. IMCG, therefore, asks that priority status is extended to "alkaline fens" or that the "Calcareous mires with Carex davalliana or Caldium mariscus" category is widened to include other base-rich and nutrient-poor fens (i.e. alkaline fens).

- <u>Support mire conservation in European countries whose economies are in transition</u>:
  The IMCG is aware of the support given by the European Union to these states (PHARE, TACIS, etc.). The IMCG, therefore, asks the European Commission <u>to consult</u> these countries over the possibilities for using E.U. instruments for nature (and mire) research and conservation.

The IMCG hopes that the European Commission will consider these observations to be helpful, and that it will be possible to report positive progress at the next Biennial IMCG Symposium.

Resolution for Finland

The International Mire Conservation Group (IMCG) is a worldwide organisation of peatland (mire) specialists who have a particular interest in the conservation of peatland habitats. The IMCG willingly places its advice and expertise at the disposal of any government seeking to establish or maintain mire conservation programmes.

The IMCG held its 6th Biennial Field Symposium in Norway in July 1994, looking at the particular issue of Norwegian mire conservation. During the symposium, considerable discussion and debate was devoted to the issues of mire conservation in other countries represented at the symposium. A number of resolutions were drawn up for the countries represented as a means of indicating various ways in which each national government could make a positive contribution to the internationally important issue of mire protection.

Finland formerly possessed about 10 million ha of mires. Now, about 70% of these have been drained for forestry, taken into agricultural use or subjected to peat extraction. Of these destructive uses, forestry drainage covers about 6 million ha. A nationwide mire conservation programme, covering 600 mires totalling 500,000 ha, was ratified by the Finnish government in 1981. About 400,000 ha of this area has so far been protected by law. In addition, about 200,000 ha of mires are included in Finnish national parks and other reserves. A supplementary mire conservation programme, covering 500 mires with a total area of 120,000 ha, has been prepared but is not yet ratified.

<u>Nonetheless, mire conservation still faces a number of problems in Finland</u>

Drainage of virgin mires is continuing to some extent, and a large-scale programme of additional ditching on drained sites, supported by the state, also continues. Since 1993, control of drainage in private territory has been considerably weakened. The Finnish Forest and Park Service still ditches mires in state-owned territory. Also, approximately 50,000 ha of the mires belonging to the nationwide mire conservation programme have been drained since 1981. The acquisition of privately-owned mires by the state, for nature conservation purposes, has been slow because insufficient financial resources have been devoted to the task. In Finland there is no single person in the environmental administration, at any level, whose main responsibility is mire conservation. All the individuals currently involved can devote only a small part of their time to mire conservation.

<u>It is thus necessary to:</u>

- protect the mires included in conservation programmes without delay
- forbid the drainage of the remaining virgin mires
- put the additional drainage of drained mires under evaluation and licence
- start a major restoration programme for drained mires

If Finland is to obtain sufficient information about the present condition of Finnish mires for conservation purposes, it will be necessary to start an immediate nationwide inventory of the distribution of mire complexes and site types, thereby obtaining information about their present condition and current conservation status. It is also necessary to employ sufficient personnel who are able to promote mire conservation and mire research.

The IMCG hopes that the Finnish Government will consider these observations to be helpful, and that it will be possible to report positive progress at the next Biennial IMCG Symposium.

Resolution for Germany

The International Mire Conservation Group (IMCG) is a worldwide organisation of mire (peatland) specialists who have a particular interest in the conservation of peatland habitats. The IMCG willingly places its advice and expertise at the disposal of any government seeking to establish or maintain mire conservation programmes.

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RECOGNISING the 1992 IMCG resolutions to the federal states of Germany we note that all the issues raised in 1992 still represent continuing, urgent problems.

AWARE OF the importance of the maintenance of functions and values of mire ecosystems, including their importance for global biodiversity, the IMCG asks the Federal Government to note the following observations and propositions, and stimulate their implementation within the Federal States.

- The IMCG considers it important that the effects of drainage should be reversed in agriculturally abandoned fens in order to stop further degradation and loss of peatland soils through oxidation and wastage.

- The IMCG emphasises that deep fen-peat areas (deeper than 2 metres) are unsustainable for agricultural and silvicultural plant production because the drained peat has a number of adverse physical properties. The most effective form of sustainable land-use for these areas would thus instead be to re-establish them as living mire systems.

- The IMCG would like to bring to the attention of the Federal Government that the protection of wetlands under the Ramsar Convention has, to date, been for the protection of waterfowl. As a result, the conservation value of mire systems has thus tended to be overlooked, despite the fact that they harbour significant plant and animal biodiversity and provide vital environmental functions as sinks for carbon and nutrients in the landscape. We therefore propose that the tasks of the institution in the Federal Republic that is responsible for the implementation of the Ramsar Convention should be enlarged, firstly to establish an inventory of mires, which are of conservation importance, in Germany, and secondly to develop a national mire conservation programme in co-operation with the Governments of the Federal States.

- Furthermore we would urge the Federal Government of Germany, as signatory to the Ramsar Convention, to promote the international conservation of mire ecosystems as a priority.

The IMCG hopes that the Federal Government will consider these observations to be helpful, and that it will be possible to report positive progress at the next Biennial IMCG Symposium.

Resolution for Hungary
The International Mire Conservation Group (IMCG) is a worldwide organisation of mire (peatland) specialists who have a particular interest in the conservation of mire habitats. The IMCG willingly places its advice and expertise at the disposal of any government seeking to establish or maintain mire conservation programmes.

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The IMCG has learnt that, over the last 200 years, all of the large mires of Hungary (over 100 km^2) have been drained. Mires that remain are rather small and predominantly composed of rich and intermediate fens as well as a small number of transitional and raised bogs. These mires are highly endangered because of earlier riverregulation and canalisation schemes, as well as by the dry climatic period experienced during the last 20 years. The IMCG therefore strongly recommends the relevant authorities to undertake the following actions:

- that a national mire inventory (which includes appropriate buffer zone definition) is compiled to allow for the construction of an effective mire conservation plan;

- that, during the ongoing land privatisation process, nationally important mire systems are conserved as state-owned areas under nature conservation management.

The IMCG hopes that the Hungarian Government will consider these observations to be helpful, and that it will be possible to report positive progress at the next Biennial IMCG Symposium.

Resolution for Ireland: Raised Bog Conservation
The International Mire Conservation Group (IMCG) is a worldwide organisation of peatland (mire) specialists who have a particular interest in the conservation of peatland habitats. The IMCG willingly places its advice and expertise at the disposal of any government seeking to establish or maintain mire conservation programmes.

The IMCG held its 6th Biennial Field Symposium in Norway in July 1994, looking at the particular problems of Norwegian mire (peatland) conservation. During the symposium, considerable discussion and debate was devoted to the issues of mire conservation in other countries represented at the meeting. A number of resolutions were drawn up for the countries represented as a means of indicating various ways in which each national government could make a positive contribution to the internationally important issue of mire protection.

As a result the IMCG seeks clarification of the following issues:

- IMCG has learned of the advances made by the Office of Public Works (OPW) in the conservation of blanket bogs in Ireland, where 2000 ha were conserved in the last year. IMCG is, however, concerned with the slow rate at which raised bog sites have been protected over that time.

- IMCG is concerned that the re-assessment of the status of Irish raised bogs as part of the National Heritage Area survey conducted by the OPW may result in the deletion from the conservation list of raised bog sites which IMCG considers of conservation importance. IMCG requests that a list of those raised bog sites now considered worthy of conservation by OPW be made available at the earliest opportunity.

- IMCG understands that within the last two years, 23 raised bogs listed by the IPCC as of European Conservation Importance (total area of 5080 ha) have been damaged by turf extraction. IMCG wishes to learn of the Irish Government's intentions of controlling this form of development by implementing the EU Environmental Impact Assessment Directive.

- IMCG requests information on the progress of hydrological research at Clara and Raheenmore bogs in Co. Offaly. IMCG is concerned that actions based on preliminary research may adversely affect the conservation and management of the 10,000 ha of raised bog that OPW intends to conserve.

- IMCG notes that since their visit to All Saints Bog, Co. Offaly in 1990, extraction of moss peat by Erin Peat has continued at this site. Considering that All Saints is a declared nature reserve, is of international importance, and that the EU has made a significant financial investment towards purchase of the site, IMCG requests that moss peat extraction be halted without further delay.

- IMCG recognises the raised bog conservation agreement made between the OPW, Bord na Mona and the Irish Peatland Conservation Council. IMCG enquires into the status of the internationally important Knockacolla Bog, Co. Laois, which appears to be intact and remains in the ownership of Bord na Mona. IMCG calls for the immediate conservation of this important site.

- IMCG is alarmed by the proposal by Bord na Mona to build a new peat-fired power station in the Irish Midlands and seeks assurance that no peat from Natural Heritage Areas will be used to fuel the station.

The IMCG hopes that the Irish Government will consider these observations to be helpful, and that it will be possible to report positive progress at the next Biennial IMCG Symposium.

Resolution for Japan

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The IMCG notes that the Japanese archipelago is located towards the southern distribution limit of the boreal peatland zone in the northern hemisphere, yet work by the Hokkaido National Agricultural Experimental Station has revealed that Hokkaido Island formerly supported rather more than 200,000 ha of peatland. Of this, the IMCG understands that only some 76,000 ha remains as peatland habitat today due to land-use change resulting from agricultural and urban development. Losses in the other Japanese islands are not so well documented because such changes took place in much earlier times and now all trace of mire habitat is lost.

The IMCG welcomes the fact that the Japanese Environmental Agency of the Prime Minister's Office (EA) has carried out two surveys through Japan which have contributed significantly to the understanding of the present distribution and status of mire systems in Japan. The first of these, a vegetation survey, has provided a certain amount of useful base-line information, but the IMCG is particularly keen to see the results of the national wetland survey, which looks at all wetlands greater than 1 ha in extent, which the IMCG understands will be published in 1995. It is recognised that even with this survey, the national catalogue of mire systems will be incomplete because such a large proportion of Japan is wooded and mountainous, and IMCG members are well aware of the problems involved in mapping mire systems in such difficult terrain.

The IMCG is pleased to learn that a number of well-known and important mire systems are already protected in some way, notably Kushiro Mire, Ozegahara Mire, Sarohetsu Mire, Kiritappu Mire and Akaiyachi Mire. However, the IMCG also recognises that such protection is, in some cases, more related to recreational use than to habitat protection, and also that a number of mires lack any form of land-use control within their catchment area. Thus Kushiro Mire, though protected, continues to experience significant impacts from uncontrolled agricultural activities within its large catchment area.

Furthermore, the IMCG notes that so far only two mire systems in Japan - Kushiro Mire and Kiritappu Mire - have been designated as Ramsar sites, and that the candidate list of Ramsar sites prepared by the International Waterfowl and Wetlands Research Bureau (IWRB) Japan Committee includes few additional mire systems. The IMCG is concerned that the emphasis for Ramsar designation in Japan appears to be continuing to focus on sites with significant waterfowl population rather than reflecting the shifting emphasis of

Ramsar which increasingly encourages signatory states to recognise the existence of important sites which are wetland habitats in their own right.

Indeed the IMCG notes that there appears to be an underlying problem which, it must be acknowledged, is not unique to Japan, and concerns the general perception of mire systems. While it is true that more than ten thousand visitors a day visit Ozegahara Mire when the symbolic skunk cabbage (*Lysichiton camtschatcense*) flowers in the stream of the mire, few of these visitors know that they are visiting a mire, and fewer still understand that the skunk cabbage will only survive as long as the mire is maintained in its present state. The level of information and educational material available about mires in Japan is extremely limited, while the only substantial textbook about the subject is 20 years old and out of print. The IMCG would therefore urge the Japanese Government to consider ways in which it might encourage a more widespread understanding and appreciation of these important ecosystems.

The IMCG would be happy to assist the Japanese Government in any way it can to take any of these points forward, and looks forward to hearing of any progress at the next IMCG Symposium in 1996, especially as the venue for this next Symposium may be in Japan.

Resolution for Latvia

The International Mire Conservation Group (IMCG) is a worldwide organisation of mire (peatland) specialists who have a particular interest in the conservation of mire habitats. The IMCG willingly places its advice and expertise at the disposal of any government seeking to establish or maintain mire conservation programmes.

The IMCG held its 6th Biennial Field Symposium in Norway in July 1994, looking at the particular issues of Norwegian mire conservation. During the symposium, considerable discussion and debate was devoted to the issues of mire conservation in other countries represented at the meeting. A number of resolutions were drawn up for the countries represented, as a means of indicating various ways in which each national government could make a positive contribution to the internationally important issue of mire protection.

The IMCG is aware of the work achieved during the last two decades in relation to the protection of mires in Latvia. The group has learnt that mires are a significant part of Latvia's landscape, comprising 9.9% of Latvia's total land area. Of this, 70% is still relatively untouched. The remaining mires have been drained for agriculture or subjected to peat extraction. However, in comparison with most European countries, Latvia still has a large number of mires in an intact state giving the sites international significance. Of particular importance are the remaining rich fen sites, as these are now a very rare habitat in Europe. At present, 12% of the remaining intact mires have been protected either as strict nature reserves, or mire, cranberry or zoological protection areas.

However, despite these measures, the IMCG has identified a number of issues which may lead to a further loss, or degradation, of this internationally important resource.

- of the remaining intact mires are currently unprotected. It is vital that the total area under protection is extended to avoid any exploitation which is likely to result from the land privatisation programme. Furthermore, to date many of the mires under protection are bogs. It is now necessary to extend protection to the full range of mires, including both bog and fen habitats.

- Although a comprehensive inventory of the exploitable peat resource exists, this does not provide enough adequate or appropriate information for nature conservation or biodiversity evaluation purposes. It is now necessary to consider the whole resource and, in particular, vegetation. There is, therefore, a need to compile an inventory of Latvia's mire systems which takes into account both the extent and biodiversity of the resource.

- We are concerned about the involvement of international funding agencies in developing proposals for peat extraction in Latvia. We would hope that concepts of sustainability, now enshrined in international law, are followed in establishing any such initiatives.

- We recognise that the international community should give assistance to Latvia for inventory and conservation of mires.

The IMCG hopes that the Latvian Government will consider these observations to be helpful, and that it will be possible to report positive progress at the next Biennial IMCG Symposium.

Resolution for Norway

The International Mire Conservation Group (IMCG), which is an international organisation of specialists with particular interest in peatland conservation, has completed its 6th Field Symposium in Norway, looking at Norwegian mire conservation issues.

The IMCG is aware of the ongoing work for protection of mires and wetlands in Norway, where more than 450 mire sites are protected in Nature Reserves and National Parks. Nevertheless, there is an urgent need for further funding of work concerning mire preservation in Norway. The following resolutions have been adopted by the IMCG:

- The IMCG is pleased to learn that the county conservation plans for mires are nearly completed. Those which are still not approved should be completed as soon as possible.

- The IMCG is aware of the Mid-Norwegian project in which research into mire regionality, mire types and mire flora is being carried out. This project must be extended to the whole of Norway. The knowledge gained from this project and other related research must be used to make a supplementary conservation plan for important regional types poorly represented in the present plans (e.g. ombrotrophic peatland types in SW Norway) and for special conservation areas (e.g. localities for mire species).

- A plan for management and restoration of mire reserves is urgently required, before irreversible successional changes occur.

- The Toppmyran mires on Smøla are of international significance as one of the most valuable assemblages of ombrotrophic bogs in Norway. The IMCG has learned that the mires on Smøla have been deleted from the Møre & Romsdal county conservation plan, and that no conservation proposal for these mires is under consideration. Though the draining of mires on Smøla has been greatly reduced over the last 10 years, the IMCG has learned that encroachments have continued. A plan for conservation of the most valuable mires on Smøla is therefore urgently required.

- While the Norwegian Government no longer gives grant-in-aid for drainage, and thus the rate of drainage has significantly diminished, the IMCG is aware that valuable mire sites continue to be destroyed by this activity. The IMCG considers that drainage and other types of damage to mires should be subject to formal planning controls, thereby allowing full assessment of the impact which these activities have on mire ecosystems.

- IMCG considers that the Trondheim Conference has made a valuable contribution to the evolution of mire conservation in East European countries, and is of the opinion that further co-operative measures should be initiated by the Norwegian Minister for the Environment.

- IMCG thanks the Minister for the Environment for sponsoring the Trondheim Conference and Norwegian Field Excursion, and looks forward to continued support for the aims and objectives of the International Mire Conservation Group.

The IMCG hopes that the Norwegian Government will consider these observations to be helpful, and that it will be possible to report positive progress at the next Biennial IMCG Symposium.

Resolution for Poland

The International Mire Conservation Group (IMCG) is a worldwide organisation of mire (peatland) specialists who have a particular interest in the conservation of peatland habitats. The IMCG willingly places its advice and expertise at the disposal of any government seeking to establish or maintain mire conservation programmes.

The IMCG held its 6th Biennial Field Symposium in Norway in July 1994, looking at aspects of Norwegian mire conservation. During the symposium, considerable discussion and debate was devoted to the issues of mire conservation in other countries represented at the meeting. A number of resolutions were drawn up for the countries represented as a means of indicating various ways in which each national government could make a positive contribution to the internationally important issue of mire protection.

IMCG wishes to make the following observations:

- The transitional period from state-controlled to private land-use creates new challenges, but also presents a unique opportunity to secure many wetland areas at minimal cost.

- IMCG recognises the problems arising from difficult economic circumstances and admires the achievements in the creation of new protected areas. The proportion of mires presently under legal protection (in nature reserves of various types and in other protected areas) is still small in relation to those areas identified by regional inventories and scientific publications as meriting conservation protection..

- There is now an opportunity to secure mires for conservation through the wider use of the protection category newly established in the Polish Nature Protection Act - namely as "areas of ecological use" (uzytki ekologiczne).

- The rapidity of the privatisation process, which has preceded the implementation of the appropriate legislation, brings new dangers to mires and peat deposits remaining in private ownership. These pieces of land, often recorded as meadows or as unused areas in land inventories, are frequently transformed or even completely destroyed. As an example of such practices, in the northwestern part of Poland several mires have been excavated or destroyed during the creation of fish ponds. The only point of control for this process is through the state authorities who grant water rights to the fish farmers. It is essential that the granting of such rights should be the prerogative of state officials who are intimately aware of the importance and value of mires.

The IMCG hopes that the Polish Government will consider these observations to be helpful, and that it will be possible to report positive progress at the next Biennial IMCG Symposium.

Resolution for the Slovak Republic

The International Mire Conservation Group (IMCG) is a worldwide organisation of mire (peatland) specialists who have a particular interest in the conservation of mire habitats. The IMCG willingly places its advice and expertise at the disposal of any government seeking to establish or maintain mire conservation programmes.

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The IMCG has learnt that mires form a small part of the Slovakian landscape. As such they have a high ecological and scientific value and, consequently, require a high degree of protection. The IMCG, therefore, strongly recommends that the responsible state authorities undertake the following actions:

- that financial support be provided to compile an inventory of all remaining unprotected and intact or functioning mire ecosystems, with emphasis given to the highly endangered minerogenic fens, which are situated in intensive agricultural landscapes;

- that a National Mire Protection Programme be drawn up which establishes National Mire Nature Reserves and/or Nature Reserves and includes plans for their optimal management and sustainable use;

- that the necessary legislative framework be enacted to prevent uncontrolled drainage, reclamation and peat extraction on mires which are owned privately or by the state, municipalities, co-operatives and other institutions;

- that support be given to all types of research institutions which conduct research concerning the ecology, functionality, management and possible restoration of mire ecosystems.

The IMCG hopes that the Government of Slovakia will consider these observations to be helpful, and that it will be possible to report positive progress at the next Biennial IMCG Symposium.

Resolution for Slovenija

The International Mire Conservation Group (IMCG) is a worldwide organisation of mire (peatland) specialists who have a particular interest in the conservation of peatland habitats. The IMCG willingly places its advice and expertise at the disposal of any government seeking to establish or maintain mire conservation programmes.

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The IMCG has learnt that only 1% of Slovenija is mire. Given such a small resource, it is important to conserve the whole mire resource, including spring mires and sloping fens.

To achieve these aims, we believe it is necessary to pursue the following aims:

- Effective measures of conserving mires should be put in place and integrated into national nature conservation and biodiversity strategies. In particular, the unusual mire complexes of Pohorje should be protected. It is, therefore, necessary to speed up the designation process for Pohorje regional park.

- Once mires are protected, a research and monitoring strategy should be implemented both to maintain their natural state and to ensure that mires are not destroyed in protected areas.

- Public awareness of mires should be increased through sensitive public access and interpretation, as well as by developing the educational potential of mires which are located near urban areas.

The IMCG hopes that the Government of Slovenija will consider these observations to be helpful, and that it will be possible to report positive progress at the next Biennial IMCG Symposium.

Resolution for Sweden

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The IMCG is pleased to note that the following issues, highlighted in IMCG Resolutions in 1988, 1990 and 1992, have been fulfilled:

- the Swedish Mire Protection Plan has been adopted by the Swedish Environmental Protection Agency;
- the Swedish Government is to finance the Inventory of Wetlands in the County of Norrbotten;
- that Blaikfjället in the County of Västerbotten is now protected as a nature reserve;
- that drainage has recently been forbidden in some parts of southern Sweden and that smaller wetlands in the agricultural landscape are now protected habitats;

However, the IMCG urges the Swedish Government to address the following issues which remain as causes for concern:

- that sufficient financial resources should be allocated to the protection of the representative mire types and mire-forest ecosystems which are included in the Swedish Mire Protection Plan;
- that restoration of mire hydrology should be initiated, with particular attention paid to southern mire types and to mires included in the Swedish Mire Protection Plan;
- that sufficient financial resourcing for mire management is achieved when necessary;
- that economic funding for scientific research and monitoring on mires must increase to allow for an effective evaluation of the mire resource;
- that the nature conservation legislation which concerns drainage (paragraph 18d) should be extended to include the remaining parts of Götaland, Svealand and the coastal area of Norrland;
- that the Swedish Government should recognise the international standing of Komosse and Blaikfjället by declaring them as National Parks.

The IMCG hopes that the Swedish Government will consider these observations to be helpful, and that it will be possible to report positive progress at the next Biennial IMCG Symposium.

Resolution for Switzerland

The International Mire Conservation Group (IMCG) is an international organisation of experts with a particular interest in the conservation of mires. Its 6th Field Symposium was held in Norway in July 1994.

In 1992 the IMCG spent two weeks in Switzerland where, with local and federal representatives, they discussed different issues including land-use conflicts caused by the implementation of the Rothenthurm Amendment to the Constitution. They also met with professional experts from the fields of forestry, agriculture and nature conservation. What was particularly evident from the journey across Switzerland was that the bogs of the Jura Mountains have a particularly important part to play in the conservation of Switzerland's mire systems.

The IMCG was pleased to learn that the Swiss Confederation has enacted the Decree on Raised Bogs and Transitional Mires of National Importance, thereby protecting these sites in a most encouraging manner. Considering the great loss of these fragile habitats in Switzerland and especially in the Canton of Neuchâtel no further degradration should be tolerated. Therefore, IMCG especially recognises the importance of the federal requirement for ecologically sufficient buffer zones.

However, the IMCG has learned that in the Canton of Neuchâtel detrimental decisions may be made concerning the above-mentioned buffer zones. Experience has shown the importance of buffer zones for maintaining the hydrology and ecology of bogs and thereby for conserving them effectively in the long term.

The IMCG therefore urges both the government and parliament of the Canton of Neuchâtel to ensure that effective buffer zones are established as they were suggested by local bog experts and directed by the federal decree.

Resolution for the United Kingdom

The International Mire Conservation Group (IMCG) is a worldwide organisation of peatland (mire) specialists who have a particular interest in the conservation of peatland habitats. The IMCG willingly places its advice and expertise at the disposal of any government seeking to establish or maintain mire conservation programmes.

The IMCG held its 6th Biennial Field Symposium in Norway in July 1994, looking at the particular issue of Norwegian mire conservation. During the symposium, considerable discussion and debate was devoted to the issues of mire conservation in other countries represented at the symposium. A number of resolutions were drawn up for the countries represented as a means of indicating various ways in which each national government could make a positive contribution to the internationally important issue of mire protection.

Subsequent to correspondence resulting from the resolution produced in 1992 during the 5th IMCG Symposium, the IMCG wishes to express particular and continuing concern about three peatland issues in the United Kingdom.

- Three of the UK's most important raised bogs continue to be affected by operations associated with the commercial extraction of peat. These are Flanders Moss (Scotland), Wedholme Flow (England) and Ballynahone Bog (Northern Ireland). The experience of the IMCG members indicates that, because of hydrological continuity within the whole bog unit, such commercial operations are incompatible with the objectives of sustainability, wise-use and nature conservation. In particular, such conditions appear to be contrary to the requirements of Article 8(e) of the Biodiversity Convention. Assuming that conservation of these three sites is seen as an important issue, the IMCG urges the UK Government to consider ways of ensuring that no further damage occurs to these sites and that they then be conserved in their entirety.

- The IMCG welcomes the establishment by the UK Government of the National Peatland Resource Inventory (NPRI), and is encouraged by the progress this important programme has made for raised bogs in Great Britain. However, we are concerned that there appears to be no strategic longer-term commitment to completing the inventory of the entire peatland resource. In particular, the need to have a clear picture of the blanket bogs of Britain, these being of global significance and a priority under Directive 92/43/EEC (EC Habitats and Species Directive), would seem to be an area for urgent action. The IMCG therefore urges the UK Government to provide sufficient resources for this important inventory programme to be completed as quickly, but also comprehensively (i.e. recognising the full range of biodiversity), as possible. We would, in addition, ask whether the UK Government considers it appropriate to extend the remit of the NPRI to provide a single unified inventory for the UK?

- The IMCG urges the UK Government to adhere to the commitments made by the UK Government in the Biodiversity Convention and the UK Biodiversity Action Plan, particularly in relation to the Precautionary Principle, biodiversity, sustainability and wise-use, and the recognition that the peatland conservation programme should be expanded. We ask the UK Government to ensure that these are all applied as fundamental principles in all its actions and deliberations in relation to the UK peatland resource.

The IMCG hopes that the UK Government will consider these observations to be helpful, and that it will be possible to report positive progress at the next Biennial IMCG Symposium.

Resolution for Ukraine

The International Mire Conservation Group (IMCG) is a worldwide organisation of mire (peatland) specialists who have a particular interest in the conservation of mire habitats. The IMCG willingly places its advice and expertise at the disposal of any government seeking to establish or maintain mire conservation programmes.

The IMCG held its 6th Biennial Field Symposium in Norway in July 1994, looking at the particular issues of Norwegian mire conservation. During the symposium, considerable discussion and debate was devoted to the issues of mire conservation in other countries represented at the meeting. A number of resolutions were drawn up for the countries represented, as a means of indicating various ways in which each national government could make a positive contribution to the internationally important issue of mire protection.

Members of the IMCG have learnt that mires cover less than 2% of the total land area of Ukraine. Being at the southernmost limit of temperate mire distribution, these mires are of international significance in terms of world biodiversity. Mires are important for the maintenance of hydrological systems. In addition, after the accident at Chernobyl, mires in the north-western part of Ukraine (Polesje) play an essential role as a natural filter of radioactivity. These mires are also important reference sites given the work of Kulzyński in the 1930s.

Given their obvious importance, it is essential that mires are conserved in Ukraine and the IMCG is pleased to note that in accordance with recent laws for Nature Protection in Ukraine, a list of newly protected nature areas is to be drawn up. This list will include areas where future land privatisation will be prohibited and will also include areas which will be a reserve for the establishment of newly protected areas. While this step is welcomed, the IMCG considers that given the small percentage of mires remaining in Ukraine it is necessary to extend this protection to include those mires which are outside protected areas.

The IMCG recognises that the international community should co-operate and provide assistance, if necessary, to help with the conservation of mires in Ukraine.

The IMCG hopes that the Ukrainian Government will consider these observations to be helpful, and that it will be possible to report positive progress at the next Biennial IMCG Symposium.

Appendix 2. Participants of the 6th IMCG field symposium 1994

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