

# Gunneria

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## 63



Asbjørn Moen

*THE PLANT COVER OF THE BOREAL UPLANDS  
OF CENTRAL NORWAY. I. VEGETATION  
ECOLOGY OF SØLENDET NATURE RESERVE;  
HAYMAKING FENS AND BIRCH WOODLANDS.*

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Universitetet i Trondheim  
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#### ABSTRACT

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Sølendet nature reserve covers an area of 2.9 km<sup>2</sup> at an altitude of 700-800 m above s.l., at the transition between the middle and northern boreal regions.

The areal extents of the plant communities were assessed from the vegetation map (copy included) and comparisons drawn with the coverage of similar vegetation elsewhere in C. Norway. Sølendet is situated in the area of Cambro-Silurian bedrocks, the phyllitic bottom moraine of the area yields a nutrient-rich soil with a rich vegetation. The flora of the reserve comprises 282 taxa of vascular plants and 253 bryophyte species. More than 50 springs (communities of the *Cratoneurion commutai* alliance) feed calcareous water (pH 7.8) to the sloping fens covering the central and lower-lying parts of the reserve.

Up to 1950 the fens and grasslands had been, for centuries past, utilized for hay production; ca. 100 tons of hay were harvested annually. Productivity studies were commenced in permanent quadrats 15 years ago, the hay yields by scything, and vegetational changes before and after the recommencement of scything, have been followed. The management plan for the reserve includes 1.6 km<sup>2</sup> of former hay lands, that have been restored and regularly mown during the last decade.

The phytosociological analyses of permanent quadrats at Sølendet were subjected to multivariate analyses, including classification (TABORD, TWINSpan) and DCA-ordination (DECORANA) of data sets of 1) mire and spring vegetation, 2) rich fen vegetation, 3) woodland vegetation and 4) open grassland vegetation; in addition a data set of wooded grassland samples from Sølendet and 3 more areas of C. Norway were analysed. A synsystematic survey of the plant communities is given, including comparisons with N. and C. European literature. The extremely rich fen vegetation covers 44 % of the reserve, predominantly communities of the *Caricion atrofuscae* alliance (additional alliances: *Stygio-Caricion limosae*, *Caricion lasiocarpae* and *Sphagno-Tomenthypnion*). The heathland vegetation (covering 35 % of the reserve) includes: *Nardo strictae-Betuletum pubescentis* ass. nov., *Myrtillo-Betuletum myrtilletosum* subass. nov. and *Myrtillo-Betuletum dryopteridetosum* subass. nov. The wooded grasslands of the *Lactucion alpinae* alliance (covering 20% of the reserve) includes three associations: *Geranietum sylvatici deschampsietosum* subass. nov., *Geranietum sylvatici aconitetosum* subass. nov., *Filipendulo-Salicetum phyllicifoliae* and *Deschampsio cespitosae-Salicetum lapponae*. Communities of open grasslands, including *Nigritella nigra*, *Botrychium* spp. and other low-herb species, are provisionally included in the *Potentillo-Polygonion vivipari* alliance.

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## PREFACE

My studies on the hay fens at Sølendet started in 1974, and from that year onwards I have visited Sølendet several times every summer; in all, making about 50 excursions from Trondheim to Brekken. The majority of these visits were made together with other botanists, institute assistants or visitors. A large number of persons have either helped me, or provided valuable information, during the field-work and other excursions to Sølendet; only a few of them can be mentioned here (full information can be found in the annual reports). In particular, Jan Erik Kofoed participated in the field work during the years 1975-1979 and Trond Arnesen in all years since 1981. Their punctilious work in connection with the production measurements and the other botanical studies have been of the greatest importance for the results presented here. Another large group of institute assistants who have contributed on a number of occasions include: Stein Johansen, Hallgeir Leirvik, Arvid Lillethun, Jo Stein Moen, Tor Øystein Olsen, Torfinn Rohde, Kari Sivertsen and Øystein Størkersen. My colleagues Liv Borgen, Simen Bretten, Reidar Elven, Arne Frisvoll and Eldar Gaare, all deserve thanks for their pleasant collaboration.

Bodil Wilmann supervised and provided fundamental help with the data analyses, data programs etc. I also wish to thank my colleagues at the Department of Botany, Egil I. Aune and Stein Singaas, for their help with the data analyses, and for making valuable comments on the draft manuscript; Olav Gjærevoll is also to be thanked in the latter connection. Kjell Ivar Flatberg is thanked for a most careful scrutiny of the manuscript that led to considerable improvement.

Olav Volden co-operated in 1976 in mapping the cultural history, i.e. the previous use of Sølendet, and the local land-owners are thanked for their valuable contributions in this respect. The supervisor of the nature reserve, Nils Stenvold, who has also been responsible for the practical work connected with the management plan, has been of fundamental importance for my work, by e.g. contributing his fund of knowledge of the farming practices in former times. He has also been responsible for scything all the quadrats for the production studies every summer since 1977; i.e. more than 600 carefully scythed quadrats. I also wish to thank his wife, Jorun Stenvold for the hospitality shown to me by the Stenvold family during all these years.

Financial aid has been received each year since 1974 from the Environmental Department of the Local Authorities through their chief administrative officer of Sør-Trøndelag. The management plans were drawn up in close collaboration with the responsible Inspectors, namely Ola Skauge, Jon Suul and Torfinn Rohde. Research grants were given to my "hay fen-project" by The Norwegian Research Council for Science and the Humanities (NAVF) in the years 1971-75, 1977, 1979, 1981 and 1983. Further grants have come from a legacy of The Royal Norwegian Society of Sciences and Letters in the years 1979 and 1984/85 (Hammers legat) and in 1982 from Bergen Privatbanks fond.

My own institution, the Museum of Natural History and Archaeology, has provided annual support for the Sølendet project, and a number of the staff have contributed to the fulfilment of this work. Åse Fjeldsæter, Else Marie Mosand and Arild Krovoll have been responsible for typing the manuscript. Kari Sivertsen and Elin Hansen have drafted the figures, maps and diagrams; Per Fredriksen has been responsible for printing the photographs.

Philip Tallantire has carefully corrected my English and also made a number of valuable comments on the manuscript.

All these persons who have helped me, given advice, etc., in connection with the management of Sølendet and the botanical research there are gratefully thanked.

Especial thanks is due to my wife Berit, who has both helped with the field-work and given me her full support during all years of research at Sølendet, and to all my family for their admirable patience during years.

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Asbjørn Moen

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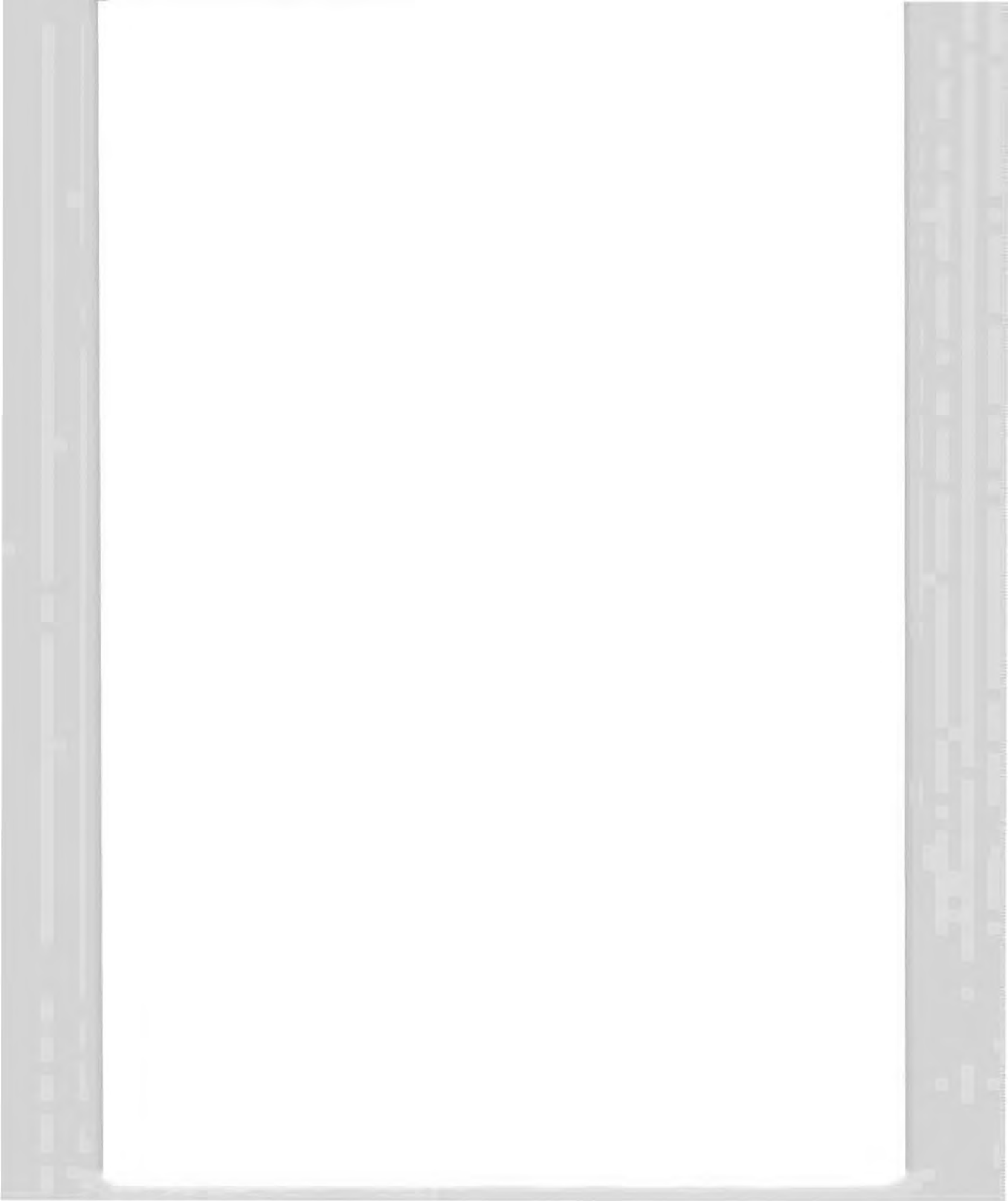


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# 1 INTRODUCTION

## 1.1 PREVIOUS STUDIES OF SØLENDET

During the years 1939 and 1949-1954, Einar Fondal studied the flora of the Brekken area, and in his flora of Brekken (Fondal 1955) he briefly described Sølendet, mentioning especially the species-rich flora and the rich occurrence of orchids.

The Botanical Society of Norway visited Sølendet for the first time in 1953 (cf. Blyttia 1954; vol. 12: 31), and again in 1962 (Blyttia 1963; vol. 21: 48-49), and 1964 (Blyttia 1965; vol. 23: 38). The first visit I made was in fact on the last-mentioned occasion. Olav Gjærevoll visited Sølendet on a number of occasions, and he was the supervisor of both Fondal and Eldar Gaare. The latter started his studies on the rich fen vegetation of Sølendet in 1959 and finished his cand. real. thesis in 1963 (Gaare 1963; description in section 6). Prestvik (1973) published a vegetation map of Sølendet and the surrounding area (cf. section 2.6). Dierssen (1982) included phytosociological analyses of 8 quadrats of rich fen vegetation from Sølendet in his monograph on North European mire vegetation (cf. section 8). Recently (in Sept. 1989), Trond Arnesen finished his cand. scient. thesis on a study of the bonfire vegetation of Sølendet nature reserve.

Surveys, made in connection with the Norwegian national plan for mire nature reserves, commenced in 1969, and in the same year Eldar Gaare outlined two alternative schemes for the protection of the most valuable mire areas at Sølendet ("Super-Sølendet" 5250 daa.; "Minima-Sølendet" 2100 daa.). The importance of designating Sølendet as a nature reserve was generally recognised and Sølendet was included among the most valuable mires in Norway, right from the conception of the national plan (e.g. Moen 1973). At the same time, however, plans had already been drawn up for draining the central parts of Sølendet for agricultural purposes. In the absence of any initial contact between the agricultural and the environmental authorities, ditching started, early in the spring of 1972, in the southern parts of Sølendet, and more than 200 daa were converted into cultivable land. Ditching was thereafter stopped and the area to the north of that already drained was placed under a temporary protection order in September 1972; in 1974 Sølendet was finally protected as a nature reserve. The regulations covering the nature reserve stated that a management plan should be drawn up. My own Department of the Museum of Natural History and Archaeology was made responsible for producing that plan.

Figures 1.1.1-2 show typical views of the Sølendet nature reserve.



- Fig. 1.1.1      A sloping fen area of Sølendet with an old stack pole. Date: 19750713. Locality no. 63.
- Fig. 1.1.2      The Dalbua area, in the foreground the newly scythed grasslands. 19770803.

## 1.2 MY OWN STUDIES

As part of the work for my cand. real. thesis, I started a study of the vegetation of hay fens at Nordmarka in Nordmøre (cf. Moen 1969, 1970). In 1974, a study of Sølendet was included as a locality of prime importance for the study of hay fens in Central Norway. From that year onwards, I have combined scientific research on the hay fens and grassland areas of Sølendet with the more practical work involved in drawing up the management plan for the nature reserve, and then in supervising its implementation. In my view this has proved to be a most opportune combination. It has in fact proved impossible to draw any hard and fast line between what is science and what is not! That the results should prove to have practical interest, does not in my opinion detract from the scientific worthiness of the work. Over the years, in close collaboration with the supervisor of the reserve (Nils Stenvold), the most effective methods of management have been evaluated, methods which are of interest in the management of nature reserves in general. A fairly detailed description of both the previous human impact on Sølendet and an evaluation of the methods employed in its reclamation and management is given in section 3, together with annual surveys of the work carried out at Sølendet during the past 14 years.

The botanical investigations at Sølendet are part of a more ambitious project concerning vegetational studies of the boreal uplands of Central Norway (i.e. the upper part of the middle boreal and the northern boreal regions). Vegetational studies of such upland areas, including vegetation maps of quite large areas, have already been published, for example for Nerskogen (Moen & Moen 1975), Innerdalen (Moen 1976a), Øvre Forradal (Moen et al. 1976, Moen & Jensen 1979), Nord-Fosen (Moen & Selnes 1979) and Garbergselva/Rotla in Selbu (Moen & Kjølsvik 1981). Both the flora and the vegetation have been studied more intensively than elsewhere at Nordmarka, Nordmøre (cf. Moen 1969, 1970, 1976b) and at Sølendet, including studies of the vegetation cover and the plant populations in permanent quadrats, estimates of the productivity of the field-layer, and the effects of scything on the different types of vegetation present.

This monograph on Sølendet, however, represents the first comprehensive publication, in English, to provide the full results of a study of the vegetation of an upper boreal area in Central Norway. The general descriptions of the methods, terminology and classification systems etc. are, therefore, relatively detailed. This publication also represents the first description of the Sølendet reserve in English, wherefore a fairly comprehensive survey of the geology, hydrology, climate, human impact etc. is given, as well as a full species list





of the vascular plants and bryophytes. More detailed description of the flora, the population ecology of some species, the changes in the flora and vegetation induced by scything etc., will be published later as separate papers.

The studies of the vegetational changes etc., based on the permanent plots at Sølendet are to be continued. In the future, I also hope to make chemical analyses of plants and soils, so as to gain a better understanding of the nutrient balances of the different plant communities, and the limiting factors for plant production of those that were and of those that are being mown for hay.

### 1.3 AIMS

The prime aim is to give a scientific contribution to the ecological knowledge of boreal ecosystems. More specific, the main aims of this paper are:

- \* To describe the **main vegetational types** at Sølendet, with an emphasis on those previously used for haymaking.
- \* To determine **ecological factors** which may account for the observed differences in the vegetation cover at Sølendet.
- \* To **compare the vegetational types** of Sølendet with similar types of vegetation elsewhere, and to give a synsystematic survey.
- \* To assess the **areal extents** of the different plant communities at Sølendet, and to compare them with those of other upper boreal areas of Central Norway.
- \* To estimate the **productivity** of the field layer of those vegetational types that were formerly scythed and to estimate the total hay yield at Sølendet.
- \* To describe and evaluate the **management methods** utilized in the attempt to reestablish the old cultural landscape of hay fens and grassland areas at Sølendet.
- \* To describe and evaluate the **methods** used in the vegetational studies of outlying lands in C. Norway, including the multivariate analyses used for establishing the vegetational types and the numerical relationships between them.
- \* To give a survey of the **ecological terminology and classification systems** for mires, and to propose a hierarchical classification system for Norwegian mire vegetation.

## 2 GENERAL DESCRIPTION AND TERMINOLOGY

### 2.1 FORMER UTILIZATION OF THE OUTLYING LANDS IN NORWAY

In the agricultural ecology of former times, wide areas of the outlying lands (Norw. "utmark") were utilized for summer-farming ("seterbruk"), haymaking ("slåttebruk") and grazing ("beitebruk"). The extent of infield ("innmark"), i.e. cultivated land in the valleys around the permanent settlements, was very limited in many parts of Norway and most of the supplies of winter fodder were obtained from the outlying lands. In fact it was the winter fodder supply that primarily set a limit to the number of head of stock that a farmer could keep. Before artificial fertilizers came into general use (less than a century ago), the productivity of the infields (mainly arable land) was directly dependent on this upland utilization. Without a supply of fodder from the outlying land there was an insufficiency of manure to spread on the infields. Figure 2.1.1 illustrates the conditions prevailing formerly (up to ca. 1900 A.D.) and nowadays.

Areas covered by a rich vegetation represented the best and most productive grazings and haymaking places, therefore these were the most heavily utilized. The evidence for this is still quite visible in many places, from the concentration of the remains of summer-farms and hay-barns ("høyløe") in just such areas of rich vegetation. Both summer-farming and haymaking were most intensively practised about the middle of the 19<sup>th</sup> century. At that time there was scarcely any area of rich fen or wooded grassland ("engskog") anywhere in Norway, with the exception of the most remote mountainous areas, that was not so utilized and in this way altered by human influence. The degree of such utilization has varied in intensity at different times in the past, as also from place to place.

The antiquity of such summer-farming and haymaking activities has been discussed in many archaeological and historical works (e.g. Hougen 1947, Frødin 1952, Reinton 1961). The sickle and the scythe have been known for about 1500 years and have been in general use for more than a 1000 years (Hagen 1977). During periods of economic depression (e.g. at the time of the Black Death), such utilization will obviously have been less intensive, but from the above-mentioned and other sources it is quite clear that haymaking in the higher-lying parts of Norway has been carried on for more than a 1000 years.

This intensive usage has declined from the end of the 19<sup>th</sup> century onwards, although the traditional methods were still being used in certain areas up to ca. 1950. The statistics of the number of farms in the two Trøndelag counties that possessed summer-farms shows this trend quite clearly (Reinton 1955): In the 19<sup>th</sup> century there were 6.600 farms that owned one or more summer-farms, in 1930 the number had fallen to 3.700, and in 1939 there were only 2.900. Today there are no summer-farms that are used in the traditional manner.

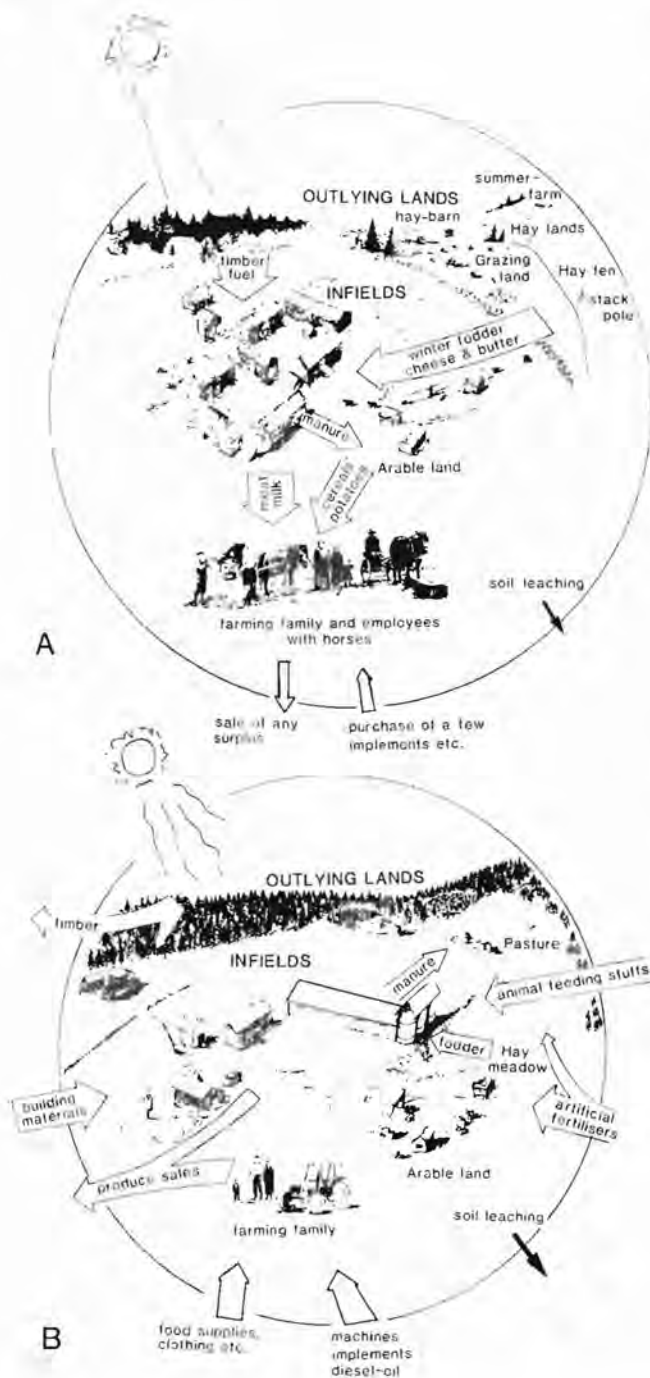


Fig. 2.1.1

**A:** Schematic representation of a typical farm ecology in the past, when most were self-sufficient, little was bought in, and the outlying lands were intensively utilized for summer-farming, haymaking and grazing.

**B:** As for figure A, but for a present-day farm, which relies on purchasing artificial fertilisers, animal feeding stuffs, machines and implements, diesel-oil etc. from commercial sources. The production resources of the outlying lands are not utilized, and the landscape is changing in character.



According to the acreage statistics for 1907 (Statistisk Sentralbyrå 1911), by which time summer-farming and haymaking in the outlying lands had already started to decline, there was a total area of 526 km<sup>2</sup> utilized for upland haymaking, representing more than 2 % of the entire extent of the two Trøndelag counties. (Statistics for haymaking lands are further dealt with in section 13.3.1). An average-sized farm brought home 8-10 tons of hay from its upland areas, though large farms might get as much as 100 tons. The upland area utilized for haymaking, expressed per inhabitant of the rural district, was in 1907 as high as 10-20 daa (mål) in many places (1 mål = 0.25 acres), according to the survey figures.

The production resources of the outlying lands are little exploited nowadays, other than being grazed by a few sheep or cattle in certain parts of the country, together with elk and other game animals. Viewed as a whole, however, this is on a very minor scale, and the vegetation and landscape are changing in character accordingly.

## 2.2 VEGETATIONAL STUDIES OF UPPER BOREAL AREAS OF CENTRAL NORWAY

### 2.2.1 Nordhagen's publications

The first Norwegian vegetation monograph was published by Nordhagen (1928); it provided a comprehensive and systematic description of the plant communities of the northern boreal and alpine regions of the Sylane (including Nedalen) area, a mountain group situated ca. 30 km N of Sølendet (see Fig. 2.2.1). In the northern boreal areas of Nedalen there are a number of plant communities which are the same as some of the types found at Sølendet. Nordhagen visited Sylane for the first time in 1914, and again in 1917, 1918 and 1919. This main phytosociological work was done in 1920-1921, though he revisited the area also in the autumns of 1922 and 1923. Nordhagen (1928), describing the influence of cultivation in the area, stated that one farm was situated in Nedalen and that (p. 10, in translation):

"The cultivated area, excluding meadowland, lies in the immediate vicinity of the farm buildings, apart from this the effects of culture within the nature park are very slight and are restricted to small haymaking areas on the grassy sloping fens and in the lush, herbaceous birch woodlands along the banks of the Nea river."

In general, such usage of the outlying lands for summer-farming, haymaking and grazing declined from the end of the 19<sup>th</sup> century onwards (cf. section 2.1), but in the years around 1920 these traditional methods were still practised all over Central Norway (cf. Reinton 1955, 1957). Only small areas were still being utilized in the Nedalen area when Nordhagen made his investigations and it seems reasonable to conclude that the major extent of the Sylane area, lying

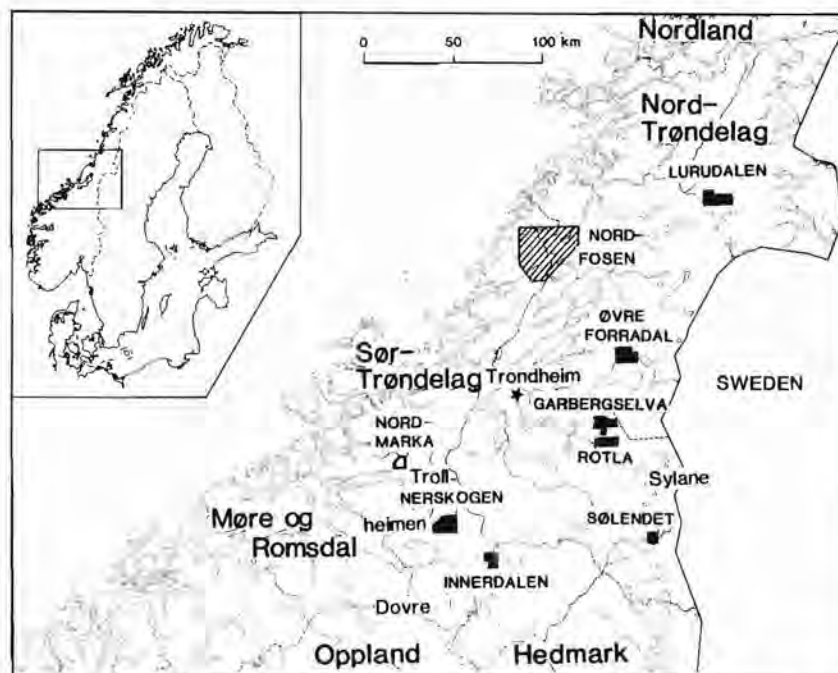


Fig. 2.2.1 Map of Central Norway showing the areas in the upper boreal regions for which vegetation maps exist (listed in Table 2.2.1); and some common names. Darkened plots represent areas covered by published, large-scale, multi-coloured vegetation maps, the Nord-Fosen map is printed in the scale 1:50.000, and Nordmarka is covered by an unpublished draft.

far away from the more densely populated valleys, was little utilized, relative to most of the comparable northern boreal areas of Central Norway.

The valley bottom in Nedalen lies ca. 700 m above s.l., and there is no area of middle boreal vegetation, since the boundary between the middle and the northern boreal regions lies thereabouts at ca. 650 m above s.l. (cf. Moen 1987a). The lowest-lying areas of Nedalen have about the same climatic conditions as found at Sølendet, and despite some differences, the Nedalen and Sølendet have many features in common.

Nordhagen described more than 100 different vegetational "associations" (= sociations in the meaning of Nordhagen 1943) from Sylane, of which six of his seven types of woodland and ca. ten of his ca. forty mire associations are those most relevant in drawing comparisons with the types of vegetation found at Sølendet. Nordhagen drew up his classification system for the northern boreal and alpine vegetation of Norway (Nordhagen 1936, 1943) on a basis of the

results of his Sylane investigations and of five other mountainous areas in South Norway. His vegetational monograph for Sikilsdalen (1943) is a particularly valuable phytosociological study which also included a hierarchical classification.

Although Sikilsdalen is situated far away from Sølendet, there is still quite a high degree of similarity between the plant covers. The Sikilsdalen monograph also includes information about and analyses of the vegetation in other areas (e.g. Sylane and Dovre). The main aim of the Sikilsdalen monograph was to serve as a basis for comparative studies of the grazing potential of the outlying lands over the whole of Norway. Sections 8 and 11 of the present publication include a comparison of the phytosociological units adopted by Nordhagen (1936, 1943) and those used here.

## 2.2.2 Areas covered by vegetation maps

During the 1970's a number of botanical investigations including vegetational mapping, were made in the upper part of the boreal regions in different parts of Central Norway. Most of these research projects were related to plans for the construction of hydroelectric dams and the vegetation map covered the areas of the planned reservoir, plus some additional parts of the catchment. Figure 2.2.1 shows the positions of these areas. A comprehensive survey of the methods employed, the units used for vegetational mapping, details of the published reports and vegetation maps etc. can be found in Moen (1981). Table 2.2.1 provides a summary of mapped parts of the 9 areas shown in figure 2.2.1, with details of the areas covered by poor fen, rich fen and grassland vegetation, i.e. the main types of vegetation formerly mown for hay, in the middle and northern boreal regions falling within the tracts covered by the vegetation maps. Because both the map scale used and the details mapped vary from one map to another, the areal extents of those vegetation types are only approximations, especially in the case of Nord-Fosen and Nordmarka, Nordmøre in the table, but the great differences in the extents of these three main types of vegetation in the 9 areas in question are clearly brought out. Phytosociological documentation of the vegetation of the upper boreal areas of Central Norway is given in a number of cand. real. theses; e.g. the forest vegetation of Nerskogen and Øvre Forradal are described by B.F. Moen (1978) and L. Kjølsvik (1978), respectively.

The Nord-Fosen area is predominantly covered by the poorer types of vegetation, mainly poor heathlands (forested and open types) and poor fens (ca. 1/3 of the mapped area). Rich fens (0,2%) and grassland vegetation (2%) cover only very limited areas, which is partly explained by the fact that the bedrock of Nord-Fosen is Pre-Cambrian (mainly gneiss & granite) as so often is the case in the western parts of Central Norway. Gneiss and granite also underly large stretches of the inland parts of South Norway (e.g. E of Aursunden, see Fig.3.2.1). The Lurudalen area in Nord-Trøndelag is one such area, where heathlands predominate (ca. 2/3 of the area), poor fens cover 18%, and rich types

Table 2.2.1 The respective areal extents of poor (plus intermediate) fen, rich fen (including moderately and extremely rich fen), and grassland vegetation (open, shrub-covered and wooded grasslands; cultivated land and summer-farms excluded) in nine areas of the middle and northern boreal regions of Central Norway. The information given for the areas is based on the vegetation maps included in the cited publications.

	Height above s.l. in m	Vege- tation region	Land area mapped in km <sup>2</sup>	Coverage in % of:			References
				Poor + interm. fen	Rich fen veg.	Grass- land veg.	
Sølandet nature reserve	700-800	MB+NB	2.9	1	44	20	Moen, present paper, vegetation map 1:5 000
Sølandet-Øvre Glomma	690-900	MB+NB	28	1	11	23	Prestvik (1973), vegetation map 1:10 000
Nerskogen	600-900	MB+NB	55	7	23	17	Moen & Moen (1975), vegetation map 1:10 000
Innerdalen	780-900	NB	15	1	16	30	Moen (1976a), vegetation map 1:10 000
Øvre Forradal	380-600	(MB)NB	66	51	8	3	Moen et al. (1976), veg. map 1:10 000
Garbergselva/Rotla, Selbu	300-700	MB+NB	82	36	5	8	Moen & Kjølvik (1981), veg. map 1:20 000
Lurudalen	200-450	MB+NB	56	18	0.1	2	Holten (1982), vegetation map 1:10 000
Nord-Fosen	150-400	MB+NB	290	ca.30	0.2	2	Moen & Selnes (1979), veg. map 1:50 000
Nordmarka, Nordmøre	350-500	MB+NB	15	ca.25	ca.20	ca.5	Moen (1970), rough vegetation map ca. 1:30 000



of vegetation cover only very small parts (0.1% rich fen, 2% grassland vegetation). The northern parts of the Nordmarka area also belong to the above mentioned, western, Pre-Cambrian gneiss and granite, i.e. all hard rocks, very resistant to weathering. The southern parts of Nordmarka and the other areas included in table 2.2.1 are situated in the extensive area of Cambro-Silurian bedrock in Central Norway. In these areas the geological conditions also vary to some extent, but readily-weathered, calcareous strata occur fairly commonly. The geological differences are also reflected in the vegetation cover, in the Øvre Forradal area, where the bedrock is favourable for soils supporting a rich vegetation in the west, though with harder rocks in the east. The western part includes quite large areas covered by rich types of vegetation, although in this area taken as a whole (66 km<sup>2</sup>) only 8% is rich fen and 3% is grassland, whereas poor fen covers 50% of the mapped area (mainly as extensive, flat fens on the drift deposits that cover the valley bottom), and heathland is also a dominant feature of the landscape.

The same situation is also found in the area covered by the vegetation map of Garbergselva and Rotla, where the rich types of vegetation are concentrated in some quite local areas. Rich fen covers 5%; and 8% is grassland, out of a total area of 82 km<sup>2</sup>. Sølendet (the area covered by the maps falls within the region of grey-green phyllites; see Fig. 3.2.1), Nerskogen and Innerdalen are all situated in areas of mainly calcareous, readily-weathered types of bedrocks and rich types of vegetation accordingly cover large areas; taken together, rich fen and grassland vegetation cover almost 50% of the mapped areas, and poor fen covers only a small area (at most 7%, in Nerskogen). Heathland series (cf. section 12.5) nevertheless covers a wide area, up to 50% in some parts, mainly on drift deposits (largely morainic in origin). Generally speaking, heathlands, of which the most common are mesotrophic forests of *Eu-Piceetum* types, cover very large areas in the boreal regions of Central Norway.

To summarise so far, the vegetationally mapped areas discussed above illustrate the typical differences in the distributions of the poor and rich types of vegetation, respectively, in Central Norway, with the poor types predominant in the coastal districts and on areas of poor bedrock elsewhere. The rich types of vegetation occupy greater areas in the boreal regions where more favourable bedrock occurs, especially in the Røros-Dovre-Trollheimen area, with its phyllites and other mineral-rich rock types (cf. also the plots of rich fen vegetation of fig. 2.3.1).

## 2.3 RICH FENS, SLOPING FENS AND HAY FENS

### 2.3.1 Rich fen vegetation of Central Norway

During the work on the Norwegian national plan for mire preservation, all mire localities were classified on a basis of the vegetational units described in section 8.2.1. Figure 2.3.1 shows the investigated mire localities in the counties

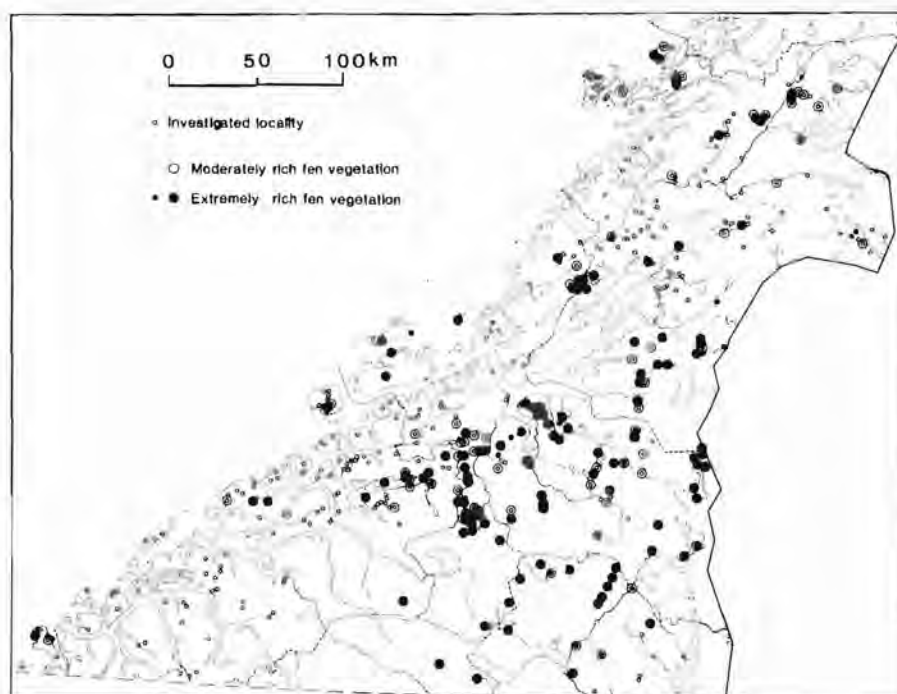


Fig. 2.3.1

Localities in Central Norway (N of 62° N. lat.) where areas of rich fen vegetation occur. The large symbols (dots and open circles) represent areas of ca. 1 ha or more; the small dots represent those of extremely rich fen below 1 ha in area. The data are taken from the 405 mire localities (small open circles) described and classified in the Norwegian national plan for mire preservation (e.g. Moen 1983).

of Trøndelag and Møre og Romsdal, together with some localities in the adjacent parts (all N of the 62° N. lat.) of Sogn og Fjordane, Oppland and Hedmark counties, cf. Moen (1983, 1984), Moen et al. (1983), Singaas (1984, 1985), Singaas & Moen (1985). Those localities where areas of extremely rich or of moderately rich fen vegetation occur are indicated by their own symbols. Moen (1985c) gave a review of the "rich fens" of Norway, their characters, utilization, conservational importance etc.

One of the main criteria adopted in the mire preservation work has been the protection of interesting ecosystems of more unusual or extreme types. The flora and vegetation of the rich fens is the most diverse and a special effort

was therefore made to locate such sites, especially in districts otherwise dominated by a poor type of fen vegetation. In some parts of Central Norway (e.g. in the Fosen Peninsula, where limited outcrops of calcareous rocks occur in an area of predominant gneiss and granite rocks), the map (Fig. 2.3.1) shows an overrepresentation of rich fen vegetation.

The map includes mire localities situated in the coastal section and in the boreal regions, together with a few localities situated in the lower part of the low alpine region. Moen (1987a, map in Fig. 9, excluding Sogn og Fjordane and Sunnmøre) gave a full survey of the southern boreal mire localities.

These two maps (Fig. 2.3.1 and Fig. 9 of Moen *op.cit.*) taken in conjunction, show that a large number of the southern boreal mire localities do not include areas of rich fen vegetation. The main reason for this, in some districts, is that the southern boreal mires are now raised bogs dominated by ombrotrophic vegetation, since the previous occurrences of minerotrophic vegetation on these areas have been subsequently obliterated by the formation of ombrogenous peat.

By and large, the map presents a fairly typical picture of the distribution of rich fens in Central Norway, with scattered occurrences in Møre og Romsdal (20 localities out of a total of 114 investigated), in the coastal districts of Trøndelag and in many parts of the Namdalen area (cf. also the comments made in section 2.2.2). The majority of mire localities in the Cambro-Silurian bedrock area of Central Norway include occurrences of rich fen vegetation, e.g. in the central and inner parts of Sør-Trøndelag and the northern parts of Hedmark. In Sør-Trøndelag county as a whole, 87 localities, out of a total of 127, include areas of rich fen vegetation.

### 2.3.2 Sloping fens of Central Norway

During the work on the Norwegian national plan for mire nature reserves (cf. section 2.7) a **sloping fen** was defined as an area of fen with a surface incline of at least 3° over an area of at least 1 daa. The sloping fens were subdivided into: gently sloping fens (inclination 3-8°), strongly sloping fens (8-15°) and very strongly sloping fens (> 15°).

In the published reports on mire localities in Central Norway (cf. list of references in section 2.3.1) all (now more than 400) have been classified in the above manner. Figure 2.3.2 shows the occurrence of sloping fens with an area of at least 1 ha, in these localities.

Sloping fens are generally found in the middle boreal-low alpine regions. In fact, the lower altitudinal limit of sloping fens is one of the criteria used to separate the middle boreal from the southern boreal region in Central Norway (cf. Moen 1987a); Moen (1988) adopted the term "the lower limit of sloping fen" for this boundary.

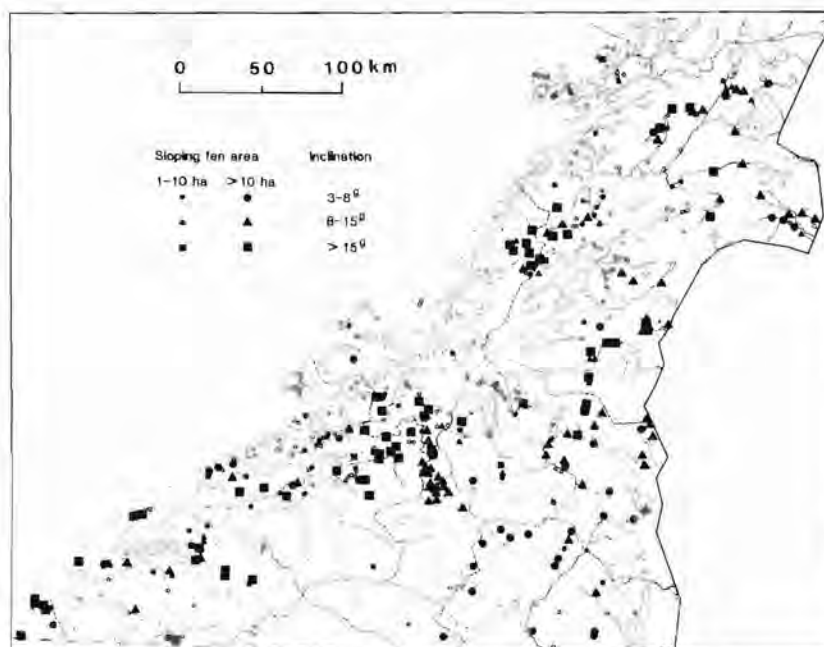


Fig. 2.3.2

Sloping fen localities covering an area of more than 1 ha in Central Norway (N of 62° N. lat.). Gently sloping fens have a surface inclination of 3-8°. Strongly sloping fens and Very strongly sloping fens have inclinations of 8-15° and > 15°, respectively, over an area of at least 1 daa. The map is based on the data from the 405 localities (small open circles) described and classified in the Norwegian national plan for mire preservation (e.g. Moen 1983).

The area covered by mires in Trøndelag accounts for ca. 20% of the middle boreal region and a little over 30% of the northern boreal region. From the lowlands upwards into the forested regions, the frequency of mires increases, cf. the typical diagram for Nord-Trøndelag in figure 2.3.3.B. In Sør-Trøndelag areas higher than 600 m above s.l. within the coniferous forest regions are mainly to be found in the southern, more continental parts of the county (i.e. in Røros and Oppdal), which explains the decrease in mire frequency there. In Hedmark county, mires cover ca. 10-20% of the middle and northern boreal regions (cf. Moen 1983). As a rough estimate, sloping fens (including flark fens with a surface incline of more than 3°) account for about a half of the total mire-covered area in the upland boreal regions, i.e. the sloping fens of Trøndelag cover ca. 10-15% of the total extent of the middle and northern boreal regions, the percentage increasing with site altitude.

The most strongly inclined sloping fens are found in the northern boreal region (and in the prealpine belt of the coastal section) in the most humid parts of Central Norway, but are virtually absent from the Røros area southwards, due to the increasingly continental nature of the climate (see Fig. 2.3.2).

Phytosociological analyses of the vegetation of the sloping fens of Central Norway have been published by Nordhagen (1928), Gaare (1963), Moen (1969, 1970, 1976b), Klokke (1982) and Selnes (1982).

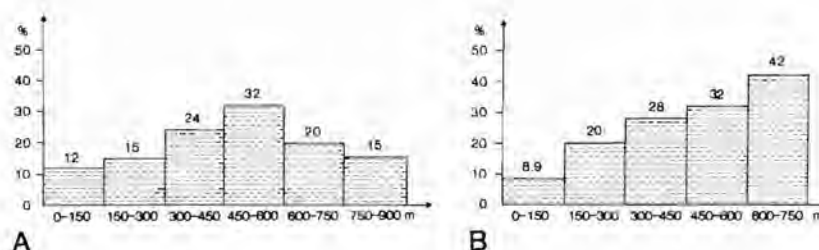


Fig. 2.3.3 The percentage of the land surface covered by mires in the counties of Sør-Trøndelag (A) and Nord-Trøndelag (B) at different altitudes, using as a basis the mire area up to the coniferous forest limit; total areas covered by mires in the two counties are 1514 km<sup>2</sup> (19% of the total area) and 2481 km<sup>2</sup> (20%), respectively. Data from the Landsskogtakseringen 1964-76, after Moen (1983) and Moen et al. (1983).

### 2.3.3 Hay fens of Fennoscandia

Moen (1987b) gave a review of the state of the hay fens of Fennoscandia, their distribution, preservation worthiness, vegetation types (11 types were described), reclamation and management methods, etc. In the **coastal section** of Scandinavia (cf. Moen 1987a), clearance, burning, scything and grazing in former times have produced the typical landscape of *Calluna* heath and open mires (cf. e.g. Kaland 1979).

Only limited areas of hay fen are found in the **nemoral**, **boreonemoral** and **southern boreal** regions, but, even so, haymaking and grazing were once important activities in many districts. The extremely rich fens and their utilisation in South Sweden have been described in detail by Tyler (e.g. 1981a, b, 1984).



In the "sloping fen region", i.e. the middle boreal, northern boreal and low alpine regions, there are wide extents of hay fens in many parts of Fennoscandia, e.g. in Trøndelag, as described previously. In these upper boreal and low alpine areas such hay fens have been of vital importance in enabling farmers to survive. In many districts the hay fens formed the main source of winter fodder. A large number of phytosociological analyses of the vegetation of these fens have been published, e.g. Booberg (1930, who also considered that scything of the fen vegetation was the main reason why *Scirpus cespitosus* and *S. hudsonianus* had become dominants on parts of the Gisselåsmynen), Sjörs (1946) and Persson (1961) for Sweden; and Ruuhijärvi (1960) and Havas (1961) for Finland. Vasari (1988) has summarized the role and history of hay-cutting in the fens at Kuusamo.

The effects of scything on the vegetation of fens, swamps and wet upland grassland in the upper parts of the boreal regions of northern Sweden have been described by Elveland (1975, 1976, 1978, 1979, 1983a,b, 1984a,b,c, 1985), Elveland & Sjøberg (1981, 1982), Elveland & Tjernberg (1984). The main descriptions of the hay fens of Central Norway are those published by myself, viz. Moen (1969, 1970, 1976b, 1985b).

## 2.4 VEGETATIONAL HISTORY OF UPLAND AREAS OF CENTRAL NORWAY SIMILAR TO SØLENDET

There are no published pollen diagrams for sites near Brekken or from adjacent areas. In this section, therefore, paleo-ecological evidence derived from sites in other areas has been used to postulate probable developments in the Brekken area, mainly in relation to the tree species and forest types. A number of peat cores have been taken from Sølendet by Lars-König Königsson in 1985, the sites for some of them on my advice, but none have yet been analysed. There is thus a likelihood that the vegetational history of Sølendet can be presented in detail at some time in the future.

### 2.4.1 Innerdalen and Øvre Forradal

Some palaeo-ecological evidence exists from sites in the upper part of the middle boreal and northern boreal regions of Central Norway. Those most relevant in the present context are the publications for Innerdalen at Kvikne (Paus et al. 1987) and for Øvre Forradal in Nord-Trøndelag (Hafsten & Solem 1976).

The valley bottom of Innerdalen is situated in the lower part of the northern boreal region, close to the border with the middle boreal region (for a general botanical description of Innerdalen, cf. Moen 1976a; for a regional description, cf. Moen 1987a), i.e. in an area with a somewhat more continental climate than Sølendet. Radiocarbon-dated pollen diagrams from nine different localities, all

situated at ca. 780 m above s.l. along the flat valley bottom of the Innerdalen (cf. Paus et al. 1987) provide evidence for the vegetational history thereabouts from the time of the disappearance of the inland ice (about 9500 years ago) up to the present day: **pioneer vegetation** - **shrub/dwarf-shrub vegetation** - **birch forest** - **pine forest** (ca. 8500-7500 years before present (= B.P.)) - **grey alder forest** (ca. 7500-4000 B.P.; with elm and hazel present ca. 6000-4000 B.P.) - **herb phases** (4000 B.P.-1600 A.D.) - **spruce phases** (1600 A.D. to the present day). Traces of human impact (forest clearance and grazing) are detectable during the past 5000 years, increasing gradually to the present.

During the **herb phases** paludification increased appreciably and the area covered by mires expanded. At the present-day, scattered, solitary trees of spruce and pine occur, but nowhere form forest. In these, as in many other respects, the present plant covers of the Innerdalen and the Sølendet areas have much in common.

The pollen diagrams from Øvre Forradal (Hafsten & Solem 1976) also show the existence of a grey alder forest phase during the period of optimal warmth (ca. 8000-3500 B.P.). These pollen profiles were taken from sites at 400-500 m above s.l. in a region of much more oceanic climate than Sølendet. Today, spruce and pine forest and vast extents of mire dominate the Forradal area (cf. Moen et al. 1976).

#### 2.4.2 Displacement of the vegetational regions during the period of warmer climate

Finds of fossil pine trunks in alpine mires in Central Scandinavia and elsewhere also provide evidence that the forest limit lay higher during the period of warmer climate. Lundquist (1969), Hafsten (1981) and Aas & Faarlund (1988) cite finds that suggest that the pine reached its highest altitudinal limit ca. 8000 B.P. Hafsten (1981) concluded that the June-September mean temperature at that time must have been about 2°C higher than at present. The finds of *Ulmus* and *Corylus* pollen (e.g. in Innerdalen, more than 200 m higher than the present localities) and the dominance of *Alnus incana* forests in these northern boreal areas at the present-day, indicates that a much warmer climate prevailed during the period ca. 8000-3500 B.P.

It seems reasonable to conclude that, in terms of the vegetational zonation (cf. Moen 1987a), an overall upward displacement of about one vegetational region, i.e. the present-day middle boreal region would previously have carried a southern boreal vegetation, etc. This very simplified concept would imply that the vegetation cover of Sølendet at that time would have been equivalent to that found nowadays in the upper part of the southern boreal - lower part of the middle boreal vegetational regions. That *Corylus* and *Ulmus* would have then been growing in the Sølendet area seems a reasonable assumption and it would also seem very likely that alder forest was once common, perhaps even dominant on those parts now covered by grassland and on parts of the rich

fen areas. Grey alder is still fairly common at Sølendet, but only occupies small areas. The main reason for this scattered occurrence is certainly the climatic conditions that now prevail.

## 2.5 PINE AND SPRUCE IN THE BREKKEN AREA

Elven (1979) mapped the recent distribution of birch (*Betula pubescens*), pine (*Pinus sylvestris*) and spruce (*Picea abies*) forests in the Røros area, and a separate, more detailed, map of the distribution of the spruce. The forest in the Aursunden area is entirely dominated by birch.

Kullman (e.g. 1979, 1981) has dealt with the dynamics of the high-altitude populations of pine and of spruce in the Swedish provinces of Jämtland and Härjedalen, the borders of which lie only a few kilometres east of the Brekken area. He has also given a survey of the occurrence and performance of these two coniferous tree species in the areas to the east of Aursunden, in the district of Røros (Kullman 1986). That paper summarizes the results of a number of older publications that described the pine and spruce forests around Røros at the turn of the century; e.g. Kellgren (1893) and Sernander (1902). The latter also included maps of the occurrences of both species and gave details of some localities in the Brekken area. Kullman (1986) stated that nowadays in the Brekken area both pine and spruce have very scattered occurrences, as solitary trees or small clones.

### 2.5.1 Pine

Pine is dominant in the valleys from the vicinity of Røros itself and southwards (i.e. on the map Fig. 3.1.2 dominant only in the southeast). Scattered occurrences of pine (not shown on any of the distribution maps) are found in the birch forest area (up to 1050 m above s.l.; Elven 1984). In some places, e.g. east of Botnen (i.e. the southern inlet of Aursunden), an island of pine forest is present within the birch forests. The Botnen locality (ca. 700-800 m above s.l.) represents the nearest occurrence of pine forest to the study area as a whole (ca. 6 km S of Sølendet); the pine is thereabouts actively recolonising since saplings and young bushy trees are common (observations made in summer 1987). Kullman (1986) stated that in this area the pine forests have advanced (ca. 4 km to the north) since Sernander's time (1902).

As regards pine in the Brekken area in general, the heavy felling during the mining era (from 1644 onwards, cf. section 3.4.1) led to a reduction in the extent of pine forest, and Kullman (1981) stated that recolonisation has been possible to only a minor degree, due to the ensuing pedological changes, (although this is not relevant in regard to its absence from the Sølendet area), and to inbreeding among the survivors.



Gaare (1963) recorded the presence of only two pines (0.5-1 m high) at Sølendet during the period 1959-1962. In subsequent fieldwork at Sølendet (1975-1987) all pine localities were noted, together with the height of the bushes/trees. After the fieldwork in 1976, altogether 18 pine localities, as trees or shrubs, were recorded at Sølendet. Only two trees were higher than 3 m, most were only 0.8-2 m high. Altogether 43 localities have been recorded for pines higher than 0.3 m (Fig. 2.5.1), but at ca. 15 of the localities these pines have since died, so that today only about 30 localities exist. 15 live trees higher than 3 m were recorded in 1987. At most of the other localities the pines were only 0.5-2 m in height and some of the smallest specimens may have been overlooked. Numerous pine seedlings (10-20 cm high) were observed during the summer of 1987, spread over the nature reserve, i.e. additional to the pine localities shown on the map. The pines are usually not scythed, and, in future, pine seems likely to become more common in the reserve. Beyond the nature reserve, the situation is the same, with scattered small pine trees and bushes present in the birch forest, on south and southeast-facing hillslopes and also, though less frequently, on the flat, sandy heathlands south and east of Sølendet.

The main cause of death of trees/bushes (most often only 1-3 m high) of pine at Sølendet is from attack by elk during the rutting season. Pine is certainly the preferred species, but other tree species are sometimes used. The elk grasps the trunk between its front hooves and twists it round whereby branches may be broken off or the entire stem broken and the tree killed (observations Nils Stenvold). Both elk and roedeer browse on pine by preference, eating the branches and the leading shoots. Nearly all the live pines found at Sølendet today show traces of treatment by elk at one time or another during their life (see Fig. 2.5.2).

In other areas of similar type to Sølendet (e.g. Nerskogen, cf. Moen & Moen 1975, B.F. Moen 1978) pine is very common in the middle boreal region, both on the heathlands and grasslands, even in the drier types of mire vegetation, but at higher altitudes in the northern boreal region, pine becomes more and more scattered. Likewise, I think that pine should be a common species (co-dominant with birch) on the southfacing areas of Sølendet and even on the flat, lower-lying areas. The main reason for the present-day absence of pine forest is certainly the heavy fellings during past centuries and decades, both by the mining industry and by farmers for building timber. The regeneration of pine forest in the Brekken area is nevertheless hampered by elk damage and the small size of the pine population, with consequent inbreeding (cf. Kullman 1986).

### 2.5.2 Spruce

Spruce forest occurs ca. 20 km away from Sølendet, in three different directions, viz. in the valleys of Gauldalen (to the NW), Neadalen (Stugusjøen to the N) and Härjedalen in Sweden (to the E). Scattered spruce trees can still

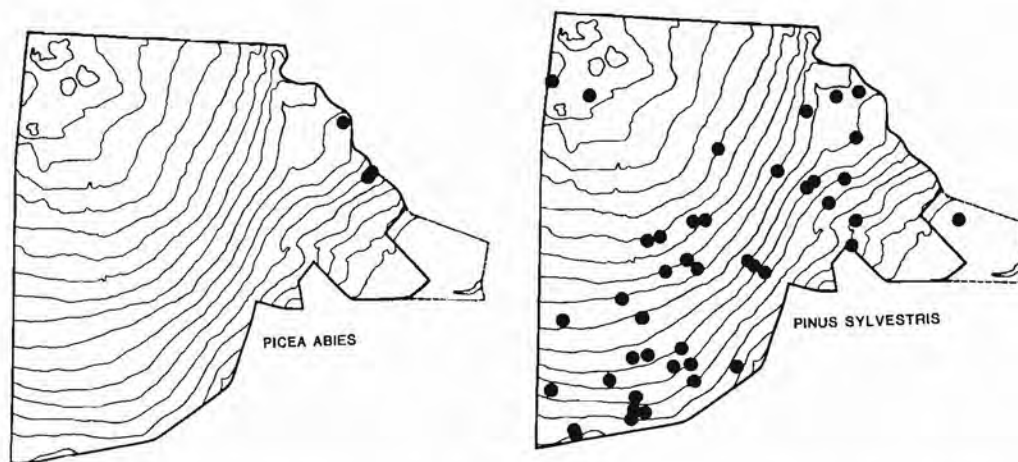


Fig. 2.5.1 Distribution maps of *Picea abies* (planted individuals) and *Pinus sylvestris* (higher than 0.3 m), recorded during 1975–1988 in the investigated area at Sølendet.



Fig. 2.5.2 Typical traces of damage by elk, seen on nearly all living pines at Sølendet. 19840523.

also be found in some places in the Aursunden area (cf. the maps in Elven 1979, Kullman 1986). In the Røros area spruce has been recorded up to an altitude of 900 m, and in the Tydal valley up to 774 m (Elven 1984). Spruce forest seems never to have become established in the Brekken area, which forms part of a wider area, mainly in the northern boreal region, from which spruce forest is entirely absent.

Small stands of planted spruce occur in the Brekken area, e.g. at Sølendet (see distribution map, Fig. 2.5.1); these saplings are growing slowly (ca. 3–4 m high ca. 35 years after planting). Kullman (1986) stated that the natural establishment of some scattered occurrences of spruce to the east of Aursunden, can all be traced back to some time during the latter half of the 19<sup>th</sup> century, and that the species has not spread further since that time. Even during the intervals of better climatic conditions during some decades of the 20<sup>th</sup> century, no spruce establishment has occurred in the Brekken area.

Kullman agreed with the view expressed by some palaeo-ecologists (e.g. Tallantire 1972, 1977), that the distribution of spruce in the Kvikne-Røros district is climatically conditioned and that no spread is likely, at least at present.

## 2.6 PREVIOUSLY PUBLISHED BOTANICAL STUDIES OF THE RØROS DISTRICT, THOSE FOR THE BREKKEN AREA IN PARTICULAR

Carl von Linné journeyed from Dalarne to Røros in 1734. His description of his travels provided the first written information that exists concerning the flora and vegetation of Røros. Further details, of that account together with a summary of the extant publications on the botany of the Røros district can be found in Elven (1979, 1984). This section primarily summarises some of the main phytogeographical/vegetational studies dealing with the Røros area and the literature relating to Brekken in particular. (Geographical position etc. is described in sections 3.1.1).

Thekla R. Resvoll and Hanna Resvoll-Holmsen visited Røros on a number of occasions during the last decade of the 19<sup>th</sup> and the first of the present century. Four of their various publications call for mention here: Resvoll (1906) dealing with the shifting sand fields at Kvitsanden; Resvoll (1942) a survey of the plant cover of Røros; Ostenfeld & Resvoll (1916), a report of *Aster sibiricus* on the lake shores of Aursunden (a new species for Fennoscandia); and Resvoll-Holmsen (1920), phytosociological analyses of alpine vegetation from the Røros district. More recently, Fondal (1955) has described the flora of Brekken and Gaare (1963) the rich fen vegetation of Sølendet (discussed in section 6).

A vast number of publications have dealt with some of the interesting plant species found at Røros, of which two deserve special mention. Dahl (1941) reported the orchid hybrid *Gymnadenia conopsea* x *Dactylorhiza traunsteineri*

(i.e. *D. pseudocordigera*), new to Norway, from a rich fen near Røros, growing together with the parent species and the suboceanic *Carex hostiana*. Skogen (1969) commented on an old herbarium collection of the suboceanic species *Pedicularis sylvatica* from Røros. Røros lies far beyond the presently known distribution limits of this species in Norway, but old records exist of *Pedicularis sylvatica* localities just across the Swedish border. This is a species found on short turf and on low-growing dwarf-shrub heath. It was previously favoured by regular scything and grazing and would seem to have become extinct in its Røros-Jämtland localities when such activities ceased. It has not been recorded there since the start of the present century.

A vegetation map of Sølendet and the surrounding area was made in 1972 by the Norwegian Institute of Land Inventory (responsible editor: Olav Hesjedal). The map was printed in colour on scale of 1:10 000; it covers an area of ca. 30 km<sup>2</sup> (Sølendet is situated ca. 1 km N and E of the southwestern corner of the map). The map forms a part of the report published by Prestvik (1973), which also described the mapping methods used and the results, together with a description of the 20 units mapped, following Hesjedal's (1973) scheme (Table 2.2.1 gives some areal extents of vegetation types on the map). Phytosociological analyses/species lists for 17 of the mapped units are included in a synoptic table that shows frequency values and degrees of cover for the vascular plant species, and frequency values for some of the bottom layer species; list of species incomplete. This incompleteness renders these analyses of little phytosociological value and I have therefore not included them in my phytosociological studies. The map, however, is valuable, because it shows the Sølendet area as a part of a larger mapped area. On comparing Prestvik's map and the enclosed map of Sølendet (covering an area 2.8 km<sup>2</sup> on a scale of 1:5 000), it is obvious that, by and large, both maps show the same picture, even though that given by Prestvik's map is much more approximate. Sølendet is dominated by extremely rich fens, wooded grasslands and mesotrophic wooded heaths (cf. section 12). Prestvik's map shows that the rich vegetation types found at Sølendet continue further westward on south-facing slopes, and also to north-eastward on east-facing slopes. In addition, rich vegetation types cover wide areas on the north-facing slopes of Dagvola, and in places to the north of Sølendet. No other area, however, contains such wide and continuous areas of extremely rich fen, nor so many springs, as the Sølendet nature reserve.

Reidar Elven has studied the vascular plant flora of Røros since 1958. Over the years he has accumulated a very comprehensive knowledge of the plant cover of Røros and the neighbouring parts of Engerdal, Tolga, Os, Ålen, Tydal and NW Härjedalen. In his unpublished manuscript (Elven 1984), he gives distribution maps and comments on the taxonomy and ecology for ca. 850 taxa found in that area. The manuscript also fully reviews the earlier botanical investigations. Although this comprehensive manuscript has not yet been published, there are three publications that yield valuable information and summaries (Elven 1978, 1979, Elven & Hveem 1986).



In all these publications Elven gave a description of the topography, geology, climate, human impact etc., together with comments on the rare species under threat of extinction, and evaluations of the preservation worthiness of the different areas. The flora mapped included the entire vascular plant material held in Norwegian herbaria; ca. 80 different persons have made collections in the Røros administrative district.

Elven (1978) described the flora of an area covering 220 km<sup>2</sup> to the north and east of Sølendet. He recorded 353 taxa altogether (included 7 hybrids) from this large area. He also brought species lists from 15 smaller areas, e.g. the Dagvola area (ca. 45 km<sup>2</sup> including the areas eastward to the Swedish border, 253 taxa listed) and the Torsvoll area (ca. 5 km<sup>2</sup>, eastwards from Sølendet, 117 taxa). Some phytosociological analyses were also included; 25 quadrats in all for woodland, scrub and mire vegetation, but because the bottom layer is incompletely recorded, I have not attempted to make any phytosociological comparisons.

Elven (1979) gave a survey of the flora and vegetation of the whole of the Røros administrative district, including a full species list (573 taxa) and a number of distribution maps, both of individual species and of species groups. The vegetation types of the Røros district were briefly described; the vegetation of serpentine outcrops in more detail, including 46 quadrats with full phytosociological information.

Elven & Hveem (1986) published some survey maps of the flora of the entire Røros district (including parts of Härjedalen, Hedmark etc.). Suboceanic species (15 taxa) are mainly found to the NW of Aursunden, species with an eastern (continental) distribution (16 taxa) are absent from the NW, but have scattered occurrences in the Sølendet area and in some southern localities (Tolga, Femunden). The southern species (= thermophilous, 48 taxa in all) grow in rock crevices in the Ålen and Røros districts, and on south-facing outcrops on Hamrafjellet in NW Härjedalen (cf. also Nilsson 1976).

### Conclusion

A large number of publications already exist that contain some information about the flora and vegetation of the Røros district. Those of Elven (the manuscript of 1984 in particular) are very comprehensive and deal with no fewer than ca. 850 vascular plant taxa. Our knowledge of the flora of the Røros district is thus quite unique for Norway, no similar sized area being botanically so well-known.

The vegetation of the Røros district is not so well-known, however, and full phytosociological analyses have so far been published for only a few vegetation types.

## 2.7 TERMINOLOGY OF MIRES AND SPRINGS

Very many different ways of classifying mires exist, cf. e.g. Løddesøl (1948), Overbeck (1975), Gore (1983) and Moore (1984). During the course of the work on the Norwegian national plan for mire nature reserves, an apposite mire terminology system for use over the whole of Norway was worked out (e.g. Moen 1973, 1983; and 1985a in English). This terminology and the criteria used in classifying the mires are for the most part in agreement with those that have commonly been used up to now in Fennoscandia (e.g. Sjörs 1948, 1983; Malmer 1973, 1985 and Gore 1983). The main emphasis in the above-mentioned scheme for mire classification has been laid on their shape and surface patterns, their vegetation cover and the composition of the flora. A brief summary only of the hydrological and geographical terms and classification system used will be given here; fuller information can be found in the references cited above. Some classification systems of mire vegetation are summarized in section 8.

### 2.7.1 Basic concepts and hydrology of mires

Mires can be subdivided into two natural types: **ombrotrophic** mires (= bogs) that receive only atmospheric (= ombrogenous) precipitation, and **minerotrophic** mires (= fens) that receive in addition, a water supply from the mineral soil (after Sjörs 1948, Du Rietz 1949, 1954). The **subsoil water-level** = **groundwater-level** (used here) is defined as the highest level at which free (hydrostatic) water occurs, and all water below this level is termed **groundwater**. Soil saturation occurs wherever the groundwater-level lies close to the soil surface.

Mires can be subdivided hydrologically into **ombrogenous** and **minerogenous** (= **geogenous**) mires. The minerogenous mires can be further subdivided into three distinct types: **topogenous** mires, which are influenced by stagnant standing water (surface of the groundwater more or less level); **soligenous** mires that are influenced by water flow (= seepage; groundwater-level not horizontal); and **limnogenous** mires which receive periodic supplies of flood water from other sources (temporary groundwater-level horizontal, having an effect similar to that in topogenous mires). The limits drawn between these three types of water supply are not always clear-cut, and it is often impossible to decide in the course of field studies to which type a particular mire area belongs. In general the ground surface beneath a soligenous mire is sloping and those of topogenous and limnogenous mires are flat. Springs were originally (Post & Granlund 1926) considered as a form of topogenous mire, but Sjörs (1946) regarded them as sometimes representing soligenous mires.

### 2.7.2 Hydrology of springs

Hydrologically, springs are classified as being either eustatic or astatic (cf. Stiny 1935, Thieneman 1942, Dahl 1957). The rate of waterflow, the water temperature and the chemical composition of the water of an **eustatic spring** remain



constant throughout the year, whereas in an **astatic spring** these parameters vary. Dahl (1957) also pointed out that, in lowland areas, the temperature of the water of an eustatic spring follows fairly closely the mean annual air temperature of the locality. In mountain areas, however, the long-lasting winter, with a snow cover, alters this parallelism in that the spring water temperature always remains somewhat higher than the mean annual temperature. The hydrology of the springs at Sølendet is described in section 3.2.4 and the flora and vegetation of such localities in section 7.

### 2.7.3 Geographical concepts, mire types

"Mire" is mainly a geographical concept that comprises both the vegetation and the substrate (i.e. the peat). In addition, the term "mire" is sometimes used to characterise the habitat. "Mire" has now become an internationally accepted term that includes both bogs and fens (cf. Gore 1983: 27).

The concept "mire complex" (Norw. "myrkompleks") was originally used by Cajander (1913); Sjörs (1948) first proposed and defined the idea of a chain of concepts: **mire feature** (myrstruktur), **mire site** (myrelement) and **mire complex**. I proposed an additional concept, the **mire synsite** (myrelementsamling) during my work on the Norwegian national plan for mire nature reserves (e.g. Moen 1983, 1985a).

The standard concepts are as follows:

**Mire feature** (Norw. myrstruktur) represents the local topographic situation where any particular plant community is growing, e.g.: hummock, string, flark, hollow (hølje), pool (gjøl).

**Mire site** (= mire element, Norw. myrdel = myrelement) is a combination of mire features, which at each site are under the influence of fairly homogeneous hydrological conditions, and designate certain large-scale topographic parts of a fully-developed mire, e.g. the lagg, soak (dråg), and marginal forest of a raised bog. The term mire element (Norw. myrelement) has previously been used by both Norwegian and Swedish authors, but is best avoided because it is illogical, since it is not an "elementary" part of a mire.

**Mire synsite** (= mire unit, Norw. myrsamling = myrelementsamling) is a characteristic combination of mire sites found on a particular mire; a few of these synsites represent important hydromorphological units, e.g. a fully-developed raised bog comprises the following sites: the open bog plain, the marginal forest, and the lagg (cf. Fig. 1 in Moen 1985a). Some mire synsites, however, may comprise only one site, e.g. in a flat fen or a sloping fen.

The synsite is the most natural unit to use when classifying mires on a basis of their shape and surface patterns, and in reality, this is the basic unit which had previously been used in the classification of "mire complex" types (cf. Sjörs 1948, Gore 1983). A detailed classification system is now in use for the whole

of Norway in the mire reserve plan, under which **mire types** (i.e. hydromorphologically-characterized mire synsites), fall into 6 main groups: Typical raised bogs, Atlantic raised bogs, Plane bogs, Blanket bogs, Mixed mires and Minerotrophic mires (fens) (cf. Moen 1985a). Each of these groups comprise two or more different types (Table 2.7.1), e.g. the last-mentioned group includes flat fens, sloping fens, and flark fens. Each of these mire types may be even further subdivided, into different subtypes, e.g. sloping fens on a basis of the degree of surface slope (cf. Fig. 2.3.2).

A **mire complex** (Norw. myrkompleks) is composed of one or more mire synsites, i.e. it refers to the entire extent of a mire as bounded by the dry surface soil. The mire complexes found in the upper boreal and low alpine regions usually consist of several mire synsites of different types. Very often, a complex includes sloping fen areas of different surface inclinations, flat fen areas and ombrotrophic areas, intermixed.

A mire complex can be characterized by the entirety of its predominant synsites (e.g. a sloping fen complex), or on grounds of a single, typical synsite. A simple classification, into ombrotrophic, minerotrophic, ombro-minerotrophic and minero-ombrotrophic types, according to the local dominance, has frequently been used in the mire reserve work (cf. e.g. Moen 1983).

Table 2.7.1 The different mire types (hydromorphological units of mire synsites) used in connection with the Norwegian national plan for mire nature reserves. (Eccentric features: regular, but not circular features). After Moen (1985a).

	x : present at Sølendet	(x): present but scarce
<hr/>		
<b>A. Typical raised bogs</b> (i.e. domed, with marginal forest and lagg)		
Concentric raised bogs		
Eccentric raised bogs		
Plateau raised bogs		
Ridge raised bogs		
<b>B. Atlantic raised bogs</b> (i.e. domed, without marginal forest and lagg)		
A.r.b. with eccentric features		
A.r.b. without regular features		
<b>C. Plane bogs</b> (not distinctly domed)		
Eccentric plane bogs		
x Marginal plane bogs		
Other plane bogs		
<b>D. Blanket bogs</b>		
Blanket bogs s.str.		
Sloping blanket bogs		
<b>E. Mixed mires</b>		
String mixed mires		
(x) Island mixed mires		
Palsa mires		
<b>F. Minerotrophic mires (fens)</b>		
x Flat fens		
x Sloping fens		
(x) Flark fens		

### 3 THE INVESTIGATED AREA

#### 3.1 GEOGRAPHICAL POSITION, PHYTOGEOGRAPHICAL SURVEY

##### 3.1.1 Delimitation

The Sølendet nature reserve is situated in Brekken parish, within the administrative district of Røros, in Sør-Trøndelag county (Figs. 3.1.1-2). It lies in the angle formed by the inflow of the Glåma river and the more northern of the two eastern arms of the lake Aursunden (water surface 690 m above s.l.). The Glåma is the longest river in Norway, with its estuary 400 km further south, near the Oslofjord. The mountain divide, forming the boundary between Norway and Sweden, lies ca. 12 km east of the reserve.

The nearest mountain areas to Sølendet are to northwestward and southeastward, about 5 km away. The nature reserve is situated in an area of gently sloping undulating topography covered by birch forest and open sloping fens.

The lowest part of Sølendet lies in the southeast, with an altitude of 700 m above s.l., and the highest part is in the northwest, at just over 800 m. The terrain is fairly flat in the southeastern and northwestern parts, the remainder having a general, though gentle, slope to the south, southeast and east. Open sloping fens alternate with birch forest with a heath and grassland vegetation, see figures 3.1.3-4, and section 3.2.3.

The nature reserve covers an area of 2854 daa. (1 daa. = 0.1 ha. = 0.25 acre). It is proposed to extend the area of the nature reserve in the future, by including a tract of land along the present southeastern margin (cf. further section 3.5). In the following sections the present nature reserve is the area referred to as the **Sølendet nature reserve**, whereas the term "**investigated area**" also includes the future extension to the SE, and the simple designation "**Sølendet**" refers to the entire area shown on the maps (Figs. 3.1.3-4), i.e. the nature reserve and a tract of land on its borders.

##### 3.1.2 Floristic phytogeography

The flora of the Røros district as a whole (cf. section 2.6) and that of Sølendet in particular (cf. section 4.1) are well known. The vascular plant flora of Sølendet includes 294 taxa, 25 of which are hybrids; the bryophyte flora includes 257 species (q.v. the species lists in Appendix B).

A more detailed description of the flora of Sølendet, including distribution maps, habitat ecology, flowering frequency, the effect of scything on species occurrence etc., will be published separately later (cf. also section 13.4).

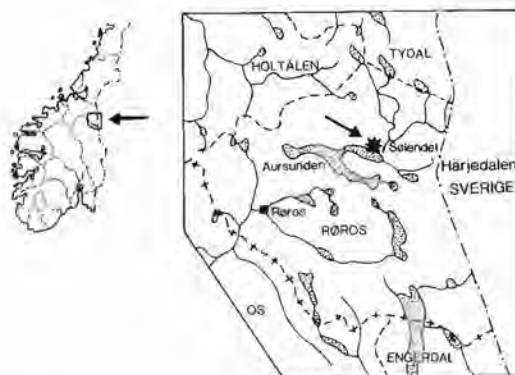


Fig. 3.1.1 Maps showing the geographical position of the Sølendet nature reserve in Norway, and its relation to the major administrative districts in the southeastern part of Sør-Trøndelag county.

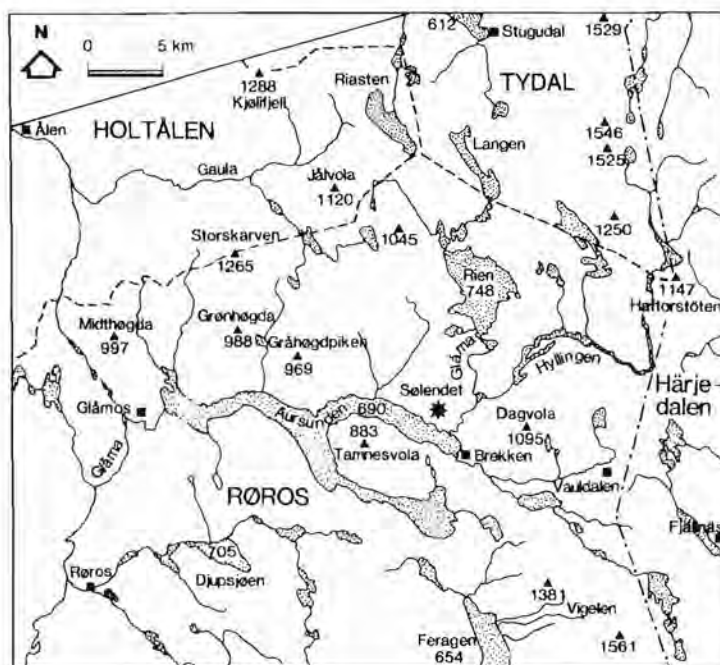


Fig. 3.1.2 Map of the northern part of the Røros district, showing lakes, rivers, settlements and mountains and their names, together with the Sølendet nature reserve.

Here, an overall survey of the four main groups of species, based on their geographical distributions in Fennoscandia will be given. The groups are heterogeneous and each of them can be split into several elements. The most important publications that have been used are: Dahl (1950), Nyholm (1954-69), Arnell (1956), Fægri (1960), Ouren (1966), Størmer (1969, 1984), Hulten (1971), Gjærevoll (1973), Sæther et al. (1980), Hallingbäck & Holmåsen (1982), Elven (1984), Lid (1985), Flatberg (1986), Hulten & Fries (1986), Moen (1987a).

### 3.1.2.1 Western species

Some of the taxa with a primarily western distribution in Fennoscandia (i.e. the suboceanic species) occur in the northern and western parts of the Røros district. Of these, *Carex hostiana* and *C. flava* x *C. hostiana* occur at Sølendet, being fairly commonly on the extremely rich fens. Farther west, in the Central Norwegian Cambro-Silurian bedrock areas, both taxa are widely distributed. They also are present in a few localities in Jämtland. Quite recently, they have also been reported from Härjedalen (cf. Danielsson 1981); both these localities are situated NE of Sølendet. The Sølendet localities represent the furthest inland ones in the eastern and southeastern parts of C. Scandinavia.

The bryophytes *Dryptodon patens*, *Racomitrium aciculare* and *Mylia taylorii* can also be included in this species group. They are all well distributed over the more humid parts of Fennoscandia. They all have very scattered occurrences at Sølendet, in shaded localities close to spring fed streams (i.e. in areas of locally high humidity).

### 3.1.2.2 Eastern species

The most typical species of this group in the Røros district, e.g. *Carex globularis* which occurs commonly in Sweden but only in the eastern parts of S. Norway, are absent from Sølendet. A large number of species with a less pronounced eastern distribution do occur (some showing a southeastern, others a northeastern pattern): *Botrychium lanceolatum*, *B. multifidum*, *Dactylorhiza cruenta*, *Daphne mezereum*, *Equisetum scirpoides*, *Galium trifidum*, *Pedicularis sceptrum-carolinum*, *Salix starkeana*, *Alopecurus aequalis*, *Calamagrostis stricta*, *Carex capitata*, *C. heleonastes*, *Poa remota*, *Dicranum drummondii*, *Drepanocladus sendtneri* and *D. tundrae*.

An even weaker trend to an eastern distribution is shown by a large number of other mire species, e.g. *Corallorhiza trifida*, *Carex buxbaumii*, *C. chordorrhiza*, *C. livida*, *C. vesicaria*, *Scirpus hudsonianus*, *Sphagnum balticum*, *S. jensenii* and *Splachnum luteum*. *Picea abies* is also often regarded as an eastern species, but only planted specimens occur at Sølendet. Its absence as a native species has already been commented on in section 2.5.2.



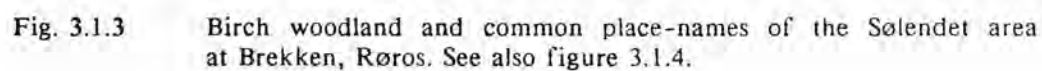


Fig. 3.1.3 Birch woodland and common place-names of the Sølendet area at Brekken, Røros. See also figure 3.1.4.



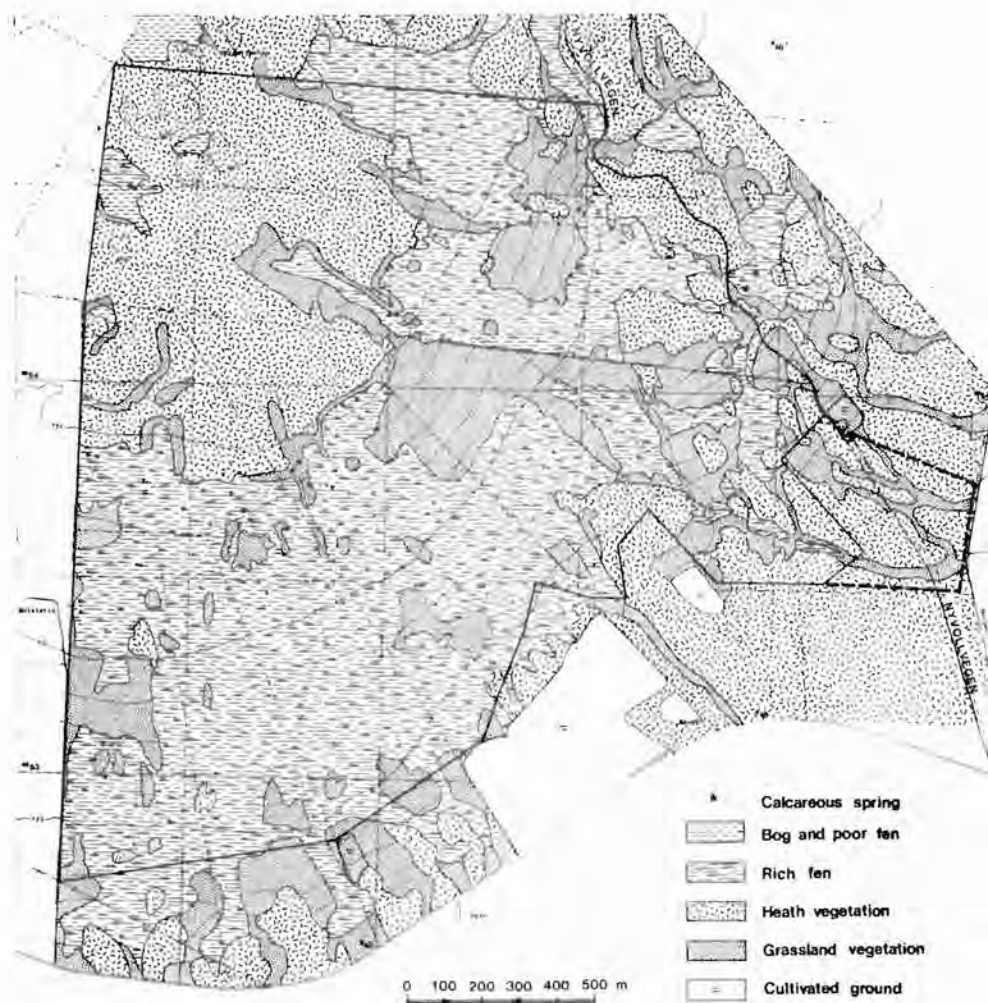


Fig. 3.1.4 A simplified vegetation map of the Sølendet area, excluding the coverage of birch woodland, which is shown separately on figure 3.1.3. These 2 maps should be used in conjunction.

### 3.1.2.3 Southern/lowland species

No species with a typical southern distribution are present at Sølendet, e.g. all those species that reach their altitudinal limits in the boreonemoral and southern boreal regions.

The species found at Sølendet that show the most pronounced trend to a southern/lowland distribution are (+: a southeastern pattern): *Alnus incana*, *Anemone nemorosa*, *Convallaria majalis*, *Knautia arvensis*, *Polygala amarella* (+), *Scheuchzeria palustris* (present just N of the reserve, at 800 m above s.l.), *Succisa pratensis* (suboceanic tendency), *Thalictrum simplex* (+), *Avenula pubescens*, *Roegneria canina*, *Brachythecium mildeanum*, *B. velutinum*, *Cirriphyllum piliferum*, *Moerckia hibernica* and *Sphagnum subnitens*.

*Carex appropinquata* has a southeastern distribution in Fennoscandia. It occurs at Sølendet close to its upper distributional limit in Norway, at 760 m above s.l. on Gråmyra and at 770 m in the Os district, S of Røros; the latter is its highest recorded altitude in Norway. The suboceanic species *C. hostiana* (as also *C. flava* x *C. hostiana*) occurs up to 780 m above s.l. at Sølendet, which is the highest altitude recorded in Fennoscandia according to the data in the literature.

### 3.1.2.4 Alpine species

A large number of species usually regarded as alpine are found at Sølendet. All of these, however, are also common in the boreal uplands of Fennoscandia. The following species show the most pronounced trend to an alpine distribution (occurring mainly in alpine and northern boreal regions): *Gentiana nivalis*, *Pedicularis oederi*, *Petasites frigidus*, *Salix arbuscula*, *S. lanata*, *Stellaria calycantha*, *Veronica alpina*, *Carex atrofusca*, *C. microglochin*, *C. saxatilis*, *Juncus castaneus*, *Kobresia simpliciuscula*.

Another very large group of alpine-boreal species that also commonly occur in the middle boreal region in Fennoscandia are e.g. *Arctostaphylos alpina*, *Diphysium alpinum*, *Epilobium alsinifolium*, *E. davuricum*, *E. hornemannii*, *E. lactiflorum*, *Salix myrsinites*, *Thalictrum alpinum*, *Viola biflora*, *Agrostis mertensii*, *Carex atrata*, *C. bigelowii*, *C. capitata* and *Juncus triglumis*. *Nigritella nigra* is another alpine-upper boreal species (fuller comments in section 11.4.4).

A number of the bryophytes found at Sølendet also occur mostly in the alpine and upper boreal regions, e.g. *Brachythecium turgidum*, *Catocopium nigratum*, *Cinclidium stygium*, *Dicranum angustum*, *D. spadiceum*, *Hypnum bambergeri*, *Meesia triquetra*, *M. uliginosa*, *Jungermannia exsertifolia* and *Lophozia borealis*.

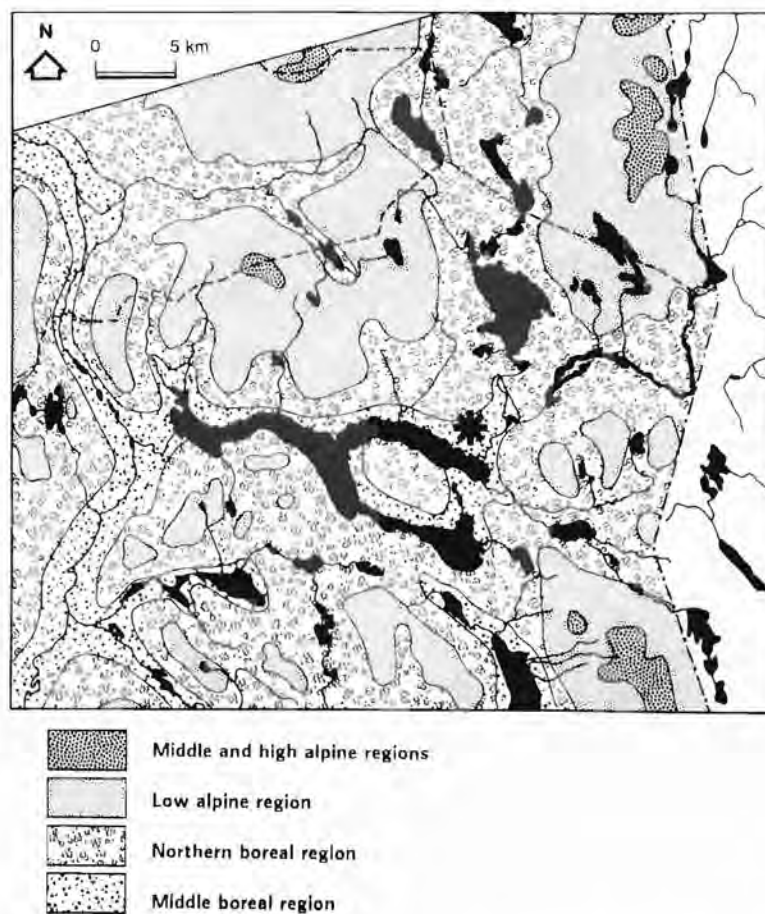


Fig. 3.1.5 The vegetational regions in the Brekken area, after Dahl et al. (1986). The asterisk indicates the position of the nature reserve.

### 3.1.3 Vegetational regions

Figure 3.1.5 shows the boundaries of the vegetational regions in the Brekken area, as they are drawn on the map published by Dahl et al. (1986). The regional criteria and a fuller description of the vegetational regions can be found in Moen (1987a).

Sølendet lies at the transition between the middle and the northern boreal regions. As the map shows, the middle boreal region comprises the south-facing slopes along the northern shores of the Aursunden lake, up to an altitude of about 730 m. On north-facing slopes the upper limit of the region is at least

50 m lower, and the areas south of the lake belong to the northern boreal. The altitudinal limit of the northern boreal region lies at about 950 m above s. l. in the Brekken area.

Sølandet as a whole, certainly exhibits most of the typical features of the northern boreal region, e.g. the dominant vegetation comprises northern boreal and alpine plant communities (of *Lactucion alpinae* and *Caricion atrofuscae*). However, at Sølandet, as on the south-facing slopes in the Aursunden area in general, lowland features, classified as middle boreal, do occur, as the species list of southern/lowland species included in the previous subsection shows. The common occurrence of *Alnus incana*, spreading into the south-facing grasslands and extremely rich fen margins, is also a typical middle boreal feature; as are the common occurrences of the following lowland fen species: *Carex appropinquata*, *C. buxbaumii*, *C. hostiana* and *Eriophorum latifolium* (a dominant species over large areas, see photo in Fig. 1.1.1).

## 3.2 GEOLOGY, HYDROLOGY AND MIRE TYPES

### 3.2.1 Solid geology

The information given in this section has been mainly compiled from the following sources: Holmsen (1942, 1956), Vogt (1955), Rui (1972a, 1981a,b), Faarlund (1975), Wolff & Roberts (1980).

The main types of bedrock in the Brekken area are shown in figure 3.2.1, of which 3 main types occur:

1. **The sparagmite group** is predominant in the eastern part of the area, towards the Swedish border. Quartzites alternate with quartzitic conglomerates. The sparagmite has a chemical composition fairly similar to that of granite. It weathers only slowly and gives rise to a poor, thin soil. As a morainic deposit it is dry and sandy.
2. **Archaean (basement) rocks** occur as domes protruding through the sparagmites. They are mainly granitic, weathering to yield a soil similar to that from the sparagmites, and a similar type of moraine.
3. **Trondheim region rocks**, which are mainly metamorphosed Cambro-Silurian sedimentary strata, occur to the west of the sparagmite area. In the Aursunden area, including Sølandet, the predominant type is a grey-green phyllite. This is a base-rich rock, yielding a fine-grained soil and a moraine type which tends to become waterlogged rather readily, leading to paludification (peat formation). The serpentine intrusions south of Aursunden, and also the scattered occurrences of amphibolite, belong to this group of rocks.

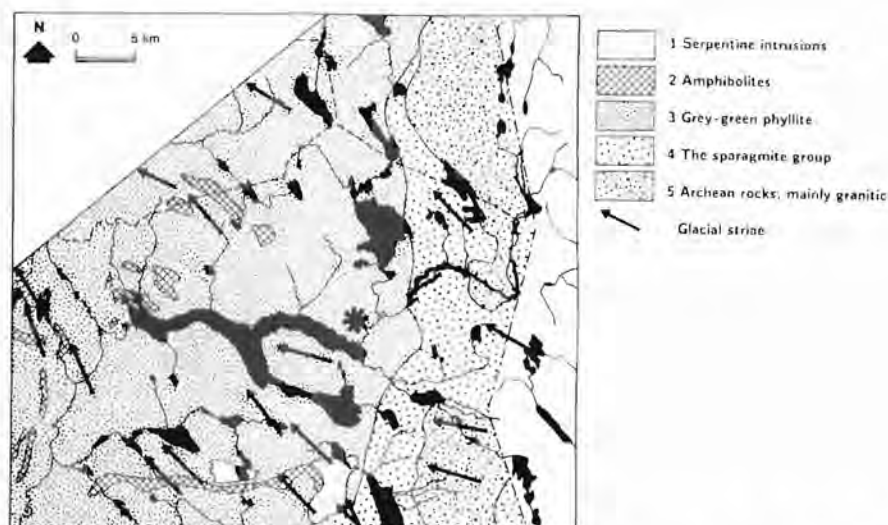


Fig. 3.2.1 Geological map of the Aursunden area showing the solid geology and the direction of the glacial striae. Sølendet is indicated by an asterisk. Mainly after Holmsen (1956), supplemented from Bakke (1977), Rui (1981a, b), Sigmond et al. (1984).

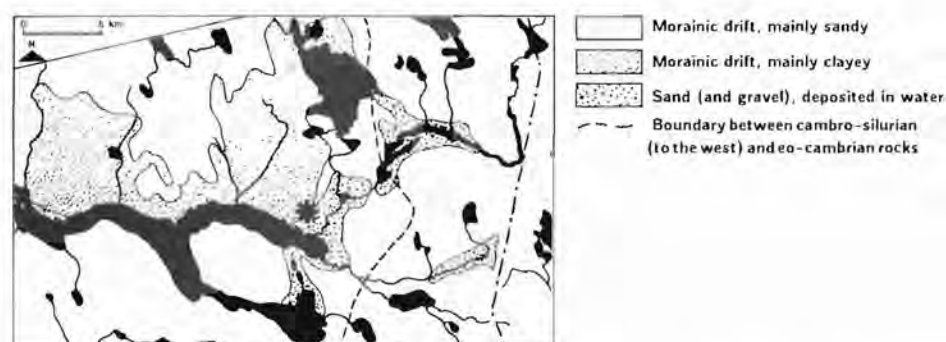


Fig. 3.2.2 Drift deposits of the Aursunden area. Mainly after Holmsen (1956), supplemented from Andersen et al. (1972) and Faarlund (1975).



### 3.2.2 Drift deposits

Figure 3.2.2 shows a simplified map of the three types of drift deposits in the area, mainly after Holmsen (1956). The map also shows the boundary between Cambro-Silurian and Eo-Cambrian rocks. The boundaries between the soil types produced by the different rock types are easily recognizable in the Brekken area. The eastern part with its poorer, coarser-grained soils, is covered mainly by wooded heathland at lower altitudes (below the alpine regions), and there are only small patches of wooded grassland and rich fens. Wide areas of rich vegetation occur west of this boundary.

The area of fine-grained soils (clayey) from the Trondheim-group rocks is extensive north of Aursunden. This area is characterised by a high frequency of mires, and the vegetation is predominantly rich fen and wooded grassland.

Judging from the direction of the glacial striae on exposed outcrops, the inland ice moved in a north-westerly direction during the final stages of the last ice-age (ca. 9000 years ago); see figure 3.2.1. This has led to erosion of the sparagmite group and deposition of sand, gravel and boulders over the area of the Trondheim-group rocks. Sparagmite erratics were recognised in this area over a hundred years ago, to the northwest of the sparagmite region (cf. Rui 1972 b).

Deposits of glacial and postglacial alluvial sediments cover large parts of the Brekken area, e.g. east of Aursunden, at Sølendet to about 706 m above s.l. (this contour is included in figure 3.2.4). These sand deposits (gravel in the eastern part, e.g. east of Hyllingen) are present in the form of terraces, and the origin of these are discussed in papers such as those by Holmsen (1956) and Nordseth (1984).

Faarlund (1975) analysed the surface sediments in the Øvre Glåma area as a whole, including two sites in the southeastern part of the Sølendet area. He found that the sediments were deposited in water and were mainly composed of a uniformly fine-grained sand (mean grain sizes 0.16 and 0.22 mm.). These deposits are readily visible in a cutting ca. 10 m in height, made by the river Glåma, about 500 m SE of the Sølendet area (cf. Holmsen 1942: Fig. 3).

Most of the Sølendet reserve is covered by drift deposits, though only a thin soil cover masks the bedrock outcrops in a few places, e.g. at Dalholmen. Three types of drift are common:

1. Fine-grained sand (Norw. "Kvabb") is predominant on the flatter parts below an altitude of ca. 706 m.
2. Phyllitic bottom moraine is the predominant deposit throughout the study area. It is fine-grained, with a high proportion of clay particles, yielding a nutrient-rich soil, with a rich vegetation, but readily waterlogging, with ensuing paludification.



3. Sparagmitic and Archaean rock moraine areas. These are readily recognisable from the occurrence of surface erratics, often as boulders ca. 1 m in diameter, although in other places the moraine may be more fine-grained and difficult to separate from the other drift types. The granite and granite-like rocks yield a soil poor in basic minerals. It seems reasonable to assume that these poorer moraines dominate some ridges at Sølandet, mainly covered with poor heathland.

### 3.2.3 Hydrology of the Aursunden area

The groundwater conditions in the Øvre Glåma river basin have been described by Andersen et al. (1972); additional information has been provided by Norges Vassdrags og Elektrisitetsvesen (NVE), Grunnvannskontoret, both by letter and by data print-outs (Dec. 8 1987; Jan. 18 and March 3 1988). They monitor 16 wells, dug for recording the changes in the groundwater-level, some of which have been in existence for more than 20 years. Vast quantities of subsoil water are present in the alluvial deposits of the Øvre Glåma watercourse.

The typical situation for a well station at Aursunden is shown by the geolimnogram reproduced in figure 3.2.3, which shows the mean monthly groundwater-levels for the years 1974-1987, together with the maximum and minimum values. The groundwater-level starts to rise at some time during the second half of April or the first half of May. The rise is sudden and strong, reaching its maximum during May. The groundwater-level then falls during June, July and August. The level rises once more in the course of September and October. There is a regular decline in the groundwater-level throughout the winter months right up to the time that the snow starts to melt, whereafter the level rises once more.

The lowest annual groundwater-level is recorded in all the wells at the end of the winter, i.e. the second half of April or the first half of May. Most wells show a second minimum during September, often close to the annual minimum value.

The maximum groundwater-level varies markedly from one well to another. In some of the wells, the rise following the snow-melt is the only high-level period, whereas in others there are two maxima, one in spring and the second in the autumn.

The pattern shown by most wells is fairly uniform. The maximum and minimum levels are attained more or less contemporaneously and the fluctuations in all the wells follow more or less the same pattern. The magnitude of the fluctuations, however, varies from well to well. Figure 3.2.3 shows the geolimnogram for a well with quite a high annual amplitude. The groundwater-level only subsides slowly during the summer, probably due to the fact that the subsoil

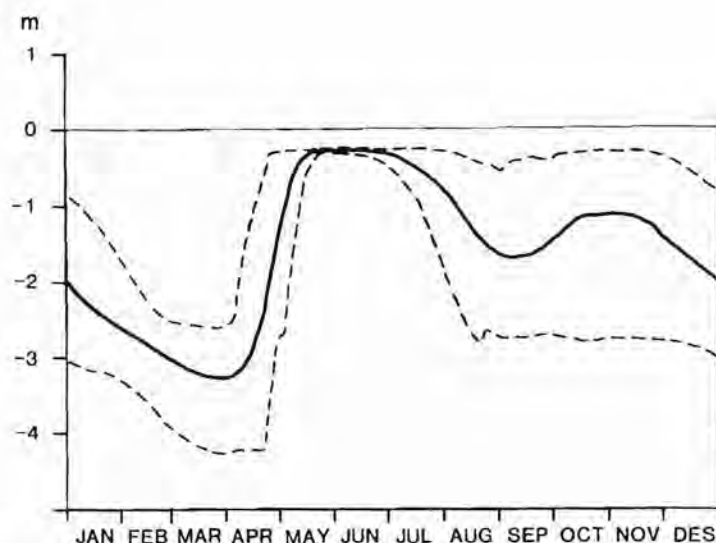


Fig. 3.2.3

Geolimnogram for the well station at Røkbuvoll (no. 4006, altitude ca. 700 m above s.l.) showing the mean monthly values for the groundwater-level for the period 1974-1987, together with the maximum & minimum values (data from NVE, Grunnvannskontoret).

is rather fine-grained (high proportion of clay particles), i.e. has a high water-retaining capacity. This well lies ca. 4 km west of Sølendet, in an area with a similarly clay-rich morainic soil. Wells situated in sandy or gravelly areas show relatively rapid and wide fluctuations in their water-levels. Wells situated on flat mire areas show little variation in their water-levels throughout the year.

The fluctuations in the groundwater-levels of the areas of Sølendet that are influenced by spring waters, or the flat mire areas, are relatively minor throughout the year. The situation shown in figure 3.2.3 is probably fairly typical of the groundwater-level changes on sloping areas of mineral soil in general, i.e. for large parts of Sølendet. The groundwater-level situation on the mires of Sølendet will be dealt with more fully in section 5.

#### 3.2.4 Hydrology of Sølendet; springs

A good number of springs occur at Sølendet, mostly situated 750-780 m above s.l. (see Fig. 3.2.4 on which the position of more than 50 springs is mapped). There is a gradation from those that represent only a weak and diffuse outflow of groundwater to astatic and to eustatic springs (for terminology see section 2.7.2). Only the most marked springs have been plotted on the map and the differentiation into two types has been made subjectively, mainly based on personal experience of the extent of flow during the summertime. Springs shown

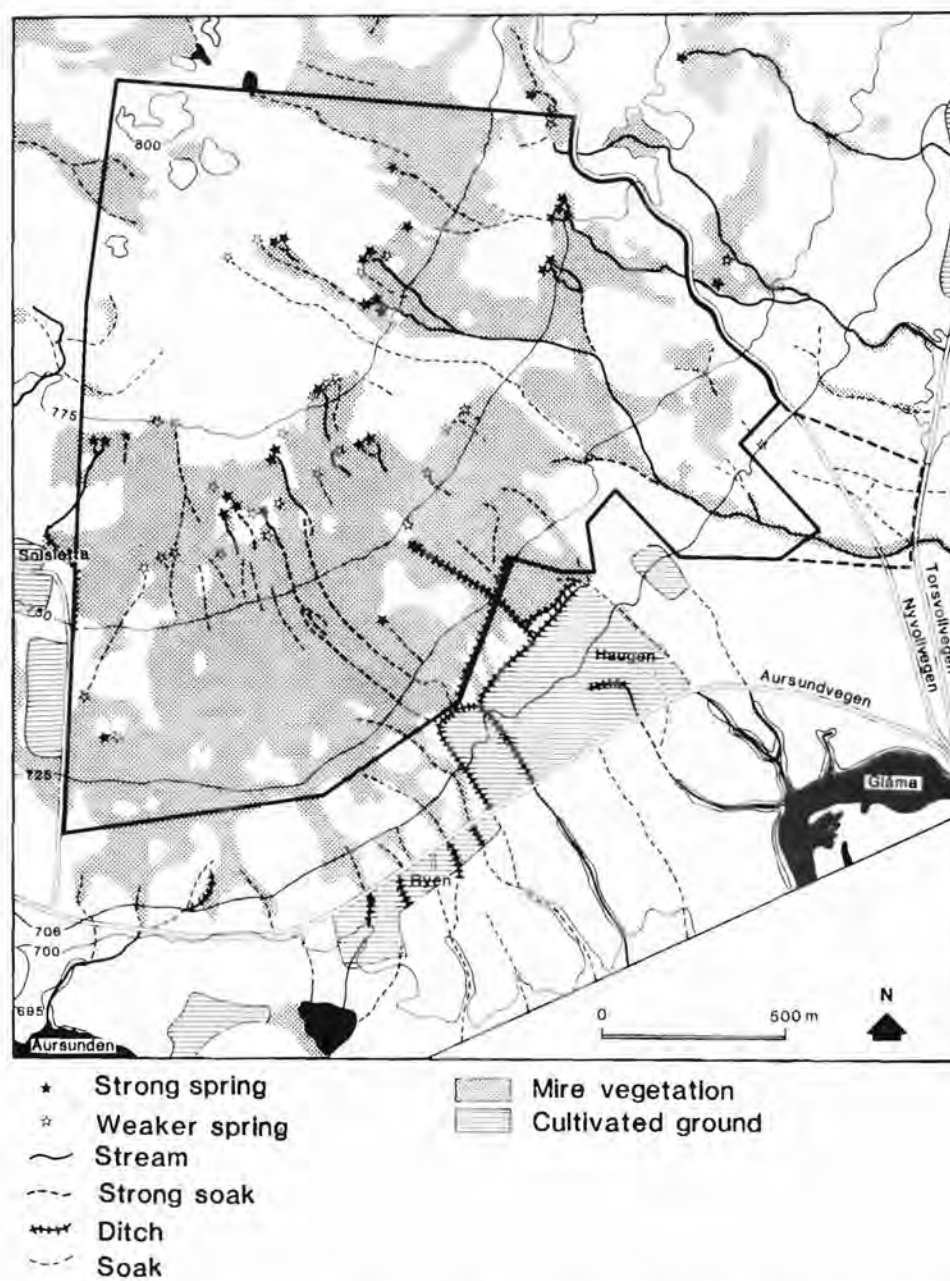


Fig. 3.2.4 Map of the Solendet area showing various hydrological structures.

as "strong springs" are mainly eustatic and they are active throughout the summer. Water temperature measurements made in two of these springs (localities 93 & 95, see Fig. 4.3.1) show that it is fairly constant throughout the year (cf. section 7.2.1.2). Water analyses indicate pH values of ca. 7.8 and conductivity values (corrected at 20°C) of ca. 180  $\mu\text{S}/\text{m}$ . The eustatic springs carry calcareous, mineral-rich water to the fen surface throughout the year.

The spring water supply is usually spread out fairly evenly over the fen surface, starting either at a point just below the outflow, or at first following a small stream/soak for a short distance before spreading laterally (see Fig. 3.2.5). Over the fen surface, the spring water supply spreads to form quite broad soaks or flushes before flowing down into a stream. A few of the springs drain directly into a distinct streambed.

After permeating through the peat, the water collects on the lower-lying parts of Sølendet to drain away along small valleys (Norw. "Vassdal") that run across the flat, sandy areas, either as subsurface flow or sometimes forming a visible stream. These streams/soaks eventually drain into the Glåma river or the Aursunden lake. In springtime, the springwater becomes mixed with snow meltwater, the groundwater-level is high and large parts of Sølendet are flooded, viz. nearly all the fen areas and a large part of the grasslands, which thus receive a supply of calcareous water at this time of year, e.g. all the soak areas shown on figure 3.2.4 have water on the surface (see Fig. 3.2.6). The hydrological conditions in one of the main drainage "valleys" of Sølendet are described, by means of transects and profiles in section 7.3.

The hydrology of Sølendet (shown in Fig. 3.2.4) well explains the extensive occurrence of extremely rich fens and of a variety of grassland types. The grassland types found on the flat, sandy areas in the south and southeast are of particular interest, since these are only flooded by calcareous water in springtime. During the rest of the year the groundwater-level lies well below the surface (cf. the description given in section 9.7).

The grey-green phyllite, which is the predominant bedrock in the area, together with the fine-grained morainic soil that is the main subsurface deposit at Sølendet, explain the occurrence of calcareous soils and mineral-rich groundwater. Why though, are there so many and such strong springs present at Sølendet? The eustatic springs receive their water supply from an appreciable depth, so two possible explanations exist: 1. The groundwater comes up through fissures in the bedrock, or 2. it arises from deep layers of drift.

As described previously, surface deposits, glacial drift of different types, are present at Sølendet, which hold appreciable quantities of water. In general, the groundwater-level in the drift deposits follows the surface contours of the ground, and the water flows from higher to lower levels. The Sølendet terrain slopes gently to southward and eastward, but to the north and west of Sølendet, the surface does not rise very much (q.v. Fig. 3.2.7). Little of the



Fig. 3.2.5 An eustatic spring at Storholmen, showing the outflow and the spring-fed stream. At the margins the extensive vegetation-free areas (dark colour on the photo) are caused by heavy grazing by voles during the winter-time. 19770607.



Fig. 3.2.6 The typical spring situation on the lower-lying parts of Sølendet; the grasslands are flooded. Locality no. 81. 19840523.







The most reasonable conclusion is that the water supply to the Sølendet springs comes from fissures in the bedrock, where the water is under pressure (such fissuring is quite common in the phyllites of the Cambro-Silurian bedrock, cf. Andersen et al 1972: 6). Various types of bottom moraine, of different ages, occur in the Sølendet area (Leif Sørbel, pers. comm.). The fine-grained phyllitic moraine that covers the central parts of Sølendet readily becomes waterlogged and the groundwater is mainly forced to the surface at the upper margins of these moraines. This also explains why there is a fairly uniform spring-line altitude.

### 3.2.5 The Sølendet mire types

Most of the mire-covered areas of Sølendet are inter-connected and may be regarded as forming a single, vast mire complex (for mire terminology cf. sect. 2.7). Within the nature reserve itself, this complex, split up by patches of woodland and crisscrossed by soaks and small streams, covers ca. 1.3 km<sup>2</sup>; this mire complex is furthermore connected with large expanses of mire present beyond the reserve boundaries. This large complex is dominated by sloping fens, and, by and large, the Sølendet mires may be regarded as forming a vast sloping fen complex. Figure 1.1.1 shows a typical picture of the Sølendet sloping fens.

The surface of the largest fen areas has an inclination of 3-5‰ (in some parts up to 7‰); the depth of the peat is in general the thinner the greater the surface inclination. The sloping fens usually have a peat depth of (0.1)0.2-0.4 m, the flat fens often one of ca. 1 m. Small areas of flat fen (inclination 0-1‰) are present mainly in the northern parts and on the southern margin of the reserve. Quite large areas are covered by mires that are transitional between flat fens and sloping fens (i.e. fen areas with an inclination of 1-3‰; see Fig. 3.2.8).

Within the mapped areas of flat fens and the types transitional between flat and sloping fens, instances of two more mire types (see Table 2.7.1) occur: 1. **Flark fens** with very low, lawn-dominated strings and carpet-dominated flarks occur in a few places, but cover only very small areas. It seems reasonable to assume that regular scything for hay in the past has prevented them from developing any further. 2. **Island mixed mires**, with islands of hummocky ombrotrophic vegetation separated by carpets and lawns of fen vegetation. Such bog "islands" are most often 1-5 m<sup>2</sup> in area. Some of them include a patch of pure, ombrotrophic vegetation, but very often, and always in the small and low islands, typical fen species occur, which are rooted in the deeper-lying fen peat strata. There are scattered occurrences of such bog "islands" in a number of localities (see Fig. 3.2.9), but they only cover small areas, and are not separated off as Island mixed mire synsites in figure 3.2.8.

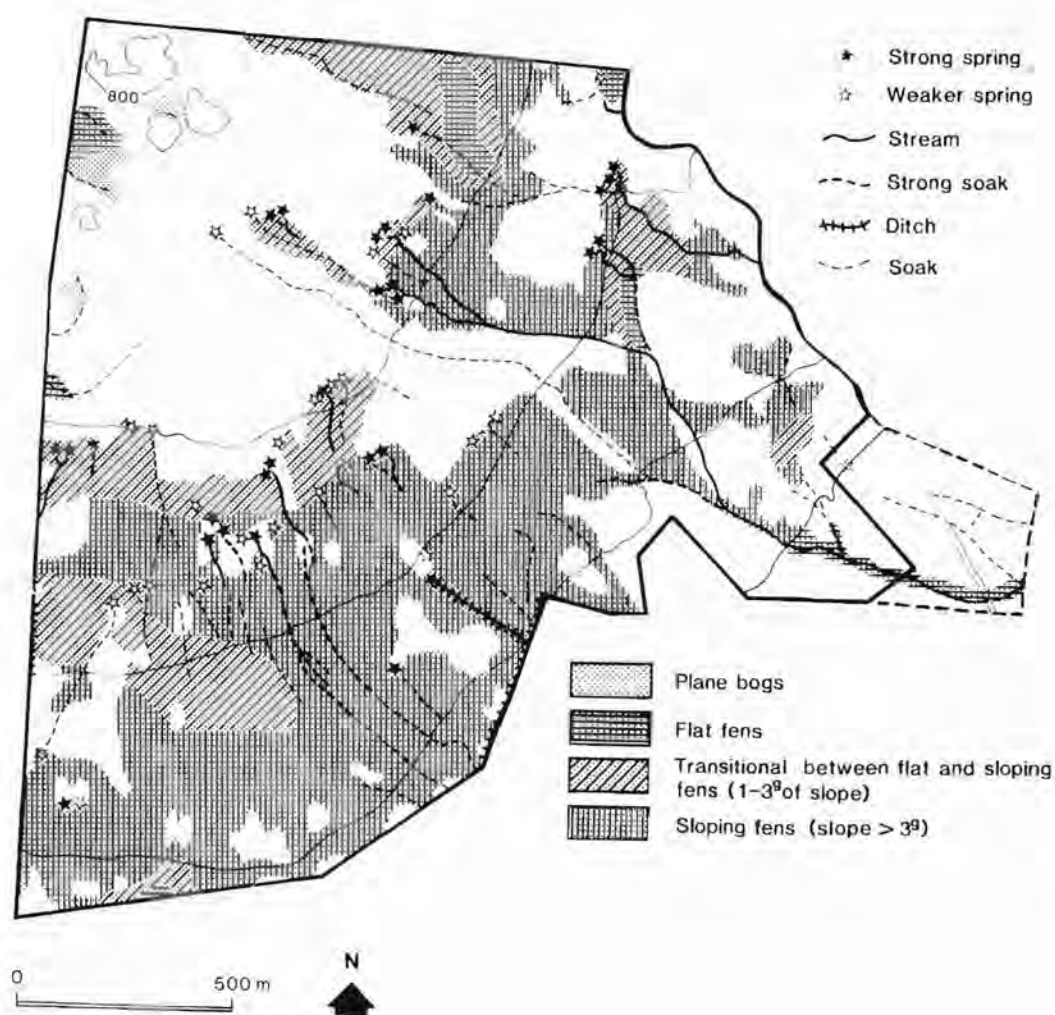


Fig. 3.2.8 The main mire types (hydromorphological types) of the Sølendet nature reserve; fen differentiation is based on the surface inclination. (Map basis as Fig. 3.2.4).

In addition to the main (sloping fen-dominated) mire complex at Sølendet, four smaller mire complexes occur in the northwestern part of the reserve (see Fig. 3.2.8). One of these complexes is a flat fen, one is a mixture of flat fen and plane bog, and two are plane bogs. The **plane bog synsites** (dominated by ombrotrophic vegetation) account for ca. 0.5% of the nature reserve. The plane bogs belong to the marginal type (cf. Moen 1983a), i.e. hummock-dominated, flat bogs with little or no differentiation between the bog expanse and the



Fig. 3.2.9 A flat fen area including an "island" of ombrotrophic hummock (locality 89) in the foreground, some more hummocks in the background. 19760807.



Fig. 3.2.10 The plane bog area of Rymyra, locality no. 71 marked by the rucksack. 19780531.

bog margin. The type was described as "Marginalhochmoore" in Nordhagen (1928). The peat of the plane bogs is deep, e.g. at locality no. 71 (see Fig. 3.2.10) peat depth is 1.40 m. The vegetation, described as type M18 in section 5.4, is dominated by *Betula nana* and dwarf-shrubs in the field-layer and *Sphagnum fuscum* in the bottom layer. There are none of the typical ombrotrophic hollows, but small depressions occur in which the vegetation is dominated by *Sphagnum balticum*. These plane bogs have developed by heavy peat growth on areas of flat fens in localities not subject to regular flooding by snowmeltwater in springtime. The plane bogs are usually to be found on flat areas near a watershed, or in areas shielded from floodwater or seepage. There is a lagg (usually weak) between the ombrotrophic parts and the higher-lying mineral ground.

### 3.3 CLIMATE

The sites of the nearest meteorological stations to the Sølendet reserve are shown in figure 3.3.1. Only one of these, that at Røros (628 m above s.l.), is still maintaining full records, including temperature. The one at Stugudal (615 m) kept temperature records for only a short period (1921-26). Kongens gruve station (856 m) was operative throughout the normal period 1901-1930, but was closed down in 1934. Tyvoll (664 m) was closed down in 1924 and, like the remaining 3 stations, only recorded precipitation and not temperature. The data and information given in this section have been compiled from the following sources: Norske Meteorologiske Institutt (1949 & 1957, plus additional precipitation data supplied in March 1980), Bruun (1967) and Kullman (1979).

#### 3.3.1 Temperature

The mean annual air temperatures for the normal period 1931-60 are shown in table 3.3.1 for three meteorological stations, all about 25 km away from Sølendet, together with the means for January and July. Røros and Stugudal both lie 100 m below the altitude of Sølendet and are typical valley-floor stations.

Table 3.3.1 Mean air temperature (normal period 1931-1960) for three meteorological stations near to Sølendet (after Bruun 1967).

Station name	m above s.l.	Standard normals		
		Year	January	July
Stugudal	615	1,5	-7,5	12,3
Kongens gruve	856	-0,1	-9,4	10,9
Røros	628	0,5	-11,2	12,4



Fig. 3.3.1

Position of the meteorological stations situated closest to Sølendet, together with the isohyets for 500, 600, 700 and 800 mm per year, taken from Aune (1981).

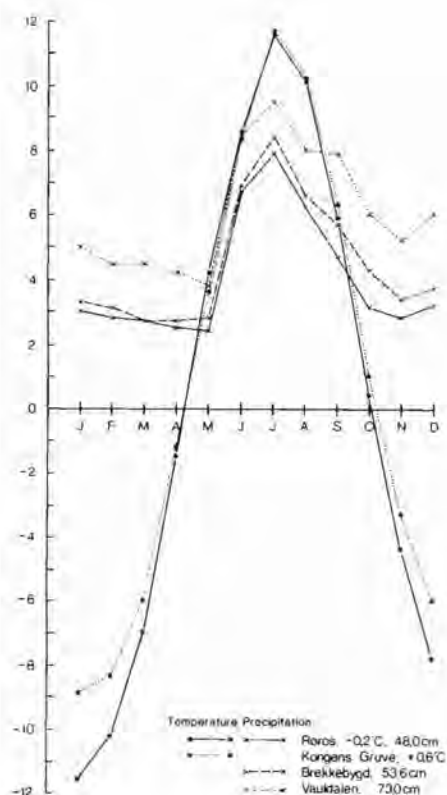


Fig. 3.3.2

Mean annual and monthly temperatures (normal period 1931-1960) in °C, and the mean annual values of precipitation (in cm) for the meteorological stations at Røros, Kongensgruve, Brekkebygd, and Vauldalen. The air temperatures are those presented by Bruun (1967), adjusted for altitude, assuming a lapse rate of 0.6 °C per 100 m, as given by the Norske Meteorologiske Institutt (1957: 46), who also supplied the precipitation data.



It is well-known that Røros, in particular, is very often affected by temperature inversions in the wintertime (cf. also Johannesen 1942). The air temperature recorded at station level is then appreciably lower than that a few hundred metres higher upslope. The station formerly operated at Kongens gruve was situated about 100 m above the altitude of Sølendet, on an east-facing hill-slope close to the forest limit. The low mean value for Røros for January is partly explained by the inversion phenomenon, mentioned above. When allowance is made for the difference in altitude of the 3 stations, and using a lapse rate of  $0.6^{\circ}\text{C}$  per 100 m, there is then little difference in the mean values recorded.

Standardisation of the annual and monthly mean temperatures to the same altitude as Sølendet (740 m) yields the results shown in figure 3.3.2, for Røros and Kongens gruve for the normal period 1931-1960. In general, Sølendet lies on a south-southeast-facing hillside, with only a small area on the flat valley bottom near the Aursunden lake. Temperature inversions are known to occur at times during the winter on this flatter area, according to the local inhabitants. Otherwise, the temperature conditions recorded at the Kongens gruve station would seem to be representative for Sølendet as a whole. In other words the annual mean temperature value is about  $+0.6^{\circ}\text{C}$ , the January mean about  $-9^{\circ}\text{C}$  and the July mean about  $+11.7^{\circ}\text{C}$ .

Tuhkanen (1984) considered that the "biotemperature" (following Holdridge) provides a better indication of the climatic conditions as they affect the vegetation. He used the gradational changes in these values to characterise the boundaries between his vegetational zones, e.g. a biotemperature of 4.25 represents the delimiting value for the middle and northern boreal zones, and 3.25 for the northern boreal and hemiarctic zones. He arrived at these particular values by examining the correlation between the biotemperatures and the vegetational zones (after Ahti et al. 1968) in northwestern Europe, particularly in Finland, Sweden and northern Norway. The biotemperature value is calculated as the sum of the values above  $0^{\circ}\text{C}$  of its monthly mean temperatures, divided by 12. The calculated value for Sølendet is 3.4 (based on the tabulated values for Røros and Kongens gruve). On Tuhkanen's criteria, the value, however, would assign the area to the upper part of the northern boreal zone!

In vegetational terms, however, the south-facing slopes, north of Aursunden, belong to the middle boreal region, up to an altitude of 720-740 m, and similarly for the north-facing slopes and flatter areas up to about 650-700 m above, s.l. (cf. Fig. 3.1.5). Even at these altitudes, though, the calculated biotemperature value is far too low to square with Tuhkanen's vegetational classification. Even the value for Røros (628 m above s.l.) of 3.8, would place it well in the upper half of his northern boreal zone.

In conclusion, the limits of the vegetational regions of the Brekken area as shown on figure 3.1.5 differ appreciably from the classification based on the biotemperature values and their correlations cited by Tuhkanen (1984). These differences are too great to be explainable in terms of exposition and better soil conditions (i.e. south-facing slopes and a calcareous drift).

**Table 3.3.2** Mean annual and seasonal precipitation data for certain meteorological stations near to Sølendet (as supplied by the Norske Meteorologiske Institutt, and from Kullman (1979: Fjällnäs)). The normal period 1931-1960 applies to all except Tyvoll and Kongens gruve (asterisked), for which the normal period is 1901-1930. The last column shows the values for the mean precipitation during the months June-Aug. expressed as a percentage of the total annual precipitation.

Station name	m above s.l	Precipitation				
		in mm				%
		Annual	Nov.-Jan.	June-Aug.	May-Aug.	
Stugudal	615	689	134	251	285	36
*Tyvoll	664	680	165	222	259	33
*Kongens gruve	856	497	86	214	243	43
Aursund	685	730	177	228	268	31
Røros	628	480	90	208	232	43
Brekkebygd	712	536	104	219	247	41
Vauldalen	830	730	162	259	297	35
Fjällnäs	795	666	-	-	-	-

### 3.3.2 Precipitation

The precipitation data are not as homogeneous as those for air temperature (Fig. 3.3.2 & Table 3.3.2). The isohyets (standardized data) for the Brekken area, after Aune (1981), are shown on figure 3.3.1. This shows a precipitation gradient across the area, from over 800 mm per year in the northwest to under 500 mm in the southwest. Sølendet itself lies between the isohyets for 600 and 700 mm/year. This seems reasonable, although the mean annual value for the station at Brekkebygd (712 m above s.l.) is only 536 mm. Precipitation increases with altitude, generally speaking, as shown by the respective mean values for Vauldalen (830 m) and Fjällnäs (795 m), both to the east of Brekken; 730 and 666 mm/year.

A summary of the climatic and hydrological data for the catchment area of the Øvre Glåma, and for the river itself, has been provided by Nordseth (1984). Information on the regional and seasonal water-flow conditions exists from a chain of hydrological stations. Nordseth concluded that the regional differences are quite marked, the highest values being recorded in the northern part, with a gradual diminution southwards, cf. Hegge's (1978) map of the water-flow rates

at different places, from north to south, in Østlandet (East Norway). Nordseth (op.cit.) has calculated that the mean annual precipitation (flow-off + evapo-transpiration) for the entire Øvre Glåma catchment area is 993 mm. This catchment includes much alpine country, over which the precipitation is much greater than at lower altitudes around the Aursunden lake.

The data for precipitation recorded by the meteorological stations (Table 3.3.2) show a wide variation. Kongens gruve, for example, reports very low mean values and would seem to be unrepresentative for the northern part of the Røros district, just as the Brekkebygd values would seem to be too low to be representative for Sølendet (cf. the isohyet maps given by Aune (1981) and Hegge (1978), as well as Nordseth's comments (1984).

The mean precipitation values for all the stations listed are highest during the summer months, those for the period June-August range from 210 to 250 mm. Least precipitation falls in the spring, e.g. the values for May for the tabulated Norwegian stations range from 24 mm (Røros) to 40 mm (Aursund). Marked regional differences are found throughout the year. Precipitation in the northern parts is much greater in wintertime than it is in the southern parts. The values for Røros and Brekkebygd for the late autumn and winter period are less than a half of those for the summer months. The differences are much smaller for the Aursund and Tyvoll stations. Since most, or all, of the precipitation falling in winter is in the form of snow, this implies that the snow cover in the southern parts is less than in the north (cf. section 3.3.4).

Since the Brekkebygd station values appear to be rather too low to be representative for Sølendet, a mean annual precipitation of 600 mm has been assumed in all further considerations (i.e. a value between those for Brekkebygd and Vauldalen, in Table 3.3.2). More than a half of the total annual precipitation at Sølendet falls during the months June-September, at a time of year when the winter snow-cover no longer has any influence on the vegetational conditions.

### 3.3.3 Oceanicity and humidity

Terms such as oceanicity, continentality, maritimity and humidity have been defined in a multitude of different ways by phytogeographers, and various indices have been proposed (Tuhkanen 1980).

#### 3.3.3.1 Oceanicity/Continentality

The terms oceanicity and continentality can be defined on a basis of the air temperature regime, using the Conrad index (after Tuhkanen 1984). This is a conventional thermal index, based on the view that in an oceanic climate the annual temperature range is small, whereas in a continental climate the range

is great. The Conrad index of continentality (C) is expressed by the equation:

$$C = \frac{1.7A}{\sin(\varnothing + 10^\circ)} - 14$$

where A is the annual temperature range and  $\varnothing$  is the latitude of the locality concerned.

Using the air temperature values recorded at the Kongens gruve station, the C value for Sølendet works out at 23 (using the values for Røros shown in Fig. 3.3.2 yields a C value of 27).

According to Tuhkanen (1984), C values of between 20 and 35 are characteristic for his O<sub>1</sub> sector, i.e. intermediate between an oceanic and a continental climate.

On the map published by Tuhkanen (1980, Fig. 35) showing the C values (as isolines) for Sweden, Finland and northern Norway, the most continental parts, in northern Finland and northern Sweden, have C values of ca. 34, compared to values of 20-30 for the central part of Sweden.

In the present paper the terms **oceanicity/continentality** are used less precisely, including conditions related to temperature (also called thermal oceanicity) and precipitation.

### 3.3.3.2 Humidity/Aridity

The humidity is a function of precipitation and air temperature at any particular time of year. That most relevant for plant life is the growing season, although the amount of moisture stored in the snow cover and released during the spring snow-melt is also important. A number of different indices have been proposed to express humidity (cf. Tuhkanen 1984 for a review). Three of the simple methods will be considered here:

1. The Martonne aridity index (e.g. Tuhkanen 1980) is one in common use. Humidity is expressed as

$$H = \frac{P}{T + 10}$$

where P is the annual mean precipitation (in mm.) and T is the annual mean temperature (in °C). The calculated Martonne value for Sølendet (740 m above s.l., assuming P = 600 mm and T = 0.6°C) is about 57, compared to values for Røros (628 m) and Stugudal (615 m) of 46 and 64, respectively. According to Hesselman (1932), this implies that Sølendet lies within an area of humid climate (an H value of 60 characterising a super-humid climate). Dahl (1950) has published a map of the Martonne index values for the Nordic countries as a whole.

2. The Tamm index. Tamm (1954, 1959) calculated humidity as the annual precipitation less the amount of evapotranspiration. The latter is difficult to estimate reliably. Tamm based it on estimates of air temperature and precipitation. Tamm's humidity index (H) is expressed by the equation:

$$H = P - E = P - 29 (7.63 + T)$$

where P is the annual mean precipitation, E is evaporation and T is the annual mean temperature (°C). The Tamm index values for Røros (628 m above s.l.) and Stugudal (615 m) are 244 and 424, respectively. The H value for Sølendet (assuming P = 600 mm and T = 0.6°C) is about 360. According to Tamm (1959), values of 200-400 are typical for a "normal humid region" and of 400-600 for a "strongly humid region". Sølendet thus lies close to the boundary between these two regions, but still within the "normal humid region".

3. Tuhkanen (1980, 1984), considered that the summer precipitation value provides a simple, yet relevant, indication of the humidity of a locality. He has published (Tuhkanen 1980: Fig. 36) a map of the values for summer precipitation expressed as a percentage of the total annual precipitation for Sweden, Finland and northern Norway. Values above 45 %, in these parts of Fennoscandia, are only found on the Finnmarksvidda in Norway. Even values over 40 % are found over relatively small areas. The calculated values for the 7 meteorological stations closest to Sølendet are shown in table 3.3.2. The values for Røros and Brekkebygd are 43 % and 41 %, respectively, those for the other 5, with the exception of Kongens gruve, all lie between 31 % and 36 %.

Tuhkanen (1984) subsequently published a classification of the humidity provinces in the circumboreal zone in North America and Eurasia based on the amount of precipitation falling during the period May-August. The values for the 7 stations near Sølendet are shown in table 3.3.2. They vary from 232 mm (Røros) to 297 mm (Vauldalen). The limit drawn between the humid and the perhumid provinces (Tuhkanen 1984: Fig. 5) in the northern boreal zone lies at 275 mm. in the sector O<sub>1</sub> where Sølendet belongs, cf. the continentality index referred to previously. Sølendet thus lies at the transition between these two provinces.

### 3.3.4 Snow-cover

The snow-cover data (for the normal period 1901-30) for two of the stations in our area are shown in table 3.3.3. Brekkebygd (715 m above s.l.) recorded a mean annual value of 203 days with a snow-cover and a mean snow depth of 29 cm. The respective values for Vauldalen (828 m) were 221 days and 28 cm.

The snow-cover conditions vary widely from place to place, and the meteorological stations are more or less representative in this respect. Elven (1984) characterised the Brekkebygd station as one with a thin snow-cover because



it is subject to strong winds. Nordseth (1984), in fact, considered that the snow depth value for Brekkebygd was unduly low on this account. Gaare (1963) estimated the average snow-depth at the site of the Brekkebygd station from the height limit of the lichen *Parmelia olivacea* on the stems of birch (*Betula pubescens*). The mean ( $\pm$  s.d.) for 20 measurements was  $1.02 \pm 0.24$  m. For the birches growing over a wide area of the mires on Sølendet, Gaare recorded an "Olivacea-limit" of 0.6–1.0 m. He thus concluded that the snow conditions recorded for the Brekkebygd station nevertheless seem to be fairly representative of the conditions prevailing on the Sølendet mires.

**Table 3.3.3** The mean annual and mean monthly snow depths in cm (1) and days with a snow-cover (2), both for the normal period 1901–1930, for the meteorological stations at Brekkebygd (715 m above s.l.) and Vauldalen (828 m). Data taken from the Norske Meteorologiske Institutt (1949).

	J	F	M	A	M	J	J	A	S	O	N	D	An
1 Brekkebygd	55	71	82	64	10	0	-	-	0	3	14	34	29
Vauldalen	61	68	72	47	14	1	-	-	-	6	20	44	28
2 Brekkebygd	31	28	31	29	12	1	-	-	2	13	25	31	203
Vauldalen	31	28	31	30	18	2	-	-	2	19	29	31	221

The personal opinion of one of the local inhabitants (Nils Stenvold) is that the annual precipitation at Sølendet is greater than that at Brekkebygd, especially with regard to the snowfall during the winter and the length of time in spring before the onset of the snow-melt.

#### 3.3.4.1 Olivacea-limit

The lower limit of growth of *Parmelia olivacea* on birch stems is considered (e.g. Nordhagen 1928, 1943) to indicate the maximum depth of the snow cover at that locality. However, a lot of problems arise in arriving at a representative mean value for a particular area, since local variations, due to the topography and wind conditions, are found in the annual accumulation of snow around the birch bases (Sonesson & Lundberg 1974). The limit has been investigated at Sølendet, as precisely as possible, at more than 100 separate places, for 5–10 birches in each place. The mean values of these trees have then been used to construct the snow-depth map (Fig. 3.3.3). The overall variation in the *Olivacea*-limit is 0.5–2.5 m, in the majority of cases between 0.7 and 1.5 m. It is highest in the denser birch stands present to south-eastward of the most extensive open areas, e.g. at Dalholmen (in the NE of the reserve) and Olderholmen (in the E) where the limit lies at 1.5–2 m. The limit usually lies at 0.7–1.0 m on the mires and mire margins. On the flat, open heathlands in the southeast of Sølendet the limit lies at 0.5–0.8 m.

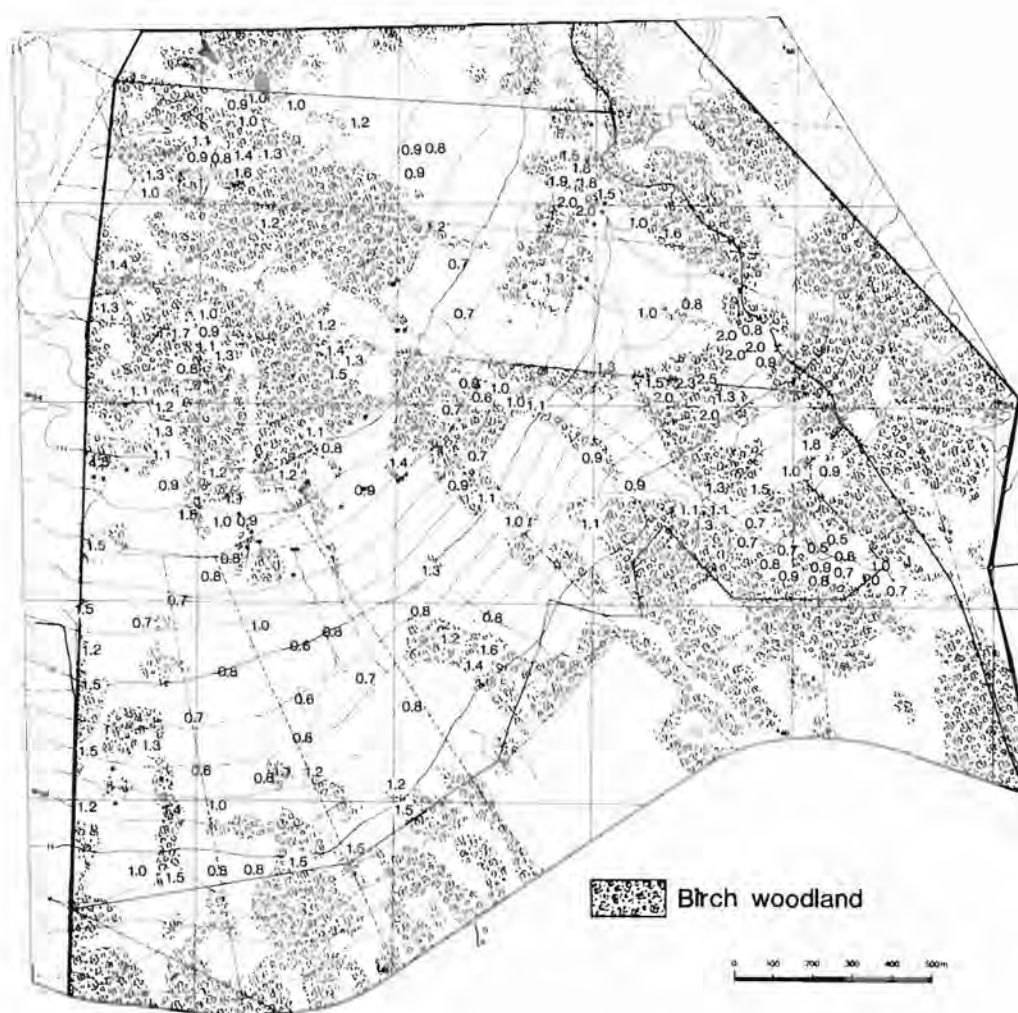


Fig. 3.3.3 The lower limit (in metres) of growth of *Parmelia olivacea* (*Olivacea*-limit) on stems of birch (*Betula pubescens*) in the investigated area. The numbers are the mean values for 5-10 birches in each place.

#### 3.3.4.2 Direct recording of the snow-cover

The snow conditions and other weather conditions have been regularly recorded by me on my visits to the nature reserve during the period 1974-1988. Other, very valuable, information has been gleaned from local inhabitants, especially Nils Stenvold.

The last of the snow usually disappears from Sølendet around May 20-25. Because of the absence of snow-beds and wind-blown ridges in the local topography, the snow disappears from wide areas of the reserve at more or less the same time. The sites of springs, and the mire areas affected by such flushes, are the first places to become snow-free in springtime (see Fig. 3.3.4), as are low ridges covered by dry, heathy vegetation. There is a regular and marked local variation, of 1-2 weeks, between the lowest-lying areas in the southeast (ca. 700 m above s.l.) and the higher-lying ground in the north (ca. 800 m). The last-remaining snow patches are to be found in the higher-lying parts of the reserve, near Rymyra, Dalholmen and Storholmen, see figure 3.3.5.

The snow conditions recorded in 1985 and 1986 can serve as typical examples. Spring was late in 1985 and even on May 5 more than 99 % of the reserve was still snow-covered and only a few of the spring areas were bare. The last of the snow disappeared ca. June 1. In some years, e.g. 1976, 1982, it finally disappeared even later. In 1986, however, spring was early. On April 14 the entire reserve was snow-covered, with a snow-cover depth of 0.7-0.9 m. The first few days of May were very warm and more or less all the snow had gone by May 10.

The time at which the snow-cover becomes established during the late autumn and winter is very important in regard to the depth of frost penetration. A full snow-cover usually becomes established sometime during November, but in some years, e.g. 1986, there is either no snow-cover, or only a very thin one, before Christmas. Should the air temperature fall low during such times, the ground becomes frozen to a considerable depth.

#### 3.3.4.3 Conclusions

The mean values for the depth and duration of the snow-cover recorded at the Brekkebygd meteorological station would seem to be too low to be used to represent the conditions prevailing at Sølendet. The values recorded for duration at the Vauldalen station would seem to be more representative of the conditions, at least in the northern parts of the reserve. The general conclusion is that the duration of the snow-cover at Sølendet in a normal year is 210-220 days. In years when there is no proper snow-cover during the period up to Christmas, the depth of frost penetration into the mineral soil and into the peat-covered areas is usually quite considerable. The depth of the snow-cover (based on the lower limit of *Parmelia olivacea* on the birches) is (0.5) 0.7-1.5 (2.5) metres. The thinnest snow-cover is generally found on the open areas (e.g. mires and heathlands) and on the flat, low-lying areas in the southeastern parts of the reserve.



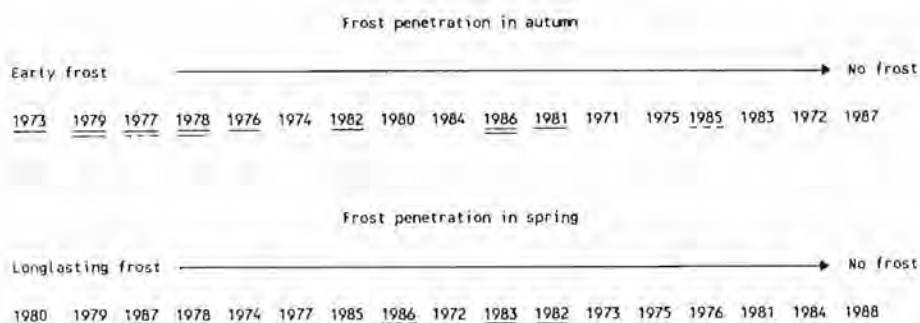
Fig. 3.3.4 One of the largest snow-free areas at Sølendet on May 15 1985 the spring area of locality no. 93.



Fig. 3.3.5 A typical picture of late May condition at Sølendet, the last of the snow is still present in the birch woodland in the higher-lying parts of the reserve; Storholmen. 19840523.

tab. 3.3.4

Relative, approximate ordination of the years during the period 1973 - summer 1988 in respect of the start of frost penetration in autumn (upper series) and duration of the period that the ground remained frozen in springtime (lower series). Years of deep frost ("tele-dybde") are doubly underlined, those of normal depth singly, and those of only very shallow frost are not underlined at all. Based on the NVE data for Abrahamsvoll (no. 4020-85) and Dølvoll (no. 4026-85) and own observations.



### 3.3.5 Depth of frozen soil (Norw. "tele")

The data for three monitoring stations in the Aursunden area that record the depth of frozen soil were provided by Norges Vassdrags og Elektrisitetsvesen, Grunnvannskontoret. Data for the following stations have been given by letter and as data print-outs (1987, 1988):

Abrahamsvoll (no. 4020-85) at an altitude of ca. 700 m, for the years 1971-1983 and 1987.

Vauldal (no. 4023-85), altitude ca. 840 m, for the years 1973-1979.

Dølvoll (no. 4026-85), altitude ca. 800 m, for the years 1975-1981 and 1983-1987.

The results for Vauldal were found to deviate markedly from those of the other stations and the station was closed in 1979. The Vauldal data have therefore not been taken into consideration in table 3.3.4. Abrahamsvoll and Dølvoll lie 15 and 18 km respectively, west of Sølendet. The data for these two stations show that the ground starts to freeze, in a normal year, sometime in October or November (see Fig. 3.3.6). There is usually a 5-10 cm (more seldom to 15 cm) layer of frozen soil in December, which has increased to 10-20 cm (up to 50 cm) in January-May. The frozen ground has normally thawed out by the end of May, sometimes first in June. The data that exist for Vauldalen showed that there, at an altitude of 830 m above s.l., the ground remains frozen until the second half of June.



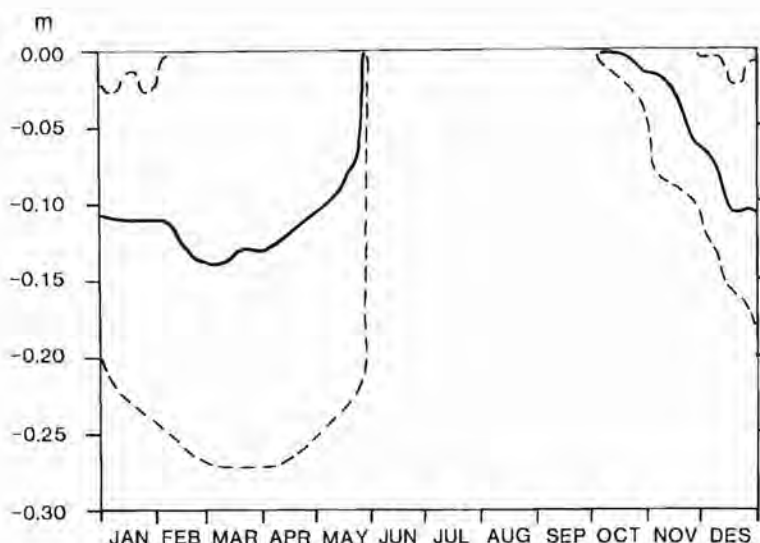


Fig. 3.3.6 Depth of frozen ground, showing the mean values and extremes, recorded during the years 1974-1987 at Abrahamsvoll (station no. 4020-85, at ca. 705 m above s.l., data from NVE, Grunnvannskontoret).

Table 3.3.4 provides a picture of years in which there was an early onset of freezing in the autumn and those in which frozen ground existed until well into spring, together with an indication, usually based on the December/January data, of whether the depth of frost penetration ("teledybde") was slight, normal or very great in the individual years relative to the mean for the period 1973-1987. There is a marked contrast between years of deep frost (1979-80, 1978-79, 1986-87, 1977-78, 1973-74, 1976-77) and those with winters in which there was little frost penetration, either because they were mild or because of an early protective snow cover (e.g. 1983-84, 1975-76, 1972-73, 1987-88). The relative ordination of the years has been based mainly on the data for Abrahamsvoll and Dølvoll, supplemented by personal observations on the conditions at Brekken each year, largely made by Nils Stenvold.

### 3.4 HUMAN IMPACT

#### 3.4.1 Brekken in the past

Viking Age graves and arrowheads have been found on the banks of the Glåma river, just E of Sølendet, and at Stenvoll in Brekken, one of the farmhouses nearest the nature reserve (ca. 1.5 km away). The grave has been dated to about 900 A.D., and it is obvious that farming has been carried on in this area at least since that time (Petersen 1942, Aspaas & Aspaas 1974). However, archaeological investigations (Pettersen 1983a, b, Gustafson 1987) have yielded evidence of people using the area from older Stone Age (i.e. about 7000 years ago); a number of artifacts used in hunting, fishing etc. were found in the Aursunden and Rien areas (cf. also Indset et al. 1957).

Iron production from fen-ore dates from at least the Viking Age, at times on an appreciable scale (Falck-Muus 1942). The region known as Rørosbygdene was deserted at the time of the Black Death (in 1350 A.D.) and was only permanently re-settled by farmers at the end of the 16<sup>th</sup>-century (Aspaas & Aspaas 1974). The distinction between home-farms and summer-farms has been blurred at certain times in the past (Hougen 1947). Reinton (1961), for example, states that Brekken was formerly the summer-farming area for the farms in the Ålen district.

Mining started at Røros in 1644 (Kvikne 1942). What had originally been only a cluster of farms, developed rapidly into a mining town. There was a considerable demand for charcoal and timber for the mining industry. As early as 1655 more than 31.000 m<sup>3</sup> of timber were used in a year and in the course of the ca. 250 years of mining activity at Røros a total of ca. 11 million m<sup>3</sup> of timber had been consumed (Sandnes 1942). The mining activity thus led to considerable deforestation in the surrounding area, Brekken included. The local woodlands have been felled on several occasions in the course of the past few centuries, leading to a depression of the natural forest limit over a wide area within the Røros administrative district (cf. Elven 1979). The fact that pine (*Pinus sylvestris*) is so scarce now in the Brekken area is largely due to the above-mentioned activities (cf. section 2.5).

Sølendet was almost certainly used for haymaking or for grazing before the depopulation due to the Black Death. Nevertheless, it is doubtful whether that usage, if it occurred, would have left visible signs in the area over and above those due to later activities. We know very little about farming in the area before the 1600s, unfortunately; nor have any palaeobotanical investigations been made in the vicinity. In section 2.4 the vegetational history of upland areas of Central Norway was summarized.

Archival evidence (Matrikkelen 1688) exists for clearance of three patches on Sølendet for summer-farms (Kvikne 1942), so that one can assume that the area was in normal use for haymaking and summer grazings from the late 17<sup>th</sup>-

century onwards, as in similar regions in other parts of Trøndelag county (cf. Reinton 1955-61, for example).

Reference to the statistical survey of the extent of such upland farming activities in Norway has been made already in section 2.1. The first reliable sources, however, are the statistics for 1907 (Statistisk Sentralbyrå 1911). At that time the area in Sør-Trøndelag so utilized was 363 km<sup>2</sup>. The Røros administrative district recorded 41.3 km<sup>2</sup> of upland haymaking areas and only 8 km<sup>2</sup> of infield haylands. The neighbouring district of Tydal, to the north, recorded 31 times as great an area of upland hay areas compared to home-farm haylands, a proportion not exceeded by any other district in Norway. No data exist for the Brekken area itself, but it is reasonable to assume that the proportion would lie somewhere between those for Røros and Tydal. In other words, there was a much greater acreage of hay cut in the outlying lands at Brekken than on the home-farm meadows during the early years of the present century. (Further statistics of haymaking areas will be given in section 13.3).

Haymaking continued at Sølendet up to the end of the 2nd World War and a little after (see following section). A reasonable assumption is that continuous utilization of the area has occurred for ca. 300 years and that such haymaking has represented an important factor in shaping the landscape and the vegetation cover as we see them today.

### 3.4.2 The utilization of Sølendet prior to 1950

The information given in this section is based on the results of an investigation into the cultural history of Sølendet, made by interviewing 13 local people who were in the past engaged in haymaking there (Volden 1977), as well as my own information given by the local landowners. Further information, in Norwegian, can be found in B.F. Moen (1983). The local people with personal knowledge of haymaking on Sølendet were so engaged during the period 1920-1950, so that the descriptions refer to methods etc. employed at that time only.

#### 3.4.2.1 Place-name terminology and description of hay-barns and other remains

Figure 3.1.3 shows the local names for various landscape features, natural and man-made. Some of them, among those explained below, are also in common use in other parts of Norway.

- floe (m): mire characterised by a hummocky vegetation with *Sphagnum fuscum* (e.g. Litjfloen).
- grubbe (f): a small tarn, liable to dry out in summer.
- holme (m): a wooded area of limited extent, a copse or grove (e.g. Litjholmen).
- kjerr (n): a scrub-covered area (e.g. Storkjerra).



Fig. 3.4.1 The hay-barns, here at Midtilaua, were used to store the year's hay-crop. 19760804.

- kås (f): an area of rich tall-herb vegetation, often occupied by willow scrub (*Salix* spp.), liable to periodic flooding (e.g. Langkåsa).
- lok (m): a small tarn (e.g. Loken på Storesmoen)
- mo (m): a level stretch of dry ground, not peat-covered (e.g. Storesmoen).
- rom (n): place or site of its qualifying prefix (e.g. Heksingrommet).
- ry (f): Wiry grass-dominated heathland (e.g. Finnskjeggrya).
- røst (f): an area of dwarf-shrub vegetation, often including *Betula nana* (e.g. Kattugle-røsta).
- skarp (adj.): a stretch of low-growing vegetation (e.g. Skarpholmen).
- stryp (n): a long, narrow open area (e.g. Klausstrypet).
- vassdal (m): a small valley supplied with water from mires and flushes (e.g. Vassdalen).
- voll (m): a dry grassland area (often around a summer-farm) once regularly mown or grazed (e.g. Storesvollen).

In former times there were eight hay-barns (see Fig. 3.4.1) and four bothies (Norw. "slåttebu" (see Fig. 1.1.2)), the latter used only during the haymaking season. Two of the hay-barns (Øverlaua and Midtilaua) and two of the bothies (Olderbua and Dalbua) have now been rebuilt, but only the ruins of the others are still visible. A fifth hay-barn (Nerlaua) in the SE extension of the study area (outside the present nature reserve) will be rebuilt in the future. The usual building material was birch timber for the bothies (e.g. Olderbua and Dalbua) and pine timber and sawn boards for the largest hay-barns. The latter materials had to be carried up to Sølendet. One of the hay-barns (Midtilaua),

however, was of birch. The hay was either stored in the hay-barns, or left on the stack pole as haystacks. Remains of such stack poles are common all over the nature reserve (see Fig. 1.1.1) and some new ones have been built for conservational purposes. A further hut, for use as a tool-shed (Norw. "red-skapsbu") was built in 1982 in traditional style, in the eastern part of the reserve, near Nyvollvegen.

#### 3.4.2.2 Hay-crop and haymaking methods

After a gradual decrease in intensity throughout the present century, haymaking at Sølendet ceased entirely ca. 1950. Formerly, most of the hay swards were only cut every second year. During the intervening year, the farmers used to say that "it should be left alone to recuperate", in other words to manure itself. A hay-crop was taken more frequently in a few places, more especially from damp copses with a good growth of grasses (Norw. "gropgras"). Those landowners such as the Stenvollen farmer, who had a large number of extensive areas that yielded a hay-crop, used to rent out some of these areas to other farmers who had hay-cutting rights on too few areas in relation to their head of stock kept. Most areas were utilized by the same farmers each year.

The hay-barns were used to store the year's hay-crop (see Fig. 3.4.1), although stack poles were also used and, in fact, most of the landowners stored their hay on haystacks. A single haystack usually held a "winter hay-load" (ca. 360 kg), but some were large enough to accommodate 1.5 or even 2 loads. The birch-timbered hay-barns most often held 2-3 loads, whilst the pine-timbered ones were larger and could hold up to 10 loads. The hay was transported down to the farm during the winter, once stable snow conditions were established (Norw. "vinterføre"), using a horse-drawn sledge fitted with slatted sides.

#### **The hay-crop yield and the amount of labour involved**

The values cited for production and work etc. are based on information supplied for each of the nine holdings (cf. Fig. 3.4.2) on the nature reserve. Table 3.4.1 shows the number of loads of hay yielded by each of the nine holdings in the 1930s. The values given by each of the landowners for the annual hay yield from all his haymaking areas in the Sølendet area as whole are shown in column 1, whilst column 2 gives the calculated yields (deliberately reduced, based on the direct relationship between the total acreages held and that held within the reserve) from the holdings within the area covered by the nature reserve. The second landowner (Haugen) in the table has quoted a very high yield for his holdings, taking the area into consideration, and compared to the other landowners. Haugen, however, pointed out (pers. comm. July 29 1976) that at ca. 1930 his holdings really yielded 35-40 loads every year, later in the 1930's the number of loads was reduced. The utilization degree of the outlying lands was diminished during our century, and it seems reasonable to explain the relatively high yield of Haugen's holdings by a intensive utilization right up to the 1930s (further comments in section 13.3.5).



Table 3.4.1 The annual number of loads of hay taken from Sølendet. The values shown in column 1 are those stated by the landowners (farmers) and apply to the entire hay-crop from all their holdings at Sølendet, not just from those parts lying within the reserve. Column 2 gives calculated yields in the reserve, and column 3 the area in the reserve for each of the nine holdings.

Landowners name	No. of hay-loads		Area in the reserve in daa
	In total area	Calculated for the reserve area only	
1. J.I. Skott	15-20	15	255
2. J.K. Haugen	35-40	30	191
3. N.J. & A.J. Feragen	20	15	250
4. T. Sjøvold	15	15	233
5. A.L. & K. Skjei	40	35	456
6. J.O. Kurås	25	22	292
7. Chr. & P. Borgos	15	12	137
8. N.O. Stenvold	35	30	574
9. N.O. Stenvold	25	20	415
Totals	225-235	194	2853

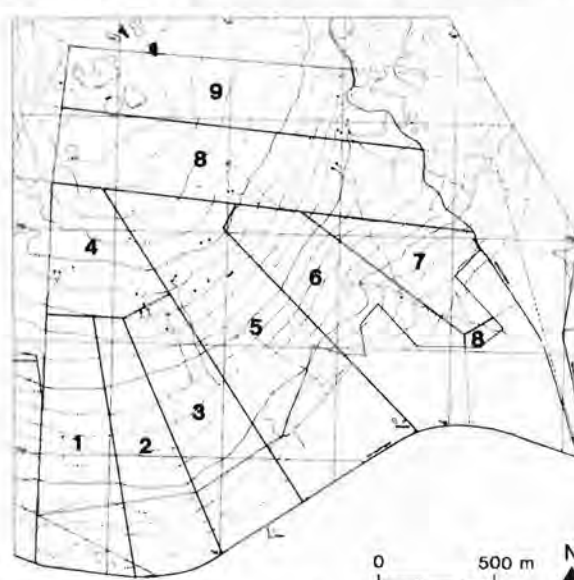


Fig. 3.4.2 Land survey of the nine properties at Sølendet, cf. table 3.4.1.

The table shows that the annual hay yield taken from the nature reserve is 194 loads; assuming that an average load weighs 360 kg, this represents a hay production of 70 tons.

According to the information supplied by the landowners, a single hay-load represents about 5-6 day's work, i.e. one day's work produces 60-70 kg of hay. Calculation thus indicates that the annual work-load in connection with hay-making on the Sølendet reserve as a whole amounts to ca. 1000 days. That means, roughly speaking, that about 1 day's work is involved per 1 daa (0.1 ha) of ground yielding a hay-crop. The amount of time spent in carrying out each of the different tasks involved in haymaking is discussed in section 3.5.

#### The tools used

The main haymaking tools have always been the scythe (Norw. "ljå") and the hay-rake ("rive"), together with an axe and a stout knife for getting rid of scrub and other woody plants. Most of the farmers with haymaking rights in the Sølendet area kept a grindstone ("slipestein") there, and the mowers would each have a whetstone ("bryne") with him for the continual sharpening needed to the scythe.

Various types of scythe-blades were used, according to the task involved. An extremely long blade, even up to 110 cm (7 "kvarting" in Norwegian), was used on mires that yielded a sparse hay-crop, but the scythe customarily used had and has a blade length of ca. 63 cm (4 "kvarting"). In the latter case the blade setting could be varied, so that a broader swathe was cut where the hay-crop was sparse.

The hay-rakes used by the mowers ("slåttekar") and by the rakers ("rakstre") had different functions and therefore different shapes. On the rakes used by the womenfolk the teeth were set closer together and were thinner than those used by the menfolk, and the shaft was also thinner (i.e. a lighter rake). That type of rake was used especially to do the clear-raking of the ground, to turn the hay-swathes, and to spread the cut grass evenly to dry. The man's rake should have longer, thicker teeth and be more suitable for handling the freshly-cut grass. The rake used by a man for upland haymaking could have teeth almost as long as 10 cm (4 "tommer" in Norwegian). Such rakes were mainly used to gather the cut grass into haystacks and for raking it up to put on to the haystack.

Most people made the teeth for the hay-rakes out of the wood of the bird-cherry (*Prunus padus*), because it is strong, yet pliable. A supply of such wood had to be taken up to the Sølendet area, because it is a very rare tree there.

A horse-drawn (summer) hay-sledge was used to cart the dried hay to the haystacks or to the hay-barns for storage, whereas a winter-type sledge was used for bringing it down to the farms from Sølendet later in the year, when the snow conditions were suitable.

### **The haymaking season**

Haymaking at Sølendet usually started at sometime during the first half of July, as a rule about the 10<sup>th</sup>, although earlier in some years. In 1930, for example, it started as early as June 26.

In Brekken and many other, similarly situated, upland districts (Reinton 1957), it was the custom to mow part of the upland areas before starting to mow the infield, manured meadows near the farm (the hay-crop known as the "frau-graset" in Norwegian). The majority of farmers spent about a fortnight at Sølendet before starting on the homefields. The duration varied somewhat, related both to the prevailing weather conditions and to the area that each particular owner had to cut.

Once the haymaking on the homefields was finished, the farmers once again went up to Sølendet to mow further areas for hay. Depending on the yield gained from the homefields, either more or less would be mown at Sølendet.

The haymaking season at Sølendet generally lasted until ca. September 15. In years when the summer was particularly unfavourable weather-wise for hay-making they might have to stay there even longer.

Both the menfolk and the women took part in the haymaking. At Sølendet, more or less everyone on the farm took part, except those whose job it was to look after the cows and the younger children. Very often there were about twice as many mowers engaged in haymaking than there were rakers: 4 mowers to 2 rakers was quite a common ratio.

On many farms it was quite a common practice to hire extra casual labour during the haymaking season. Swedish men, many of whom worked as timber-fellers in the winter, were preferred as hired mowers.

### **The haymaking itself**

The work involved in mowing and drying the hay, in building haycocks, and finally storing it in the barns or on the haystacks, was carried out in much the same manner in different regions of Norway, cf. Reinton (1957) for a survey. The Brekken district had certain traditions and methods of its own, details of which can be found in Volden (1977) and B.F. Moen (1983). The following section provides a broad summary of the haymaking methods.

Mowing began at daybreak, whilst the dew was still on the grass, because the scythe cuts a lot better on wet grass. The swathes were then spread out over the ground, usually by one of the womenfolk.

Given favourable weather later on in summer, it might prove possible to turn the herbage after it had been left to dry for only a day. After a further day's

drying, haymaking could then be started in the afternoon of the following day. The dry hay was raked up into small heaps by the womenfolk.

Thereafter the work was done by the menfolk, the mowers, who raked the hay up into bundles ("kjemmer") and then built it either into large haycocks ("såter") or set it up on the haystacks using a horse-drawn hay-sledge of summer type to transport it thence, or into the hay-barns. At least two-thirds of the Sølendet hay-crop was stored on a stack pole, which was a stout pole ("stakkstang") supported by at least three split poles arranged to form a tripod round the base and resting about one meter up the pole. The height of the stack pole was chosen according to the size of the mown area. Such poles were usually made from a young straight-stemmed birch. About 100 such hay-poles would have been needed to accommodate the hay mown on Sølendet. The pole was thrust as firmly into the ground as possible and birch or juniper twigs were laid around the base to provide a dry foundation on which to start laying the dried grass. The bundles were carefully raked so that the grass haulms lay parallel to each other. An armful of such "combed" hay would be picked up and so laid around the stack pole that the haulms lay flat (see Fig. 3.4.3). It was very important to ensure that the hay haulms lay more or less parallel and that the armfuls packed well together. The haulm should lie pointing away from the stack pole, so that there was no danger that the stacked hay should fall apart and so that the rain would be channelled to the exterior, not run into the centre.

After the pole was full to the halfway mark with stacked hay, a further layer of twigs was added. This was termed the "middlewood" (Norw. "midtskogen"), and usually the twigs used were longer and straighter than those used around the base. These mid-layer twigs were intended both to further bind the stacked hay together and allow the hay to remain dry, or to dry out entirely if not completely dry when stacked. In the latter case a second, or even a third layer of "middlewood" twigs would be inserted. Two such layers were also generally used if the hay crop contained a lot of matgrass (*Nardus stricta*), or wavy hair grass (*Deschampsia flexuosa*) because the haulm is very smooth, and short, wherefore there was a danger of the stack collapsing later if too few twigs were inserted at intervals to bind together.

A well-made haystack on such a stack pole was considered to be one shaped like an egg, i.e. narrowing towards a pointed top and also slightly from the middle towards the base (cf. Fig. 3.4.3). The final touch was to impale a cut peat on the top of the stack pole. A suitable peat for this purpose was one that was resilient, not brittle, and dense, having been formed from fine-stemmed, fine-rooted plants. A small hole was cut in the centre of the peat, to allow it to be thrust on to the pole. Its main purposes were to keep the upper hay firmly in place and to prevent rain running down the pole into the interior of the stack. Such a "pole-peat" (Norw. "stakktorv") was often used for several years on end.

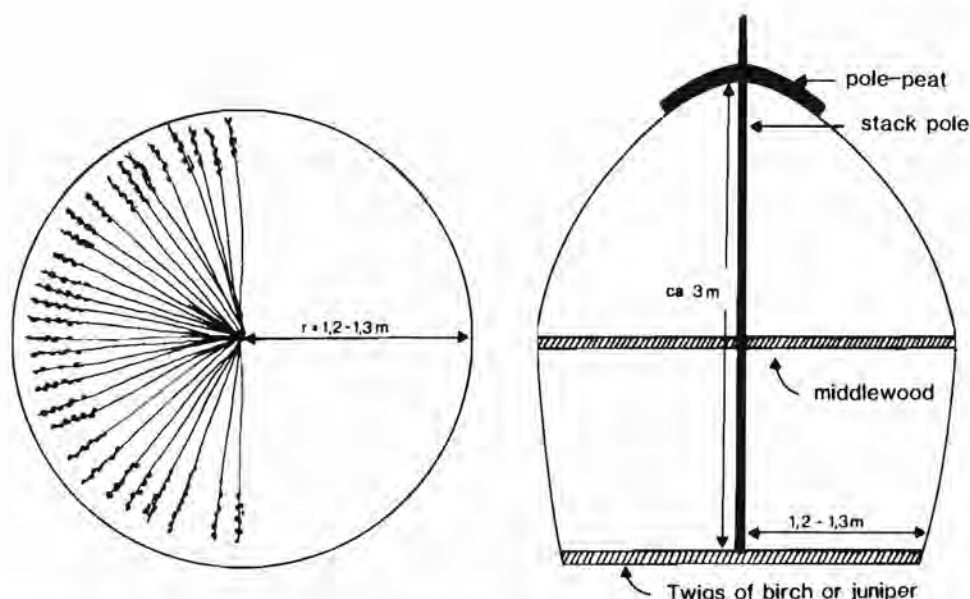


Fig. 3.4.3 Schematic representation of a typical haystack, as seen in horizontal and in vertical section.

#### 3.4.2.3 Grazing, woodland products, and hunting for game

The outlying lands at Sølendet were not very much used for grazing. Occasionally one or two herds might wander into the area to graze, but only the Stenvold area was regularly grazed. It was customary to let the horses graze locally during the haymaking season. Apart from the above-mentioned, some reindeer from the owned (not wild) herds might wander across the area at times during the summer. In recent years quite a number of such reindeer, up to several hundred strong, travel across the Sølendet reserve in August on their annual migration from their summer pasturage to north-westward over to the winter pasturage in the south-east.

According to information from the landowners (Volden 1977), the annual volume of timber cut for fuel on the nature reserve area has amounted to ca. 24 "famner" (about 38 cubic metres; 1 Norw. "famn" =  $1.6 m^3$  (Heie & Nygaard 1975)). The estimated total volume of timber (birch with trunks more than 9 cm diam. at breast-height) present within the reserve is presently  $2380 m^3$ , according to the timber-owners association for South Trøndelag county (Finstad & Lerfald 1975). Assuming a turnover time of 40 years for a crop, this means a potential annual yield of cut timber of ca.  $60 m^3$ . The actual amount taken, according to the landowners, is thus substantially less, but indicates that the potential yield is being reasonably well attained, although little timber has been taken from the reserve during the past few years.



Any twigs shed during the winter on to the areas normally mown were gathered up, carried off and piled together on the places where cut timber had been taken. Some farmers used to burn such piles of "natural brash", but the majority just used to let them stand and rot in situ. The haymaking areas were often raked over during the early spring, so as to remove twigs that would impede the mowing later.

It was the custom to de-bark the trunks of birch. The outer layer of birch bark (Norw. "never") was subsequently used as roofing material, since it peels off in long strips. Sometimes the inner bark was also kept and used, after boiling it in water to a kind of soup (Norw. "barklåg"). This was given to the cows in the wintertime. Twigs of birch and willow, occasionally those of juniper too, would be gathered up and fed to the farm stock.

Few berry-bearing plants grow in the Sølendet area. Just very occasionally one can gather a few cloudberries (*Rubus chamaemorus*).

The haymaking areas at Sølendet provide good browse for elk and a fairly stable and sizeable population of elk has been present in the area in recent years. The farmers have hunted elk here for several generations, certainly during the past century at least. A certain amount of minor game is also hunted, including setting snares during the winter for hare, capercaillie, willow grouse and black grouse.

#### 3.4.2.4 Effects of harvesting on the vegetation

Hay-harvesting of the fens and grasslands obviously led to a disruption of the natural recycling of mineral nutrients. In the years in which a hay-crop was taken from an area, there was little plant litter deposited, which will have led to changes in the microclimate of the ground surface and the upper soil and humus layers, amongst others. Treading and other mechanical disturbance of the fen surface (hay transport by horse-drawn sledges in summer etc.) will have caused the peat to consolidate and led to flow-changes of the ground-water, which in many cases will have brought more mineral-rich water to the surface. Scything and raking, with their associated treading of the surface, and other activities involved in haymaking, will have further disturbed the plant cover, as also will the clearance of scrub, heather etc., and the levelling out of hummocks etc. Such effects will have changed the competitive relationships of the different plant species forming the vegetation cover, which will have changed its character eventually, because of repeated interferences of the same kind over periods of years, perhaps over several centuries in the past.

As mentioned earlier, the felling of timber for the copper mines at Røros, as well as for local use by the farmers, has had clearly visible effects on the landscape. The complete absence of pine forest in the area now must well be



Fig. 3.4.4 A wooded grassland three decades after cessation of haymaking: hundreds of birch bushes have become established. Locality no. 35. 19770608.



Fig. 3.4.5 The same area as above, after clearance (1977) and mowing (1977, 1980). The marker stake of the stand and the same trees are seen in both pictures. 19820610.



Fig. 3.4.6 A typical photo of a mire margin area three decades after cessation of haymaking: shrubs of birch, dwarf birch and willows (*Betula pubescens*, *B. nana*, *Salix* spp.) have colonised the previously open areas. Blautmyra 19750812.



Fig. 3.4.7 The same area as above, after clearance and mowing in 1979. Blautmyra 19820731.

due to these activities in the past, although to just what extent the pine (*Pinus sylvestris*) is a component of the potential natural vegetation cover hereabouts is still uncertain. The intention at present is to try to create an open type of birch woodland cover on the nature reserve, of birch groves and copses (Norw. "lund") with a ground cover of grasses and tall herbs on the drier, better soil areas.

On Sølendet, as elsewhere, the intensity of utilisation has been much reduced during the decades of the first half of the present century. Most of the land-owners mowed their holdings for hay during the second World War. The last time that Stenvold took a hay crop was 1947 and the other farmers stopped at about the same time.

A vegetational succession commenced as soon as haymaking ceased entirely. The vegetational changes were often particularly rapid on the mire margins and in the grassland/tall herb communities (Figs. 3.4.4-7). The most obvious change was the formation of scrub. Tree birches (*Betula pubescens*), the dwarf birch (*Betula nana*) and willows (*Salix* spp.) have colonised areas that were previously open, having been mown for hay. The more detailed changes in the vegetation cover are described in section 13.4.

### 3.5 RECLAMATION AND MANAGEMENT OF SØLENDET

#### 3.5.1 Machines and implements used

Clearance of the larger trees on the reserve was done with a saw (sometimes a motorsaw). Scrubby growth was removed with an axe. Several types of brashing hooks, brashing axes, crowbars, and chain-type motorsaws were evaluated and some tried out in practice in the clearance work. All trunks, stems etc. had to be chopped off as close to ground-level as possible, so as not to interfere with the subsequent mowing and raking. Nils Stenvold's opinion was that the common axe was the best clearance tool.

A scythe fitted with a normal blade (about 63 cm long) is generally used on the whole for mowing; a scythe is the only tool which is used for mowing uneven, stony areas etc. Scything is shown in figure 3.5.1.

A rake of the old-fashioned type, with wooden teeth, has been used on occasion, but more usually a rake with teeth made of plastic is employed.

A motor mower (type Gutbrod MF 72) was purchased in 1977 (see Fig. 3.5.2), and the same kind of machine in 1982. The mower is used with a cutting bar (without fingers) 137 cm broad. When fully equipped, the tractor weighs 130 kg. A "Dalen" trailer is used for transporting the hay etc., capable of carrying 400 kg and measuring internally 90 x 132 cm, with wheels 12 cm in diameter.





Fig. 3.5.1 Mowing in the old-fashioned way with a scythe, showing the parallel-laid swaths. Locality no. 1. 19810809.



Fig. 3.5.2 Mowing with a motor mower (Gutbrod MF72) at Gråmyra. 19770804.



A larger type of motor mower (a Bucher M 600) was purchased in 1979. The cutting bar has a breadth of 155 cm and is fingered. Fully equipped the mower weighs ca. 320 kg. Its trailer measures 108 x 157 cm and the wheels, placed beyond the frame, are 16 cm in diameter. Transportation of fodder is shown in figure 3.5.3.



Fig. 3.5.3 Transportation of cut herbage with the Bucher motor transporter. Locality no. 1. 19810809.

#### Assessment of the motor mowers

The Gutbrod motor mower is well adapted to the job. The tractor is light in weight and no problems were encountered in mowing any of the mires at Sørendet, even after wet weather periods. The Bucher 600 has been little used for hay-mowing. Nils Stenvold considers that it is much less well-adapted for this type of job. This is partly due to the fact that it is both heavier and bulkier and that the cutting bar is fingered, which leads to greater difficulty being encountered when mowing natural vegetation, especially on uneven ground.

The Gutbrod is only useful as a transporter over short distances, since it can only travel at a low speed (stated maximum 10 km/hour). The Bucher is more powerful and travels faster (max. 16 km/hour). In consequence this machine has been generally used for transport during recent years. When carrying a load over a mire, however, the trailer and load sink into the ground more quickly than the tractor.

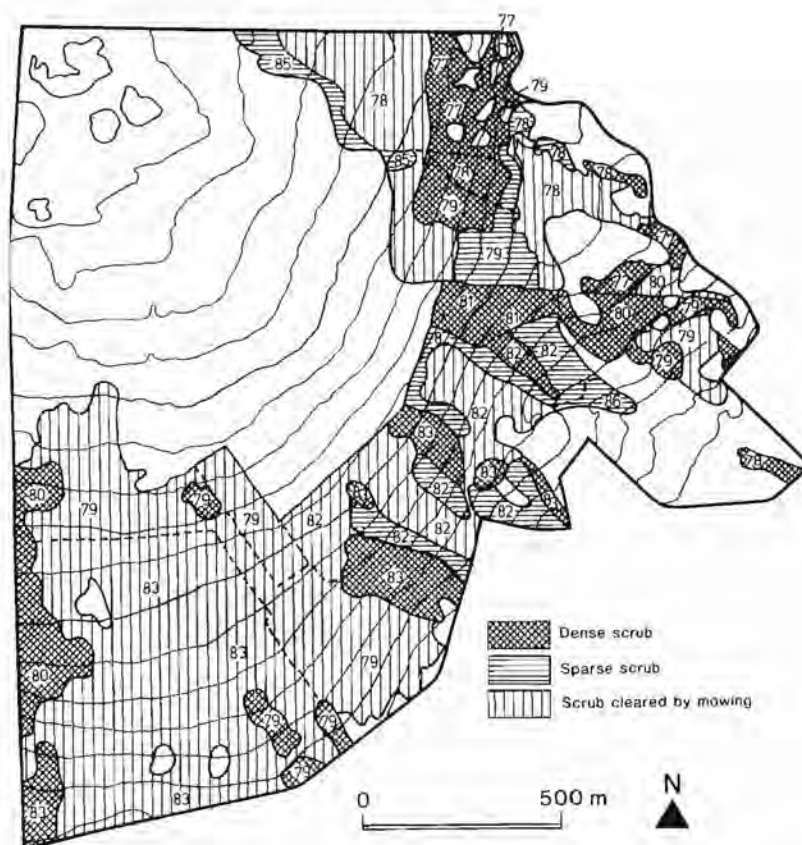


Fig. 3.5.4 Map of the reclaimed and now regularly mown areas of Sølendet nature reserve. The numbers refer to the year of clearance or to the first year of mowing during the period 1977(77)-1986(86).

### 3.5.2 Survey of the clearance operations and haymaking during the period 1976-1987.

#### 3.5.2.1 Clearance

To clear the ca. 560 daa covered with scrub on the reserve (see Fig. 3.5.4) took about 4000 man-hours (cf. Table 3.5.1). This estimate is for the entire time involved, including time spent in moving implements etc. from one area to another, in preparing the machines for work etc. The experience gained in each year has been included in the annual reports. The amount of work involved has varied very considerably from one part of the reserve to another. The cited times per unit area must therefore be interpreted with a high degree of caution.

Table 3.5.1 Summary of the practical work carried out annually in connection with the management of the Sølendet nature reserve during the period 1976-1987. Most of the tabulated values are approximations.

Year	No. of hours work involved in clearance	The area of land involved (in daa)	
		Cleared	Mown
1976	5	1	7
1977	200	59	56
1978	330	50	180
1979	600	85	340
1980	1600	100	30
1981	300	35	160
1982	400	100	210
1983	600	100	560
1984	-	2	140
1985	-	15	190
1986	-	10	360
1987	-	-	140
Totals ca. 4000		ca. 560	ca. 2370

It is also obvious that the results achieved have varied a lot depending on the person(s) involved in the clearance work. The examples quoted below all refer to work carried out by Nils Stenvold, sometimes with his assistants. All areas were regularly mown up to and after the second World War, and the coppice process was in the starting stage, a very favourable situation for restoring the area.

Attempts were made in 1979 and 1980 to have several people engaged in clearance work at the same time. This was particularly unsuccessful in 1980 (mainly due to lack of skill by the workers involved), when over 1000 man-hours were spent in clearing quite small areas of ground. The individual surveys of the work carried out each year are given in section 3.5.2.4. Broadly speaking, our experiences at Sølendet show that clearance of rather dense scrub (i.e. a cover value of over ca. (15)-20% of *Betula nana*, *B. pubescens*, *Juniperus communis* and *Salix* spp.) involves ca. 10 hours work per daa (see Fig. 3.5.5). This time estimate was only exceeded in a few of the places that were cleared by Nils Stenvold. The general clearance rate was 5-10 hours/daa for areas of rather dense scrub of just about 400 daa in extent and 4-5 hours/daa for clearance of sparse scrub (ca. 5-20 % cover value of scrub).

Such large-scale clearance was a one-off job, however, and had mostly been completed by the end of 1983. The reclaimed areas (ca. 1600 daa in all) have easily been kept open, after the primary clearance, by mowing them regularly since then.



Fig. 3.5.5      Axe clearance of scrub (mainly *Betula nana*) south of Skarpholmen (involved ca. 10 hours work per daa). Locality no. 74. 19800807.

#### 3.5.2.2    Burning of brash

After clearance, the brash (twigs, branches, stems etc.) was transported away, piled up in large heaps and burnt (see Fig. 3.5.6). The number of bonfire sites was kept as low as possible, eventually only 78 (see Fig. 3.5.7). During the initial years of clearance work, the brash was left lying over the winter and burnt in the following spring. Experience showed that such brash was difficult to burn and, from 1980 onwards, Nils Stenvold has burnt the brash straightway, a little at a time. He considers this is advantageous. Once a bonfire at one site has burnt itself out, Stenvold removes any half-burnt remains to the site of the next bonfire. The same bonfire sites are often used several times. The flora and vegetation on the sites of such bonfires have been studied by Arnesen (1989).

#### 3.5.2.3      Scything, mowing with tractor, transport etc.

Scything has been carried out in the reserve each year since 1974 and mowing using the two-wheeled tractor every year since 1976. Gathering the cut sward, drying it, and transporting the hay for storage have been far more time-consuming than the actual mowing. A great potential exists for carrying out



Fig. 3.5.6 Burning of brash near Midtilaau. 19780610.

all these activities much more efficiently by using modern implements. A summary of the experience gained from Sølendet is given below. Figure 3.5.8 shows the area mown one or more times during the period 1976-1987.

#### 1. Trials on 3 experimental plots in 1981

A trial involving scything the vegetation, raking up the cut sward and transporting it away was carried out on August 9. The plots were mown in an attempt to harvest 50 kg of hay for a feeding trial. The times taken for each operation were noted approximately. The Bucher 2-wheeled tractor was used to transport the hay from the plots.

Stand 1 was a sedge fen vegetation (*Carex rostrata* and *C. lasiocarpa*) with an annual yield in the field layer from scything of ca. 120 g/m<sup>2</sup>. It took an hour to mow 400 m<sup>2</sup>. Raking up and loading into the trailer took ca. 1 hour, and transport with the Bucher tractor (2 loads, 300 m distance) took ca. 1/2 hour. Scything the stand is shown on the picture in figure 3.5.1, transportation in figure 3.5.3.

Stand 87 was a *Crepis paludosa*-*Molinia caerulea* fen community with an annual productivity of ca. 100 g/m<sup>2</sup>. 500 m<sup>2</sup> were mown in an hour. Raking up, loading and transport took the same time as for stand 1.



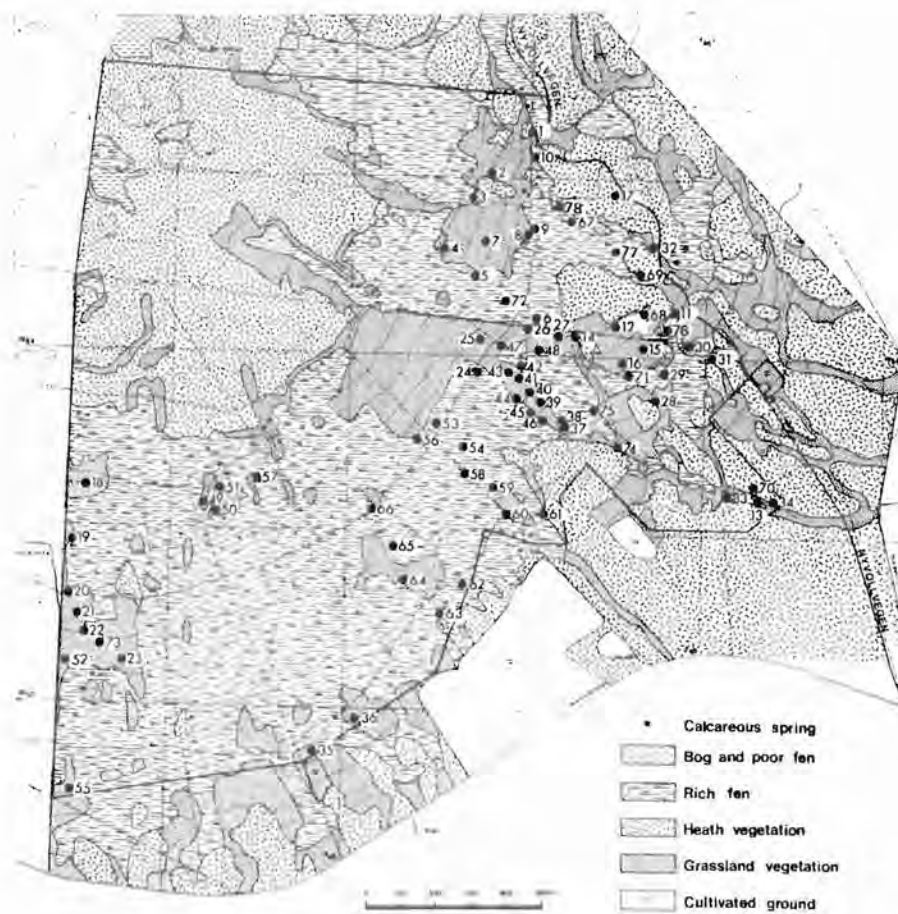


Fig. 3.5.7 Bonfire sites at Sølendet nature reserve. After clearance, the brash (twigs, branches, stems etc.) and litter were burnt at these 78 sites, established 1976-1987.

Stand 86 was a *Geranium sylvaticum*-*Alchemilla* spp. wooded grassland community with an annual productivity of  $150 \text{ g/m}^2$ . It took ca. 1.5 hours to mow  $340 \text{ m}^2$ . Raking up, loading and tractor transport (ca.  $350 \text{ m}$ ) took about the same time as for stand 1.

Stand 1 was mown at daybreak whilst the dew was still about, whereas stand 86 was mown later in the day, without dew, and was thus harder to mow. The time involved would otherwise have been roughly similar in both cases. The cited time rates do not include rest pauses, the time involved in mowing/changing implements, sharpening the scythe blade, etc.

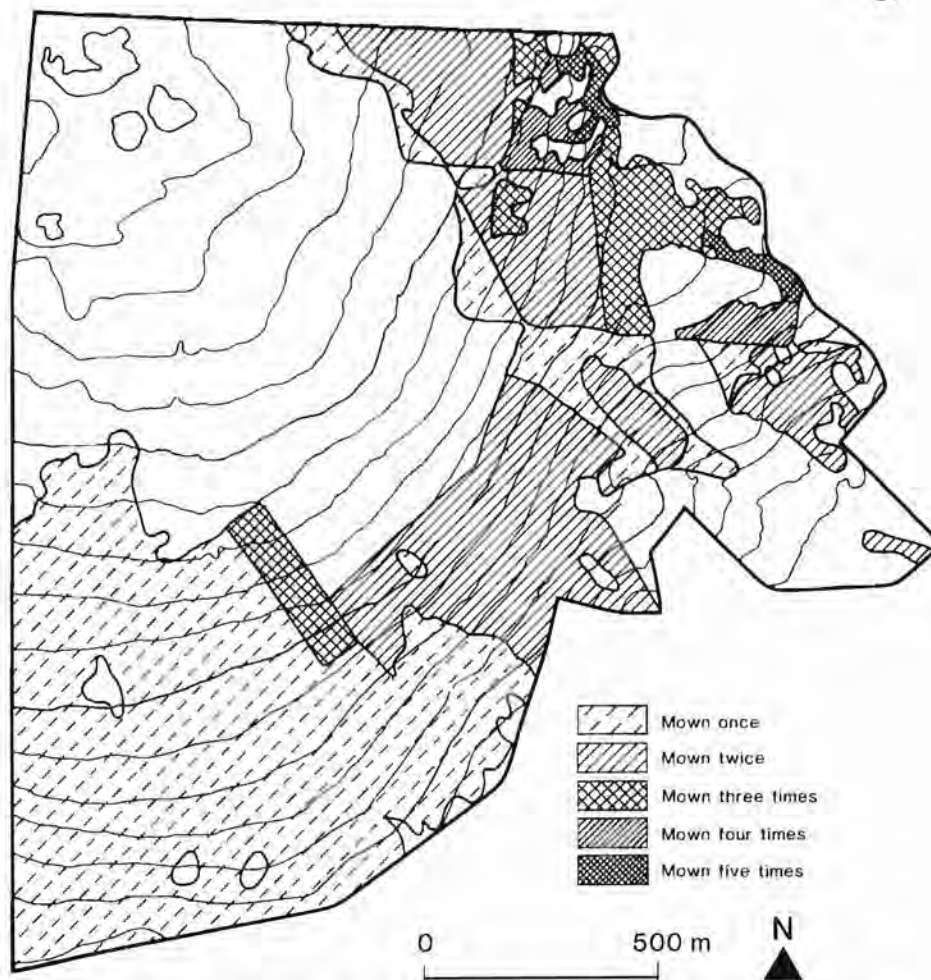


Fig. 3.5.8 Map of the Sølendet nature reserve showing the areas mown from one to five times during the years 1976-1987.

#### Conclusion

The trial results indicate that about 2-3 hours work are involved in mowing 1 daa of the more productive mires, compared to 3-4 hours/daa to mow a slightly above-average wooded grassland vegetation. About 30 % extra should be added to the time-rates to allow for sharpening and moving/changing implements, etc. (cf. Moen & Leirvik 1979).

#### 2. Scything

An area of 7 daa was mown in about 21 hours in 1976. The time taken for the actual scything, in the light of experience gained in later years, is also about 3 hours/daa (cf. the trial referred to above). However, wide variation exists,

depending on the type of vegetation involved; an appreciably greater area of relatively low-productive mire vegetation can be mown per unit time compared to the most highly productive tall-herb, wooded grassland communities. Mowing by scythe has been used on the whole, since the tractor mower is difficult to use on uneven ground littered with stones, birch stumps etc. Such areas can be scythed at a rate of ca. 3 hours/daa on average.

### 3. Mowing with the 2-wheeled tractor

The first time that the 2-wheeled tractor was used for mowing larger areas of sward was in 1977. About 70 daa of the Floen area was mown in 1978, with a time expenditure of about half an hour per daa. In 1979, it was used to mow 280 daa in the southwestern part of the nature reserve, taking ca. 130 hours for the job, i.e. ca. 0.5 hour/daa again. In 1981, 56 daa on Skarpholmen were mown, some of which included patches of uneven ground, with hummocks and stones, and therefore a more difficult job than on a flat mire surface. The job took 35 hours, i.e. ca. 0.6 hours/daa. In 1983, 560 daa in the western part of the reserve were mown, at an average rate of 0.5 hours/daa.

### Conclusion

The two-wheeled (Gutbrod) tractor is capable of mowing 1 daa per 0.5 hour on level fens. This is an acceptable mowing rate. An additional 30 % of time needs to be allowed for transport, sharpening of the blades etc.

### 4. Mowing without raking

A trial with mowing and allowing all the cut vegetation to remain *in situ*, without raking up to remove litter, woody bits etc., has been made since 1977. The use of the two-wheeled tractor to mow relatively wide areas that had not been mown, or the scrub cleared, for several decades has been mentioned above.

Use of the tractor in this type of work involves setting the cutting blades relatively high, and in consequence leaving a high stubble (most often ca. 5 cm).

The tractor was capable of cutting through bushes and other woody plants provided the stems were not more than ca. 1-2 cm in diameter. Incipient hummocks and suchlike protuberances were flattened out in the course of mowing, because the blades sliced off the tops of projecting cushions of *Sphagnum* moss etc. This seemed to provide an effective means of mowing the majority of mire areas, since it helps to reduce the formation of scrub, helps to smooth out the surface, and reduces the amount of plant litter. It is an effective method that can be used at least for low and moderately productive fen vegetation, which produces only a thin litter layer in the first place. Mowing then leads to a rapid decomposition of the cut vegetation, for the most part, and results in the following year in the presence of less litter than on unmown areas. Decomposition of the cut pieces of bushes and other woody plants takes a long

time, however, wherefore twigs etc. should be removed. Picking up such twiggy material, in the following spring, from the mown fen surface has proved its worth in practice.

The amount of old litter lying on the highly-productive fens, left uncut for decades, is quite considerable (often more than 100 g/m<sup>2</sup>). Before such mires are suitable for haymaking once again, therefore, the old litter layer needs to be either removed completely, or at least reduced. This is difficult to achieve simply by mowing without a prior raking-over. Parts of the extensive haymaking areas in the western part of the reserve were dealt with in this manner in 1983. The grass etc. being thereafter piled and burnt, which took 2-3 times longer than the actual mowing itself.

#### Conclusion

Mowing with the 2-wheeled tractor, without raking up the cut sward afterwards is an effective method for tackling a large area of ground (a working rate of ca. 0.5 hours/daa). The method yields good results for low and moderately productive fens without woody scrub. On highly productive fens and areas with some scrub, the twiggy material and some of the old plant litter needs to be removed.

#### 5. Time taken to gather up cut sward

##### Spreading and drying in the old-fashioned way

The grass was mown and spread out to dry in 1976 and 1977. The trials indicated that mowing took 3 hours/daa and spreading ca. 2 hours/daa. These are very approximate average values, with a wide variation depending on the type of vegetation cover being mown and its productivity. Drying, and gathering up of the herbage, took a varying time dependent on the prevailing weather conditions, whilst the transport time obviously varied according to the distance involved. Where a mown area lay close to a track, the time taken for drying the herbage, gathering it up and carrying it away was roughly the same as that taken to mow it and spread it. From interviews held with the landowners (Volden 1977), it was possible to arrive at an average value for the time taken per unit area per farmer when haymaking was still a regular practice on Sølendet. They indicated that it took about 1 day's work per daa for mowing, spreading out, drying, transport to the barn or haystack, stacking the hay etc.

##### Gathering and transport using the two-wheeled tractor without drying

The results of this method for three different stands of vegetation in 1981, have been presented already in part 1 of this section. Raking up, loading and tractor transport for about 300 m together took 3-5 hours/daa.

In 1977, we found that, for the area cut for hay in that year, the transport time was ca. 3 hours/daa (cf. Moen, Koefod & Moen 1978). The haymaking

areas that year lay close to the road (mainly 0-200 m distant), but we were using the smaller of the two tractors (the Gutbrod).

28 daa of Storholmen were mown in 1979. This area lies 300-400 m away from the track and this time the Bucher tractor was being used. Whereas the mowing took 40 hours (32 of which were using the scythe), 82 hours were needed for gathering up the hay and transporting it, i.e. ca. 3 hours/daa (cf. Moen & Leirvik 1979).

#### Conclusion

Spreading out the cut sward and drying it in the traditional manner involves a lot of work, especially when the weather is not particularly favourable. This method, in fact, was only used in 1976 and 1977.

Gathering up and transport of herbage to the roadside takes ca. 3 hours/daa in the case of moderately to highly productive vegetation when the distance it has to be transported is ca. 300-400 m. With a shorter transport distance the time rate declines, of course, and the rate per unit area varies greatly in accord with the differences in stand productivity.

The intensively-managed area in the eastern part of the reserve (see Fig. 3.5.10) lies quite near to a track and the proportions of poorly productive and highly productive stands are about average for the reserve as a whole, so that the time taken for gathering up and transport can be estimated as just under 3 hours/daa for these areas.

#### 6. Collection of herbage for farm use

Except in 1982, fresh-cut, green herbage has been taken away from Sølendet, for feeding to farm stock, every year from 1977 to the present day. The quantity involved has varied between 1 and 12 tons measured as dry hay, i.e. over the entire period ca. 50 tons. A lot of the remaining cut sward has had to be burnt each year, however, because of the cost of transport from the reserve to the farms.

##### 3.5.2.4 Annual surveys of work carried out

Figure 3.5.4 shows the year clearance started in different parts of Sølendet nature reserve, figure 3.5.9 shows the yearly area mown 1976-1987.

#### 1976 - 1977

About 1 daa of scrub was cleared from the Mittilaua area in 1976. Larger scale clearance began in the spring of 1977. Some 200 hours work were involved and the greater part of the area proposed for intensive management, in the eastern part of the nature reserve, was cleared. An estimated 59 daa of scrub was cleared, i.e. a rate of 3.4 hours/daa, but in this case the brash was not



burnt afterwards. 7 daa and 56 daa in 1976 and 1977, respectively, were mown in the northeastern part of the reserve.

#### 1978

The twigs and other clearance brash from 1976 and 1977 were burnt. The remaining clearance work on the plot for intensive management in the east was done and, in addition, a start was made on clearing Storholmen, and Vassdalen was cleared. Altogether ca. 330 hours work were involved in clearing a total of ca. 50 daa of scrub, i.e. ca. 6.6 hours/daa. An additional 180 daa. of sward, previously untouched, was mown in the east of the reserve in 1978.

#### 1979

The remainder of Storholmen, the eastern side of Skarpholmen (ca. 20 daa with little scrub on it) and a small area at Dallaua were cleared. It took Mr. Stenvold 260 hours work for the above, a total clearance of 60 daa. Several small birch copses in the western part of the reserve were cleared of the densest scrub growth, ca. 25 daa in all, which took 325 hours work, i.e. 13 hours/daa. In addition, appreciable areas of fen, with some scrub growth, were mown for the first time, 340 daa altogether this year.

#### 1980

Several wooded patches ("skogsholmer") in the western part of the reserve were cleared, totalling a little over 50 daa. This work took more than 1000 hours to complete, excluding that involved in transporting and piling the resultant brash in small heaps and burning them. In other words more than 20 hours/daa were needed to clear these areas. There was quite a lot of scrub to be cleared in places, but, nevertheless, these values are not in line with the experience gained from Mr. Stenvold's work. Mr. Stenvold cleared an area of ca. 45 daa at Øverlaua at a rate of ca. 7 hours/daa. Small areas of sward, within the area previously mown in the northeast of the reserve, were mown this year (32 daa).

#### 1981

An area of ca. 35 daa south of Skarpholmen was cleared. It was covered by dense scrub, a lot of both tall-growing *Betula nana* and scrubby *Betula pubescens* and *Salix* spp. The work (including burning the brash) took ca. 300 hours altogether. 160 daa in the northeastern part of the reserve were mown, a half of which was areas that had not previously been mown.

#### 1982

This year Mr. Stenvold used a new combined clearance/mowing method on some mires to the north of Olderbua. The following work was carried out during the early summer (ca. 150 hours work on ca. 30 daa): an initial rough mowing was done with the 2-wheeled tractor, after which all the cut material was raked together. Any woody stems that had been missed or left uncut by the mowing machine were then cleared using an axe. Everything was then burnt. This method, although involving relatively a lot of work, yielded a good result. The

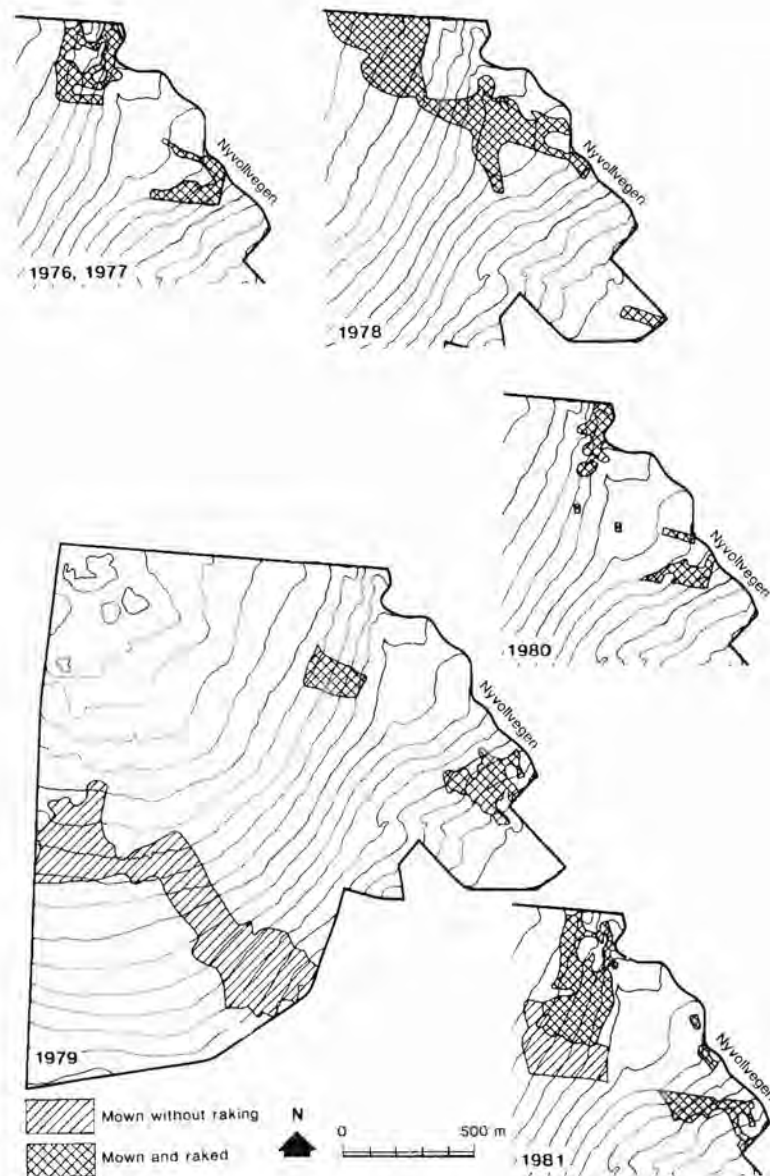


Fig. 3.5.9

Maps of parts of the Sølendet nature reserve showing the areas mown annually 1976-1987. On the areas mown without raking, the cut vegetation remains in situ. On the raked areas the herbage was used as fodder, or burnt.

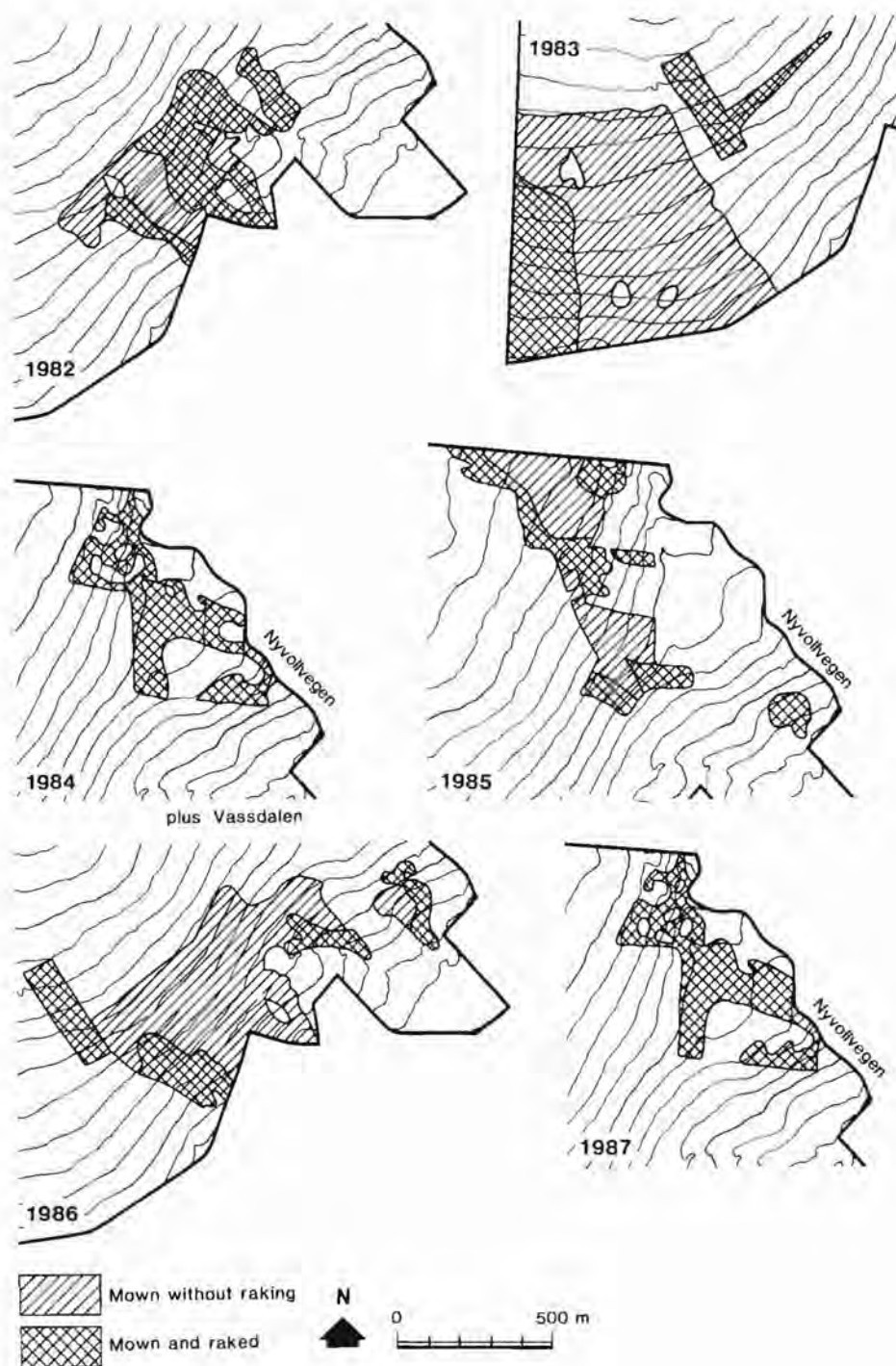


Fig. 3.5.9 continued.

method is a suitable one for clearing areas covered by relatively dense, but not too old and tall, scrub. It was employed to clear more than 100 daa in 1982. In addition, a wooded patch, ca. 12 daa with dense scrub growth, was cleared to the south of Kjerrstokkenget. More than 200 daa of sward was mown in 1982, all on areas not previously mown.

#### 1983

About 50 daa of dense scrub was cleared on Stormannsholmen, Litjholmen and a wooded patch in the far south-west of the reserve. Extensive areas in the western part of the reserve (560 daa altogether) were mown for the first time, as well as the removal of a lot of scrub growth in certain parts. The Sølendet nature reserve could be considered to have been more or less entirely reclaimed and restored by the late summer of this year, since most of the areas it was intended to maintain as haymaking areas in the future had now been cleared and mown at least once.

#### 1984

The area for intensive management in the eastern part of the reserve (137 daa), and the Vassdalen area were mown. Some of the previously mown areas were widened by 1-3 m along the margins. Otherwise, no new areas were either cleared or mown this year.

#### 1985

The western margins of the Floen area were extended by mowing and clearing scrub growth. Almost 200 daa of sward was mown this year.

#### 1986

An area to the north of Olderbua was cleared and mown for the first time (ca. 10 daa), as well as 350 daa mown in the southeastern part of the reserve.

#### 1987

No new clearances were made. The area of intensive management in the north-east was mown (ca. 140 daa).

The management operations during 1988 and 1989 are not included in the previous descriptions. In 1988 an area of 425 daa were mown, most of the area in the western part of the reserve; in 1989 the areas of intensive management and Vassdalen (altogether 138 daa) were mown. Further details can be found in the annual reports, the last one (Moen & Arnesen 1989) includes a full reference list to all the reports issued during 1976-1989.

### 3.5.3 The management plan for the nature reserve

Several drafts of the management plan have been prepared (Moen 1977, Moen & Leirvik 1979, Moen 1982a). The plan finally agreed in 1985 (cf. also Moen & Rohde 1985) is based on achievement of the following aims:

1. Preservation of a former, typical upland haymaking area, with its vegetation and flora, as a feature of the farming landscape of the past.
2. Preservation of the varied nature of the vegetation within the reserve as produced by different methods of mowing/haymaking.
3. Preservation of rare species and of those of interest from a phytogeographical point of view, by management specifically designed to further their growth and thrift.

The management plan makes specific provision for the following parts of the reserve (cf. Fig. 3.5.10):

- A. Areas of intensive management, 268 daa altogether, of which ca. 180 daa are scythed regularly.
- B. Areas of more extensive management only, ca. 1400 daa of land formerly mown for hay.
- C. Areas to be left untouched, 520 daa, of which 320 daa were formerly mown for hay.

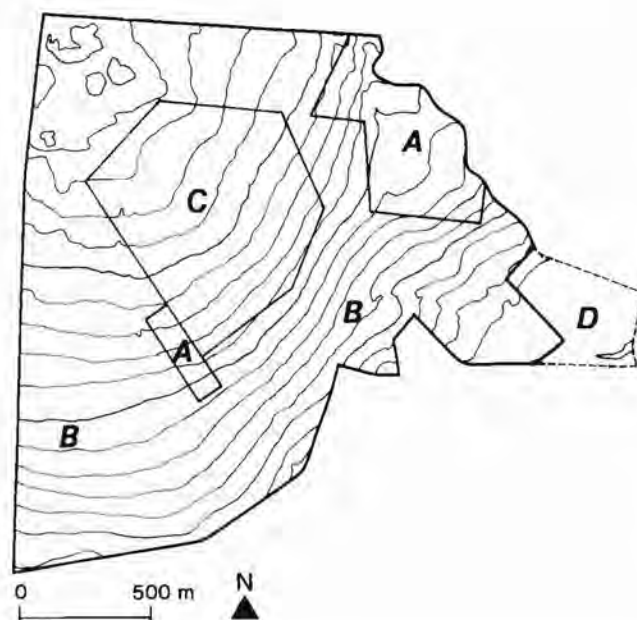


Fig. 3.5.10

The investigated area at Sølendet, showing the different types of areas according to the management plan:

- A: Areas of intensive management
- B: Areas of extensive management
- C: Areas to be left untouched.
- D: The proposed extension of the reserve to the southeast.



## 4 METHODS AND MATERIAL

### 4.1 MAPPING OF THE FLORA

#### 4.1.1 Nomenclature

Species lists of vascular plants and bryophytes of the Sølendet nature reserve are included in Appendix B. The nomenclature for vascular plants follows Lid (1985), with the following exceptions/additions: *Cardamine pratensis* coll. includes var. *pratensis*, var. *palustris* and *C. cf. nymanii*. The separate species of *Hieracium* and *Taraxacum* are amalgamated; *Pyrola rotundifolia* includes *P. norvegica*; *Rhinanthus minor* includes *R. groenlandicus*; *Hierochloë odorata* includes *H. hirta*; *Luzula frigida* and *L. multiflora* are separated at subspecies-level.

In the phytosociological analyses a number of separate taxa are amalgamated: *Alchemilla* sp. includes species of *A. vulgaris* agg.; *Dactylorhiza pseudocordigera* includes *D. pseudocordigera*-hybrids; The *Hieracium* species are separated in two groups: *H.* section *Piloselloidea* and *H.* sp. (including species of the other sections; in some tables *H.* sect. *Vulgata* is separated). *Salix nigricans* coll. includes *S. borealis* and *S. nigricans*-hybrids. *Viola palustris/epipsila* includes the two taxa and perhaps the hybrid between them. *Carex nigra* includes *C. juncella* and types between them. *Carex vaginata* includes the hybrid *C. panicea* x *C. vaginata*.

The nomenclature of bryophytes follows Flatberg et al. (1977) and Frisvoll et al. (1984). In addition *Sphagnum jensenii* is recognised as a separate species (Flatberg 1988); *Sphagnum* n.n. is a new taxon of the *S. recurvum* complex that will be published later (by Flatberg). *Dicranum muehlenbeckii* is used in the old-fashioned sense, i.e. at Sølendet it is equivalent to *D. acutifolium* (Nyholm 1986). *Drepanocladus revolvens* at Sølendet is equivalent to var. *intermedius* (Nyholm 1965).

In the phytosociological analyses a number of taxa are amalgamated: *Bryum* sp. includes mainly *B. capillare*, *B. creberrimum*, *B. pallens* and *B. pallescens*. *B. pseudotriquetrum* is stressed as a separate taxon (even so, *B. creberrimum* and *B. pallescens* may be included in some quadrats), as is also the distinct taxon *B. weigelii*. *Philonotis fontana/tomentella* and *Rhytidiadelphus squarrosus/subpinnatus* are most often not separated in the tables.

*Cephalozia lunulifolia* coll. includes *C. loitlesbergeri*, *C. lunulifolia* and *C. pleniceps*. The species of *Cephaloziella* are not separated. *Lophozia bantriensis* and *L. gillmanii* are amalgamated in some tables. *Lophozia* subg. *Lophozia* may include a number of species, mainly *L. ventricosa* coll.

Lichen nomenclature follows Krog et al. (1980), except for *Cladonia*, from which *Cladina* is split off as a separate genus (as in Moberg & Holmåsén 1982).

#### 4.1.2 Vascular plants

Fondal (1955) first described the rich flora of Sølendet, and both he and other botanists made a number of collections, a number of which are kept at the herbarium in Trondheim (TRH). All the species records from Sølendet found in the literature (e.g. Fondal 1955, Gaare 1963, Elven 1979) and all species found in the herbarium at TRH were also found during the botanical surveys carried out at Sølendet 1974-1989. All the information given on occurrences, ecology, etc is therefore based on the material gathered during those years.

Systematic mapping of the flora of the Sølendet nature reserve started in 1975, the participants being Simen Bretten, Asbjørn Moen and Tor Øystein Olsen. The nature reserve was divided in 15 parts and at least one species list from each of these parts exists. Distribution maps of a large number of species were made and maps of three of them have been published by Moen (1976c), viz. *Dactylorhiza cruenta*, *D. pseudocordigera* and *Kobresia simpliciuscula*.

Recording of the flora has continued every year since 1975, and every summer new species or hybrids of vascular plants have been recorded. After the summer of 1976 a list of 221 species was published (Moen 1977), though only a single species was assigned to each of the apomictic taxa *Alchemilla vulgaris* agg., *Hieracium* and *Taraxacum*. At present (after the summer of 1989), the list of vascular plants found inside the nature reserve comprises 255 species (two species have each been separated into two taxa) and 25 hybrids. This latest species list includes 8 species of *Alchemilla*, and single types of *Hieracium* and *Taraxacum*, respectively.

In the rich low-herb communities present just outside the nature reserve, in the southeast, 12 further species not recorded inside the present limits of the nature reserve, have been found; cf. table 1 of Appendix B, which includes all the 294 taxa present, with indications of their frequency at Sølendet. Just N of the limits of the nature reserve, 3 more mire species occurs, viz. *Drosera rotundifolia*, *Pinguicula villosa* and *Scheuchzeria palustris* (further comments in section 12.4.3).

18 field check-lists of vascular plants are stored in the archives of the Department of Botany. During the first few years of the investigations, a number of collections were added to the herbarium, although the exact number is not known. I have been responsible for making more than 450 collections of vascular plants, and at least 100 more need to be added when estimating the total number derived from the botanical investigations at Sølendet. A number of collections have been made in connection with a critical study of the species/hybrids in genera such as: *Alchemilla*, *Carex*, *Cardamine*, *Dactylorhiza*, *Euphrasia*, *Hieracium*, *Hierochloë*, *Luzula* and *Salix*.

In July 1986 Liv Borgen and I collected 35 specimens of orchids for counting the chromosome numbers of some of the species and some postulated hybrids. Chromosome numbers were obtained for 21 specimens (results in a letter from

Liv Borgen 19880405). The chromosome numbers were (in parentheses the number of specimens examined): *Dactylorhiza cruenta* (3),  $2n = 40$ ; *D. fuchsii* (pale flowers and leaves 4, pink flowers + leaves with spots 2),  $2n = 40$ ; *D. incarnata* (3),  $2n = 40$ ; *D. maculata* (4),  $2n = 80$ ; *D. pseudocordigera* (5),  $2n = 80$ ; *D. cruenta*  $\times$  *D. pseudocordigera* (2),  $2n = 60$ ; *D. maculata*  $\times$  *D. pseudocordigera* (1),  $2n = 80$ . Further details will be published later.

#### 4.1.3 Bryophytes

In the initial years of the investigation, the bryophyte flora was not studied systematically, although some collections were made, e.g. in connection with the phytosociological analyses. In 1980–1982, Arne A. Frisvoll made systematic records of the bryophyte flora of the reserve. Kjell Ivar Flatberg, in 1981, recorded the *Sphagnum* species present.

179 species of mosses and 74 species of hepatics have been recorded from the Solendet nature reserve. No systematic investigations have been carried out outside the reserve, but 2 additional species of mosses and one further hepatic have been recorded in the area of the proposed extension of the reserve in the southeast. Table 2 of Appendix B lists all the species. In addition some other species are found just north of the reserve, in poor, intermediate and moderately rich fens; cf. section 12.4.3.

Specimens of all but 3 of the 256 species of the bryophytes (*Racomitrium ericoides*, *R. sudeticum* & *Saelania glaucescens*) were collected and are to be found in the TRH. A. Frisvoll has been responsible for making more than 500 of the collections, I have made more than 200 and other botanists (K.I. Flatberg, Trond Arnesen & Stein Singsaas) have also contributed some collections.

## 4.2 TERMINOLOGY, VEGETATION MAPPING

### 4.2.1 Vegetational series, "poor" and "rich" vegetation

The vegetational series **mires**, **heathlands** and **grasslands** (after Nilsson 1902, modified by Sjörs 1967) represent the main vegetational units (differing main sections) of this monograph. These three series also represent the main units for systematic mapping of the vegetation, each of them allocated one of the main colour codes used on the vegetation map (blue, brown and green, respectively). For each of the series, the vegetation is characterised as woodland, scrub-covered or open areas.

A terminology related to the series system, is the separation of "poor" and "rich" vegetational types. These terms are used only to characterize the vegetation types according to their species composition, with no reference to the

habitat conditions or to the number of species involved (cf. e.g. Sjörs 1948, Du Rietz 1949, Malmer 1962).

#### 4.2.2 Mapping of the vegetation

The vegetation map (enclosed) lists definitions of the different terms, symbols, colour codes, etc., used. An explanation in English is given in section 12.2. The printed map is on a scale of 1:5000, with a contour interval of 5 m.

The 25 main vegetational units (see map legend) were mapped by Simen Bretten and myself in 1976. We used a stereo model of black and white air photos (Fjellanger Widerøe A/S series 5181, scale 1:12.000, date: 19760705. Infrared colour photos, series 5205, taken on the same date and to the same scale, were also used.). Each vegetational unit (or mosaic of units, see map legend) was delineated directly on to these photos. The vegetational units shown on the map have a minimum area of ca. 250 m<sup>2</sup>. Jan Erik Kofoed mapped the tree and shrub layers, also by using the air photos. The individual occurrences of the various vegetational units were entered on the map, using an autograph, by Fjellanger Widerøe A/S.

The area covered by each vegetational unit was measured using a planimeter, likewise the total area covered by the reserve (2853 daa.). The technique involved in making the map, measuring the area of the units etc. is described in detail in Moen & Moen (1975). Each of the vegetational units is described in section 12.2, together with details of the area covered.

### 4.3 THE VEGETATIONAL ANALYSES

The term **vegetation ecology** was introduced by Mueller-Dombois & Ellenberg (1974: 7) as, "the study of composition, development, geographic distribution, and environmental relationships of plant communities". Vegetation ecology is a wide concept, including for example vegetation mapping, and vegetational phytogeography. It includes the more restricted term **phytosociology**, which emphasizes the structure and systematics of the vegetation, or "the typological, plant community approach" (Maarel 1979a: 163).

Within any area of vegetation, discontinua, or sharp boundaries; and continua, or gradually changing patterns, may exist. Both types of distribution may occur within any one area. The structure of the vegetation has been studied using phytosociological analyses of stands (stand samples) which were both classified and evaluated by ordination techniques. The methods of classification and ordination are described in section 4.4. In addition, two belt transects, representing direct gradient analyses (Whittaker 1973: 7), are described in section 7 (Figs. 7.2.1 & 7.3.1).



#### 4.3.1 Field technique

Nordhagen (1922) was the first to stress the fundamental importance of homogeneity in phytosociology (Dahl 1957:28). Small quadrat analysis of homogeneous stands has been a characteristic of Scandinavian phytosociology (e.g. Nordhagen 1928, 1943, Sjörs 1948, Gjærevoll 1956, Persson 1961 and Malmer 1962). Trass & Malmer (1973) have summarized the Scandinavian approach to vegetational science (cf. also Malmer 1974).

##### Sample stands and localities

In my work, I chose the stands on a criterion of their internal homogeneity. Their strict delimitation from other stands was not stressed. Each stand locality (i.e. numbered localities including phytosociological analyses) at Sølendet represent only one stand s.lat. In each of these localities, one or more quadrats of 12.5-25 m<sup>2</sup>, each representing as homogeneous areas as possible, have been delimited and marked by stakes. In some communities, however, the stands cover a much smaller area, e.g. in springs.

At first, one stand quadrat (usually represented by a sampling area of 25 m<sup>2</sup>) in each locality was analysed. A number of these quadrats were later split into two 12.5 m<sup>2</sup> quadrats. In some localities, those representing larger homogeneous areas, further quadrats were established adjacent to the first ones. Some of these quadrats have been cleared, the scything frequency differs from quadrat to quadrat. The sampling areas for the phytosociological reanalyses, production and population studies were always these homogeneous quadrats. Reanalyses of these permanent quadrats are regarded as stand samples in their own right. In this way records for two or more sample stands may exist for a single permanent quadrat.

Figure 4.3.1 shows the positions of all the localities at Sølendet at which phytosociological analyses were made. Table 1 of Appendix A provides a survey of the sample stand numbers, localization (including a reference to quadrats of 10 m x 10 m or 100 m x 100 m in the UTM-system), number and size of the analysed quadrats, person responsible for making the field analyses, date of analysis, altitude and inclination (i.e. 16 types of aspect, slope expressed in "new degrees" = grade (g)). The years in which the quadrat was scythed before the phytosociological analysis was made, are also listed.

##### Analysed quadrats

The size of the analysed quadrats has generally been fixed for each of the main vegetational units, e.g. quadrats of 0.5 m x 0.5 m were used for most mire and spring communities. Most often 3-5 smaller quadrats of 0.25 m<sup>2</sup> (using a frame) have been studied within each stand quadrat of 12.5-25 m<sup>2</sup>. If the vegetation within a stand quadrat was considered to be homogeneous, the smaller quadrats were chosen in a standardised manner, i.e., fixed, regular placement in a grid. If the stand quadrat was not regarded as entirely homogeneous, the smaller quadrats were selected in such a way that the vegetation within each small quadrat should be as homogeneous as possible (cf. Sjörs 1948:



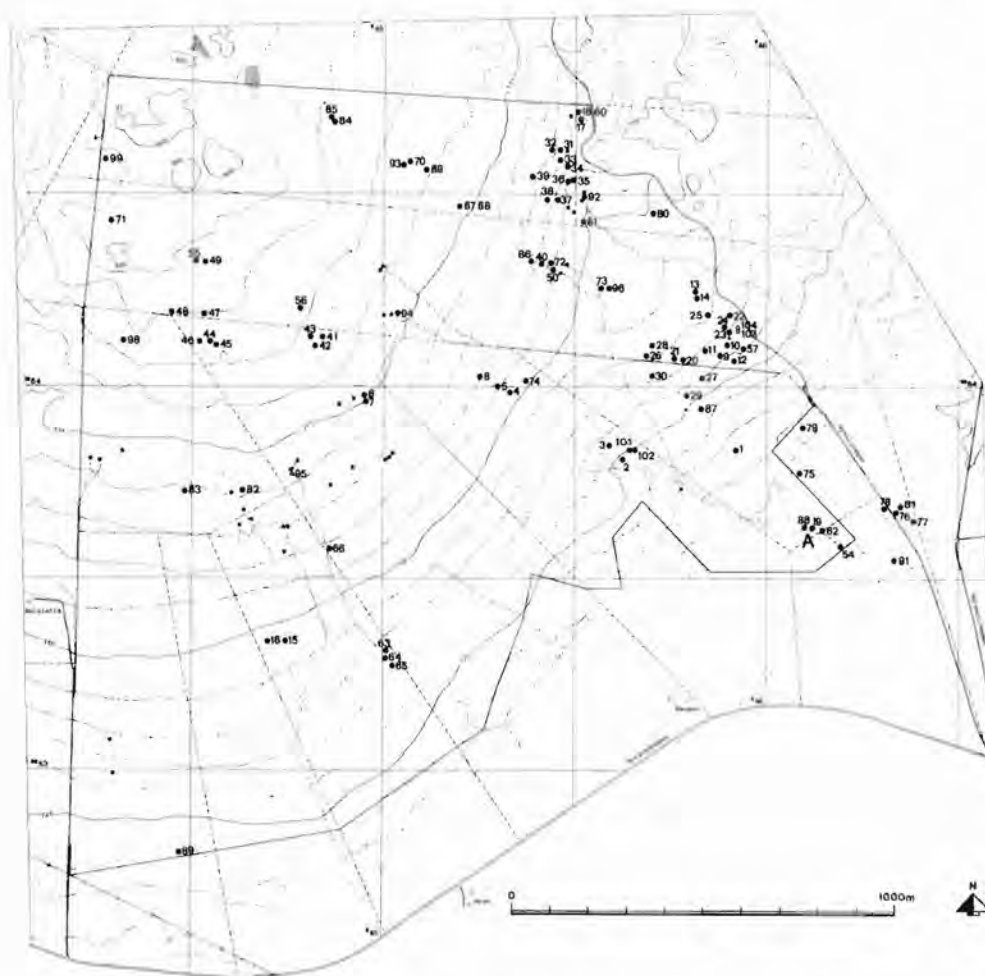


Fig. 4.3.1. Positions of the localities at Sølendet selected for phytosociological analysis. The stands of the numbered localities and of the transect of Vassdalen (A) are listed in table 1 of Appendix A.

281), thereby ensuring that the small quadrats should indicate the differentiation within the stand. (The same principles as those applying to the sample stands in the localities).

Quadrats of 1-4 m<sup>2</sup> were analysed in the scrub-covered areas, 1-4 in each stand quadrat, whereas the whole stand quadrat, usually (12.5)-25 m<sup>2</sup> was analysed as a single unit in the woodland areas.

### Vegetation layers

The vegetation cover was divided into four layers:

- A - the tree layer, i.e. woody plants more than 2 m tall.
- B - the shrub layer, i.e. woody plants 0.3-2 m tall.
- C - the field layer, i.e. woody plants not taller than 0.3 m; herbs (including ferns) and graminoids (sedges and grasses) without regard to their height
- D - the bottom layer, i.e. bryophytes (mosses, including *Sphagnum* spp. and *Andreaea* spp.; and hepatics) and lichens.

The degree of cover of each layer, and of litter and mud bottom (in mires) was estimated in terms of the scale used for each species (cf. sect. 4.3.2) and details are presented in tables 9.2.1, 9.3.1 and the tables of Appendices C and D. The heights of the layers and of the *Parmelia olivacea* limit on birch trees, together with the numbers of birch trunks and their circumference at ca. 1.5 m above the ground in the plots are also stated in the two first-mentioned tables.

Stress has been laid on executing exact analyses with complete species lists. Cryptogams have been collected from most stands, and the identifications checked in the laboratory. Most of the stand quadrats have been visited many times and critical species collected.

### 4.3.2 Cover scale

The degree of cover of each species present in a quadrat was estimated in terms of cover classes based on the Hult-Sernander-Du Rietz scale (cf. Malmer 1962). Some additions were made to this strictly geometric scale, cf. table 4.3.1: r means reduced plants (i.e. impoverished, e.g. seedlings; not taken into consideration by the multivariate analyses), + is used for a species belonging to the stand analysed, but not occurring in the particular quadrat(s) analysed, (transformed to value 1 by the multivariate analyses). The scale was also further extended by subdividing both the classes 1 and 5. Class 5 was subdivided in all the analyses (into 5 and 6, with the limits as shown in Table 4.3.1). This has been the common practice of many other phytosociologists (e.g. Fransson 1972).

The original cover class 1 was subdivided into three classes in all analyses made after 1978, s (0-1 % of cover), u (1 % - 3.125 %) and l (3.125 - 6.25 %). The broadest scale used in any of the analyses has been the criterion determining the scale of the multivariate analyses of the material in question. Those analyses made on a more detailed scale were then always transformed to the broader scale.

As seen from table 4.3.1, the detailed scale: r, +, s, u, 1-6, was transformed to a 9-degree scale for use in the multivariate analyses. This 9-degree scale

Table 4.3.1 Cover classes and transformed degrees of cover used in the present study.

- 1) r: "reduced" specimen (seedlings, etc.)  
 2) +: belonging to the analysed stand, but not occurring in the particular quadrat(s) analysed.  
 3) [ 1 The "normal" cover value 1 in the Hult-Sernander-Du Rietz scale.

Degree of cover	Percent and parts of the quadrat covered (cover class)		Cover class mean, in %	Transformed degree of cover
	In %	Parts		
1) r	0	0	0	0
2) +	0	0	0	1
s	0-1	0-1/100	0.5	2
u	1-3.125	1/100-1/32	2.0625	3
1	3.125-6.25	1/32-1/16	4.6875	4
3) [1	0-6.25	0-1/16	3.125	4]
2	6.25-12.5	1/16-1/8	9.375	5
3	12.5-25	1/8-1/4	18.75	6
4	25-50	1/4-1/2	37.5	7
5	50-75	1/2-3/4	62.5	8
6	75-100	3/4-1	87.5	9

includes one value (+ = 1) indicating abundance, the other 8 values forming a cover series which is partially geometric (except s-u and 5-6).

In the multivariate analyses, the cover scale used is of fundamental importance for the results obtained, and transformation (weighting) procedures are commonly employed (e.g. Jensen 1978, Maarel 1979 a,b, Gauch 1982). Any scale can be characterized by the relationship between its lowest and highest values, i.e. the scale range (Jensen 1978). I used a 9-degree scale in the multivariate analyses, one which approximates closely to the ordinal scale of Maarel (1979a: 183) and to the octave scale of Gauch (1982), both of which have been highly recommended as being suitable to obtain a balance between qualitative and quantitative values when Wisharts "similarity ratio" is used for calculating the degree of similarity (cf. also Pakarinen 1984).

#### 4.3.3 Synthesis samples

In the classification and ordination of samples in phytosociology it is important to ensure that the species content of the stands studied are as completely represented as possible in the sample data. It is common practice to determine the so-called "minimal area" of the communities, i.e. the smallest area within which the species composition of the community in question is adequately represented (e.g. Mueller-Dombois & Ellenberg 1974). The minimal area varies with the vegetation type, and, in addition, it varies according to how the extent of homogeneity is judged (e.g. Dahl 1957).

Small-sized quadrats ( $0.25 \text{ m}^2$ ) are usually considered to be too small to be representative for the communities involved, and for further treatment of the data, synthesis samples (with stand cover) are made. The stand cover has to take into consideration all the species present in the stand, and the cover is a synthesis of the cover as constituted by all the smaller quadrats taken together. In this way the requisite demand for minimal area is fulfilled in most cases. The "stand cover" of the synthesis samples has been calculated in the following manner: The degree of cover in each small quadrat is converted to the mean value of the cover class (Table 4.3.1) and the values added up (as described by Malmer 1962). This sum is then divided by the total number of quadrats (in opposition to determination of the "characteristic degree of cover" where only those quadrats that include the particular species are taken into consideration). The value so obtained is then referred back to the degree of cover, and used as the cover value for the particular sample stand. The "characteristic degree of cover" of Malmer (1962) is used in the synoptic tables.

When using a purely geometric cover scale it is most logical also to convert the cover value geometrically, as done by Sjörs (1954). Malmer's (1962) method, converting a geometric scale to an arithmetic mean, has been much criticized, e.g. by Oksanen (1976, 1984). My cover scale forms only a partial geometric series, and in consequence, I have used the arithmetic mean of the cover class value. The alternative would be to use the geometric class mean in the logarithmic section of the scale. The actual geometric means, according to Oksanen (1984) would be: (arithmetic means in Table 4.3.1, shown in brackets): 2: 8.8 % (9.375) 3: 18 % (18.75) 4: 35 % (37.5). As seen, the deviations are small, and if this method was applied to the existing data there would be little significant difference in practice.

The synthesis samples have been calculated using the data program SCANTAB (Wilmann 1987a), whereby data derived from a single stand quadrat can be analysed together with the synthesis sample of 2-5 small quadrats. Some intermediate-sized quadrats ( $1-4 \text{ m}^2$  in size) have, in the analyses of the open grassland vegetation (cf. section 9.3), been considered as separate sample stands, at other times synthesis samples have been calculated and used instead in the multivariate analyses. The description given of the vegetation types in sections 5, 6 and 9 provides full information as to whether the samples concerned are single-quadrat or multi-quadrat types (cf. also Table 1 of Appendix A).

#### 4.4 CLASSIFICATION AND ORDINATION OF VEGETATION

##### 4.4.1 General

Sections 5-11 are concerned with the phytosociology of the plant communities. In this study multivariate methods have been used, i.e. methods for establishing the numerical relationships between the different phytosociological entities.

A phytosociological entity may be a concrete stand (phytocoenose), or a type of plant community (phytocoenon). The numerical relationships are analysed and interpreted accordingly.

In the past few years a number of textbooks etc. describing the application of multivariate analysis in phytosociology have been published (e.g. Whittaker 1973, 1978, Gauch 1982, Greig-Smith 1983, Pielou 1984, Moore & Chapman 1986, Digby & Kempton 1987, Jongman et al. 1987).

The multivariate methods used in phytosociology are of two kinds: classification and ordination. Classification can be best described as the procedure of creating types of vegetation to which phytosociological entities can be assigned (Maarel 1979a). Any vegetation type (= plant community type = phytocoenon) is an abstraction of a group of entities, related to each other in all respects, which are considered relevant for the classification. Phytosociological ordination is the procedure involved in arranging these phytosociological entities along axes of variation in a uni- or multi-dimensional scheme, according to the specific relationships between the entities. The variables in these multivariate analyses are the quantitative data for the occurrences of the plant species present in the stands.

All the ecological data given for the plant communities apply to concrete stands, quadrats or localities. Even so, for practical reasons, in the text, ecological data are sometimes ascribed to clusters, types etc., e.g.: "the cluster x has a podsolic profile". The real meaning, however, is always: "the stands of cluster x has ..."

#### 4.4.2 Classification technique and table arrangements

Figure 4.4.1 shows the main computer programs utilised and the most important methods used in data processing, from the raw field data to the final tables and diagrams. In addition, a number of subsidiary and general writing programs (e.g. WORDPERFECT, TURBO Editor etc.) were used. Bodil Wilmann has been responsible for the EDP-system used (cf. Wilmann 1985, 1987a-e).

The SCANTAB-program (Wilmann 1987a) was used for:

- 1) production of the preliminary phytosociological tables
- 2) obtaining the synthesis samples for the small quadrats
- 3) producing a data file which was later used in the classification and ordination programs.

The TABORD program (Persson 1977, Maarel et al. 1978, Aune 1984) was used to obtain the sample clusters, based on sample similarity. The index (Wishart) "similarity ratio" has been used for all the tables presented, but the "percentage dissimilarity" index (= Canberra metric) was also tried out.





3. Relocation-homogenization of clusters through removal of deviant samples by adopting a **threshold value**. I have used different values for each data set (cf. the information given in the tables and text). When the similarity between a sample and its own cluster is calculated during relocation procedure, the sample has been removed from its own cluster.
4. Fusion of clusters on the basis of between-cluster similarity, by adopting a **fusion limit**. The fusion limit used in my trials, has also varied.
5. Construction of the table. In our version of TABORD, the first cluster chosen is the one that shows the lowest value of the ratio "number of constant species"/"number of samples". Constant species are defined, usually as 80 %, 70 % or 60 %. The next cluster is chosen according to the highest number of constant species in common with cluster 1, and so on.

The TABORD method of arranging the tables did not satisfy my requirements, wherefore the arrangement of the clusters was done subjectively (using FLEXCLUS) after studying the results of a number of TABORD trials, TWINS-PAN classifications and DCA ordinations.

TABORD also provides certain additional information about cluster structure and about species occurrence in the clusters. Different types of figures (diagrams etc.) and tables presented in sections 5, 6, 9 and 10 are mainly derived from the TABORD output (cf. Maarel et al. 1978):

1. **Within-cluster similarity**, is defined as the average similarity of the individual samples to the centroid of the cluster; this represents a measure of the homogeneity of the cluster.
2. **Between-cluster similarity**, which concerns the centroids of the clusters.

The FLEXCLUS program (cf. Tongeren 1986, Wilmann 1987d) has been used for the arrangement of the clusters in the tables. FLEXCLUS is an interactive program which provides several options in constructing the phytosociological table, including the possibility of influencing the results obtained, e.g. the clustering strategy.

The main phytosociological tables (viz. Tables 3 and 4 of Appendix C, Tables 1-3 of Appendix D) were constructed by the FLEXCLUS program after different choices had been made (with minor editing made by WORDPERFECT using PC). The structure of each of the main tables is the same, and the species are ordered according to their preference for the clusters. A block of constant species in all clusters are listed first, followed by two diagonal structures: the first for species of limited occurrence (either in a single cluster or in two neighbouring clusters), the second for species with a wider occurrence in the clusters. Rarer species (i.e. species not occurring as constants in any cluster) are thereafter listed and species with only a single occurrence in all the tables, are listed finally at the bottom of the tables.

TWINSPAN is a two-way indicator species analysis devised by Hill (1979b). Both species and samples are classified, and the result is intended to be similar to that obtained by the Braun-Blanquet table arrangement. TWINSPAN uses reciprocal averaging and it dichotomizes an initial ordination of stands, identifies "differential species" and uses these to refine the ordination. The procedure is then repeated for each branch of the dichotomy.

In TWINSPAN a number of parameters can be varied, and the choices of these parameters directly influence the results of the classification. Omission of certain samples, the group size for division, the maximum level of division etc., all represent parameters which may differ from the standard type, but are visible in the final tables. Standard analysis was used for most of the parameters, but for "pseudospecies cut level" the cover values were used unchanged (except where information to the contrary is given on a table or figure). The weighting for the levels of pseudospecies are not standard either, since the value + has been assigned to value 1, the rest of the cover classes given value 2.

TWINSPAN produces a table showing both a sample hierarchy and a species hierarchy, but in the case of my material, the structure of these tables was not as good, or as readable, as the tables produced by TABORD & FLEXCLUS. The TWINSPAN phytosociological tables have therefore not been included in this paper. The structure of the TWINSPAN classification of the samples is presented in the form of dendrograms, as drawn by the DENDRO program (Loman & Leemans 1986). This program does not compute any measure for the actual division, but instead computes a heterogeneity-measure within a cluster. The heterogeneity of a cluster is:  $\Sigma (\min(\text{freq}, 1 - \text{freq}))$ . The heterogeneity of two samples including exactly the same species is 0. The heterogeneity value summarizes the difference in occurrence of each species, wherefore species-poor samples never attain high values. This measure of heterogeneity differs from the method used for clustering in the TWINSPAN program. The dichotomy of the diagrams, however, was made using TWINSPAN and this is the most important information shown in the diagrams, not the scale showing the degree of heterogeneity.

The SAMTAB program (Wilman 1987e) constructs a synoptic table of the TABORD/FLEXCLUS tables, showing the frequency and characteristic degree of cover (cf. Malmer 1962). These synoptic tables, only including constant species of at least one cluster, are included in the descriptive sections (cf. Tables 5.2.1, 6.2.1, 9.2.2 and 10.2.1).

#### 4.4.3 Ordination technique

DECORANA is a program devised by Hill (1979a) for detrended correspondence analysis (DCA). DCA is an improvement on reciprocal averaging (RA), as it avoids the "arch" or "horseshoe" problems of RA, and, in addition, DCA also scales the ordination axes to avoid the contraction of the axes' ends as occurs

in RA. DCA ordinales both samples and species simultaneously, in an objective manner without endpoints or weights. DCA has proved to be most successful when applied to community analyses, Hill & Gauch (1980), Gauch (1982), Økland (1986).

In DECORANA, as in TWINSpan, a number of the parameters may be varied. In most cases, in this study at Sølendet, only "visible" parameters (e.g. omission of samples) have been changed from the standard adopted. The transformed cover scale (1-9) has been used unchanged. In DCA, the "outliers" of samples and species greatly influence the final result (Gauch 1982), and omission of samples and species is recommended in the literature. Different sets of samples have been used for the ordination of the data from Sølendet, but no species have ever been omitted. Instead, downweighting of rare species has been used in some of the ordinations. Such downweighting is described by Hill (1979a). The effect is to reduce the abundance of species rarer than ca. 20 % in proportion to their frequency. When such downweighting of rare species has been done, indication is given in the tables, figures and text.

The ORDIPLOT program, devised by Tongeren (cf. Wilmann 1987b), automatically designs plots of samples and species from the data file of DECORANA. A number of such diagrams have been included in sections 5, 6, 9 and 10, showing DCA-plots of the vegetation cover at Sølendet. The eigenvalue is given for each axis in the DCA-diagrams. Normally the plots of axes 1 & 2 and of 1 & 3 are shown, and usually the eigenvalues of all axes higher than the 3<sup>rd</sup> are very small. For each axis, the length of the gradient is the length of the sample ordination shown in the diagrams. The unit of ordination length is the standard deviation (s.d.), Hill & Gauch (1980).

#### 4.4.4 Vegetational types, terminology

The vegetation types described in sections 5-9 (communities; *noda sensu* Poor, cf. Mueller-Dombois & Ellenberg 1974) are local, i.e. they are based on the vegetation at Sølendet, without any attempt being made to apply systems made for related vegetation in other districts. Samples from different areas of Central Norway are included in the multivariate analyses of section 10. The types are mostly identical with the clusters resulting from the TABORD and/or the TWINSpan classifications.

The defined clusters (= vegetational types) of each of the five multivariate analyses in this monograph have their own symbols, used to avoid misunderstanding:

Section 5 includes	18 mire and spring vegetational types, i.e. clusters M1-18
Section 6 includes	15 rich fen vegetational types, i.e. clusters a-o
Section 9 includes	12 types of woodland vegetation, i.e. clusters W1-12; and 5 types of open grassland vegetation, i.e. clusters O1-5
Section 10 includes	7 types of wooded grasslands of the boreal uplands of C. Norway, i.e. clusters U1-7.

**Characteristic species** is defined as a species that is more or less confined to a single plant community. It may be either **exclusive**, i.e. entirely or almost entirely confined to one community (the character species concept of the Braun-Blanquet-school, cf. Mueller-Dombois & Ellenberg 1974) or **preferential**, i.e. occurs as dominant or reaches high frequency in one community only (Malmer 1962: 50). The preferential species is often termed **typical** in the present monograph. **Regionally characteristic species** is more or less confined to a defined vegetational region (e.g. northern boreal).

**Differential species** is defined as a species that is more or less confined to one of two communities being compared. It may be either **exclusive** or **preferential**.

**Constant species** is defined as a species that occurs in more than 70 % (sometimes 60 % or 80 %) of the samples in each cluster.

**Dominant species** is defined as a constant species that has a cover value of  $\geq 3$  on the scale used here (i.e. covering 12.5 % or more).

**Common species** is defined as one that occurs in more than 50 % of the quadrats involved.

#### 4.5 ECOLOGICAL MEASUREMENTS, PRODUCTION STUDIES, PHOTOGRAPHY

##### 4.5.1 Measurements in the field

The field technique used in analysing the vegetation is described in section 4.3.1. Ca. 100 localities, at which phytosociological analyses were made at Sølendet, have one or more permanent quadrats marked with stakes. Simple equipment such as a **tape measure** was used for measuring the heights of the different layers, the *Parmelia olivacea* limit (cf. section 3.3.4.1) etc.; a **compass** was used to determine slope aspect, a **clinometer** (Suunto PM-5/400 PC) for measuring slope inclination (in "new grades" = ‰) and the height of the trees. A normal levelling instrument was used for mapping the transect profiles.

##### 4.5.2 Analyses of soil and water, groundwater-level

A **soil profile** was dug at most of the localities, usually only a few dm deep; the different layers were described. The terminology used for soil classification is mainly that of (Stålfelt 1965). Peat depth was measured by using a peat sampler of the Hiller type.

**Soil samples** were taken ca. 3-5 cm below the surface. Ca. 0.5 dl of soil was collected into a plastic bottle (with a cap) and distilled water was added to



saturation; thereafter the bottle was shaken and pH was measured after ca. 12 hours. Usually less than 0.5 dl of water was added to the soil; tests indicated that a little more or less water in the mixture had little or no effect on the pH reading. Two parallel soil profiles and samples were analysed at each locality, taken from the southwestern and northeastern corners of the prime stand quadrat.

**Water samples** were also taken at the mire and spring localities, from the same corners of the quadrats as the soil samples; wherever possible surface water was collected, quite often involving a little hand pressure. The water was collected in a long and narrow glass tube (with a cap), each sample ca. 0.5 dl. The water sample was allowed to stand for some hours; thereafter the specific conductivity was measured first, in the clear upper part of the water, then the pH.

pH was measured with a Radiometer pH-meter, type PHM 29, using a combined glass-calomel electrode. Two buffers (pH = 4.0 and pH = 7.0) were used for reference.

The **specific conductivity** was measured using a Wheatstone bridge of the type Normameter R1, with a headset. Platinum electrodes of the type Philips PW 9510 were used, with a cell factor of  $f = 1.44$  cm (i.e. cell constant of  $1/1.44 = 0.69$ ). The specific conductivity was calculated at 20°C, and the hydrogen ion values were subtracted, as described by Sjörs (1952). For a number of the water samples, in addition to the method described above, the specific conductivity was calculated using a Delta mod. 1014. For single samples of rich fen water from Sølendet, the two methods always yielded similar values (with less than 5% deviation, cf. also Kofoed 1981).

The specific conductivity values recorded for the water samples from the rich fens and springs at Sølendet lie in the range from  $36 \cdot 10^{-6}$  S/cm to  $220 \cdot 10^{-6}$  S/cm ( $S = \text{Siemens}$ ). The values were multiplied by  $10^6$  and these are the values used in the text and the tables, i.e. the unit of  $\mu\text{S/cm}$  (cf. Elveland 1976). This unit is the same as that generally used by mire ecologists, e.g. Sjörs (1948, 1952), Malmer (1962), Persson (1962). This value is termed the "reduced specific conductivity" ( $= K_{20}$ ). The mean values for localities and clusters based on the 112 single measurements of water samples, are shown in table 2 of Appendix C and table 5.3.1, respectively.

The groundwater conditions of the Aursunden - Sølendet area were described in sections 3.2.3-4. The values for the **groundwater-level** of the mire localities represents the distance between the open water surface in peat pits and the surface of the peat. In most of the mire localities at Sølendet, a 30-40 cm deep pit, ca. 8-10 cm in diameter, was dug at least one day before the measurements were made. The groundwater-level was measured on different dates, during the summertime in 1981-1982. I regard the values for four days of 1982 (those shown in Tables 2 of App. C and 5.3.1) as representative of the spring - (dry) summer - autumn conditions of the mire localities at Sølendet. This method

of measuring the groundwater-level in mires, in relation to the vegetational types, has been used by many other scientists, e.g. Sjörs (1948), Havas (1961), Malmer (1962) and Persson (1962).

#### 4.5.3 Productivity studies, hay water content

##### 4.5.3.1 Harvesting methods

Field layer production was estimated by harvesting the vegetation in two main ways: 1. **Cutting with scissors**, in quadrats of 0.25 m<sup>2</sup>, usually three quadrats in each stand. This method was described in Moen (1976b, when some production results from Nordmarka were published). At Sølendet, this rather time-consuming method has been used at a few localities; in some quadrats even differentiating between the different species (cf. section 13.4.2 where a few initial results are presented). The full results of the production studies made using scissors will be published later. In this monograph mainly the results from the second method are presented: 2. **Cutting by scythe**. Permanent quadrats have been scythed every year since 1974. In that year 5 quadrats of 25 m<sup>2</sup> were scythed by two of the landowners on Sølendet. In 1975 and 1976, 8 and 38 quadrats, respectively, were scythed. From 1977 to the present day, the supervisor of the reserve, Nils Stenvold, has scythed all the quadrats (ca. 40-50 each year). The great majority of the quadrats have been 12.5 m<sup>2</sup> in size. The quadrats have been scythed each year early in August (latest date: Aug. 15 in 1975; earliest date: July 29 in 1988 - a very "early" summer, the only year in which the quadrats were scythed in July).

Table 1 of Appendix E gives a survey of all the scythed quadrats during 1974-1988; i.e. 624 crops from 130 permanent quadrats in 59 different localities.

As far as possible scything of the quadrats for production estimates has been done whilst the dew was still on the grass; in dry weather the scything has been done at daybreak. The scythe cuts better on wet grass. Usually 2-4 cm of sward was left. Scything in dry conditions may result in a higher sward, i.e. lower production values.

A difference in the sharpness of the scythe-blade, the different weather conditions etc., represent an appreciable source of error, especially in vegetation types with a low productivity. The quadrats scythed are small, and differences of a few percent in the scythed area can occur. Since 1977, the same person has scythed every quadrat, thus eliminating differences caused by individual scything techniques. Even so, the scything method is a somewhat inaccurate one. The rest of the production estimation procedure (drying, weighing etc.) is certainly more accurate.

The scythed crop was raked together and placed and weighed on a plastic flake using a steelyard (Norw. "bismar"), see figure 4.5.1. Three herbage samples were put into plastic bags and taken to the laboratory for measurement of the



Fig. 4.5.1 Weighing of a scythed crop, using a plastic flake and a steelyard.

wet/dry weights. The samples were dried at 80°C to a stable dry weight (usually ca. 24 hours of drying). A "Saunter K 1200" balance with an accuracy of 0.1 g was used in the laboratory.

The net dry weight of the samples varied between ca. 30-90 g., the standard deviation (s.d.) value for the production estimates was usually 1%-5% (-10%), i.e. representing a much smaller source of error than that involved in the actual scything.

In 1977, 1979 and 1985, a large number of samples were sorted, in order to remove the litter. These production values are also shown in table 1 of Appendix E.

#### 4.5.3.2 Dry matter and water contents of scythed herbage and of hay

The estimated water content of the scythed herbage will vary according to the drying temperature used. Dry matter s.str. (= 0% of water) normally refers to herbage samples dried at 105°C until they attain a stable weight. However, a drying temperature of 80°C is also a commonly used value for recording dry

matter in productivity studies (cf. the IBP-CT studies described in section 13.1.2, e.g. Wielgolaski & Kjølvik 1975). All the estimated plant production values from Sølendet have been obtained by drying the samples in an oven at 80°C (i.e. a residual water content of 1-2%).

The water content of hay is conventionally considered to be 15% (e.g. Sjörs 1954, Heie 1971), or 17% (e.g. Solberg 1975). The old-fashioned method of hay-making, by letting it dry on the ground and then storing it in haystacks or hay-barns (cf. section 3.4.2) certainly led to variable contents of water, depending on the weather conditions.

Some estimates of the water contents of scythed herbage and hay samples from Sølendet carried out at different temperatures in the drying oven have led me to conclude that:

Herbage dried at 105°C will contain 0% of water (= dry matter s.str.).

Herbage dried at 80°C contains 1-2% of water (= the "normal" dry matter).

Herbage dried at 20°C contains ca. 7-10% of water.

Herbage converted into hay by the farmers contains 15-20% of water.

Herbage (fresh) just after scything contains (50)60-70(80)% of water.

#### 4.5.4 Photographic records

From the start of the research studies at Sølendet (i.e. 1974) up to the present day, a number of photos have been taken every year. In 1976 and 1977 more than 100 fixed points for photography were defined, new ones were added later, i.e. more than one photo in black and white and one slide exists for all the ca. 100 localities of the permanent quadrats. A majority of these localities have been photographed at different times of the year (spring, summer, winter), before and after reclamation and scything etc. A few fixed-point photographs, showing the "before-after" situations are included in this monograph, e.g. the following pairs shown in figures: 3.4.6 & 7, 7.3.2 & 3 and 9.6.5 & 6, respectively. The photos shown in figures 3.4.4 & 5 and 9.6.1 & 2 have all been taken from the same fixed-points.

In addition to the fixed-point photographs, a large number have also been taken to show the landscapes, vegetational types, plant species, buildings, working situations, etc. In all ca. 1100 black and white photos and ca. 1500 slides exist. The photos shown in the present paper are all "project" photos (taken at Sølendet by T. Arnesen, J.E. Kofoed & A. Moen), except for figures 10.4.1-2 from Nerskogen and Innerdalen (A. Moen) and figure 4.5.1 (Ø. Størkersen).

## 5 MIRE AND SPRING VEGETATION AT SØLENDET, VEGETATIONAL TYPES AND HABITAT CONDITIONS

### 5.1 INTRODUCTION

I have analysed the composition of the mire and spring vegetation of ca. 75 localities at Sølendet. At a number of these localities, the stand quadrats were reanalysed after clearance and scything, and in some localities more than one stand quadrat has been analysed; i.e. a number of sample stands may derive from each locality, for example the 13 samples (nos. 1, 110-119 and 151-152) for locality no. 1. Table 1 of Appendix A provides a survey of all the phytosociological samples. A number of such samples from single localities, which show vegetational changes induced by scything, will be dealt with in a future publication, cf. also section 13.4.

In section 5.2 the main body of data, the phytosociological analyses of the mire and spring vegetation types, collected by myself, are dealt with. The data for all sample stands scythed more than once have been omitted from that treatment.

The vegetational types (= clusters M1-18) are defined as a result of the multivariate analyses of the mire and spring vegetation at Sølendet. The clusters are named by 2-3 typical or constant species; they are described under the headings of larger groups (1-3 clusters in each) in section 5.4. These cluster groups coincide with the main units of the classification system used in section 8.4. The names of the cluster groups are based on one (or two) dominant species, mainly bryophytes, i.e.: *Scorpidium scorpioides*, *Campylium stellatum*, *Sphagnum warnstorffii*, *Drepanocladus revolvens*, *Meesia triquetra*, *Salix* spp., *Sphagnum fuscum*, *Cratoneuron commutatum*.

The mire vegetation at Sølendet is dealt with in four different sections of this monograph, i.e. sections 5 (also including spring vegetation), 6, 8 and 12.4. In each of these sections the names of the cluster groups are used as headings for the same type of vegetation, i.e.:

Rich fen, *Scorpidium* communities

Rich fen, *Campylium* communities (partly separated into fen expanse and fen margin)

Rich fen, *Sphagnum warnstorffii* communities

Rich fen, *Drepanocladus-Meesia* communities

Rich fen, *Salix* communities

Bog hummock, *Sphagnum fuscum* communities

Rich spring, *Cratoneuron* communities (only in section 5).

Habitat conditions and estimates of the field layer production for the mire communities are dealt with under the heading of the cluster groups in section 5.4.



In section 6 the 38 samples of Gaare are dealt with, together with the data from 59 samples of rich fen vegetation analysed by myself. A synsystematic survey of the mire vegetation at Sølendet is given in section 8, including comparisons with the literature. An evaluation of the relationship between the mapped units and the mire types is given in section 12.4. The spring vegetation is further dealt with in section 7.

## 5.2 MULTIVARIATE ANALYSES

### 5.2.1 The full data set

The full data set includes 80 phytosociological samples of mire and spring vegetation, cf. tables 1 and 2 of Appendix C. Most of the samples were synthesis samples of the data from 3-5 small quadrats. About 10 of the samples were based on one or more analyses of quadrats of ca. 4 m<sup>2</sup>, and the basis for the synthesis samples for a further 13 samples was only two small (0.25 m<sup>2</sup>) quadrats. Altogether 269 small quadrats are included in the 80 samples.

The full 9-degree cover scale for the samples was used, and even all the 9 pseudospecies cut levels were assigned in the TWINSpan classification.

The full data set (= 80 samples) are presented in two DCA-ordination diagrams (see Figs. 5.2.4-5). In the TWINSpan classification results, the ombrotrophic samples (nos. 71 & 89) have been omitted from the figure (5.2.3). In the TABORD and FLEXCLUS results (Figs. 5.2.1-2), 6 samples have been omitted, viz. nos. 60, 66, 91, 92, 98, 193. These samples were included in the residual group in the TABORD classification procedure, with threshold and fusion levels of 0.45/0.82, i.e. all samples having a lower similarity value than 0.45 to any of the clusters. Table 5.2.1 provides survey of the constant species of the 18 clusters. Table 3 of Appendix C gives a complete list of species, with cover values for all the 74 samples of the 18 clusters. The orders of samples and species are the same for the two tables referred to. Tables 5-13 of Appendix C gives full phytosociological analyses of the small quadrats of all the synthesis samples of the full data set.

### 5.2.2 Classification

A number of TABORD classifications were made. The fusion level of 0.82 was finally chosen to separate the very close clusters 3, 4 and 5. At a fusion level of ca. 0.70 all the samples of clusters 3-7 became grouped into a single large cluster (see Fig. 5.2.2 showing the 39 samples of "cluster 3" at the referred level of similarity).

The full phytosociological table (Appendix C-Table 3, cf. also Table 5.2.1) has been arranged by the FLEXCLUS program, with a subjectively chosen order

Table 5.2.1 Synoptic table of the mire and spring vegetation at Sørendet, showing s; frequency and characteristic degree of cover. Only species occurring as com (limit 70%) in at least one cluster are listed. Table 3 of Appendix C has co list of species, with cover values for the 74 samples classified into 18 clu II. Constant species of one or two neighbouring clusters. III. Constant spec other clusters. A: tree layer; B: shrub layer.

Cluster no.	M1	M2	M3	M4	M5	M6	M7	M8	M
No. of samples	2	3	5	14	4	12	4	2	
II <i>Carex flava</i> x <i>C. hostiana</i>	.	.	.	.	100-1	8-s	25-s	50-0	
<i>Ditrichum flexicaule</i>	.	.	20-s	7-s	50-u	33-u	100-1	.	
<i>Tortella tortuosa</i>	.	.	.	.	.	.	75-2	.	
<i>Betula nana</i> - B	.	.	.	.	.	.	50-2	100-5	2
<i>Salix nigricans</i> coll. - B	.	.	.	.	.	.	.	100-s	
<i>Salix nigricans</i> coll.	.	.	.	.	.	.	.	100-s	
<i>Listera ovata</i>	.	.	.	.	.	25-0	50-0	100-u	
<i>Hylacomium pyrenaicum</i>	.	.	.	14-s	.	17-u	25-s	100-1	2
<i>Pleurozium schreberi</i>	.	.	.	.	.	.	.	100-u	5
<i>Barbilophozia lycopodioides</i>	.	.	.	.	.	.	25-u	100-u	10
<i>Rhinanthus minor</i>	.	.	.	.	.	.	.	.	7
<i>Agrostis capillaris</i>	.	.	.	.	.	.	.	.	7
<i>Anthoxanthum odoratum</i>	.	.	.	.	.	.	.	50-0	7
<i>Paludella squarrosa</i>	.	.	.	7-s	.	8-1	.	.	10
<i>Rhizomnium pseudopunctatum</i>	.	.	.	.	.	17-u	.	.	10



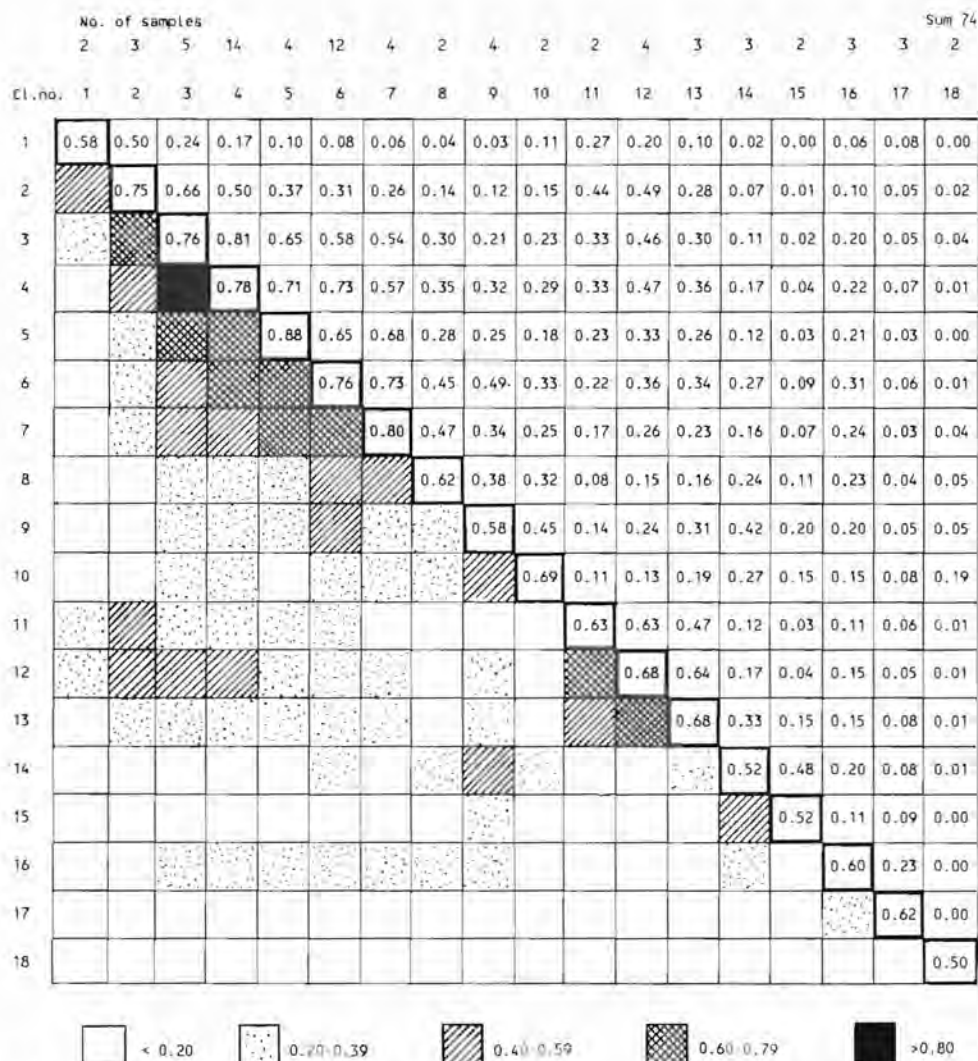


Fig. 5.2.1 Resemblance between the 18 clusters (80-sample data set, 6 residual samples omitted) of mire and spring vegetation at Sølendet, calculated from the "similarity ratio" value. The diagonal shows the within-cluster similarity.

of the clusters and a polar ordination of the samples for each cluster. The DCA-ordination diagrams (Figs. 5.2.4-6) provided valuable information for the order of clusters 1-18. Two main "chains" of clusters are listed: The first (clusters 1-10) represents a gradient of samples from mud bottom to carpet and lawn in the fen expanse, to fen margin sequence. The second chain starts with clusters 11 and 12, which are both primarily carpet communities with

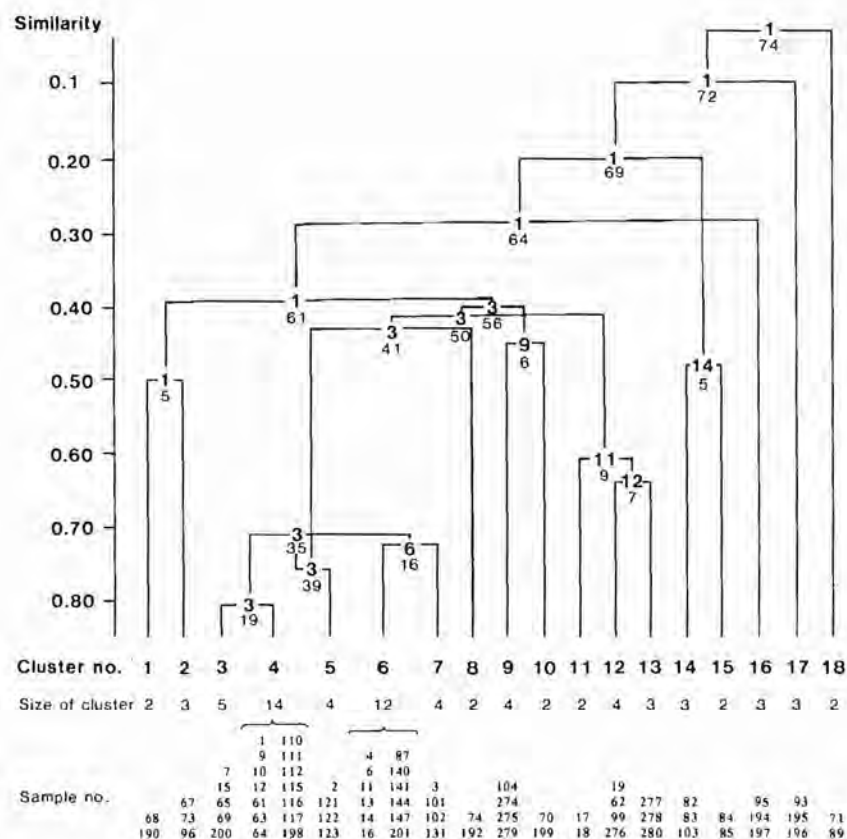


Fig. 5.2.2

TABORD dendrogram of the 18 clusters (80-sample data set, 6 residual samples omitted) of mire and spring vegetation at Sølendet. These starting clusters are the TABORD clusters for threshold and fusion levels of 0.45 and 0.82. The dendrogram shows how the 18 clusters agglomerate using threshold and fusion levels of 0, and allowing no sample relocations during the agglomerative process. Index: similarity ratio.

characteristic moss cushions, cluster 13 is a drier type with *Salix*, and clusters 14 and 15 are *Salix*-dominated clusters in the transition between fen and grass-land vegetation. In addition to these two "chains", clusters 16 and 17 represent spring vegetation and cluster 18 an ombrotrophic hummock vegetation.

Figure 5.2.1 shows the degree of resemblance between the 18 clusters and the within-cluster similarity values. The TWINSpan classification is shown in figure 5.2.3.



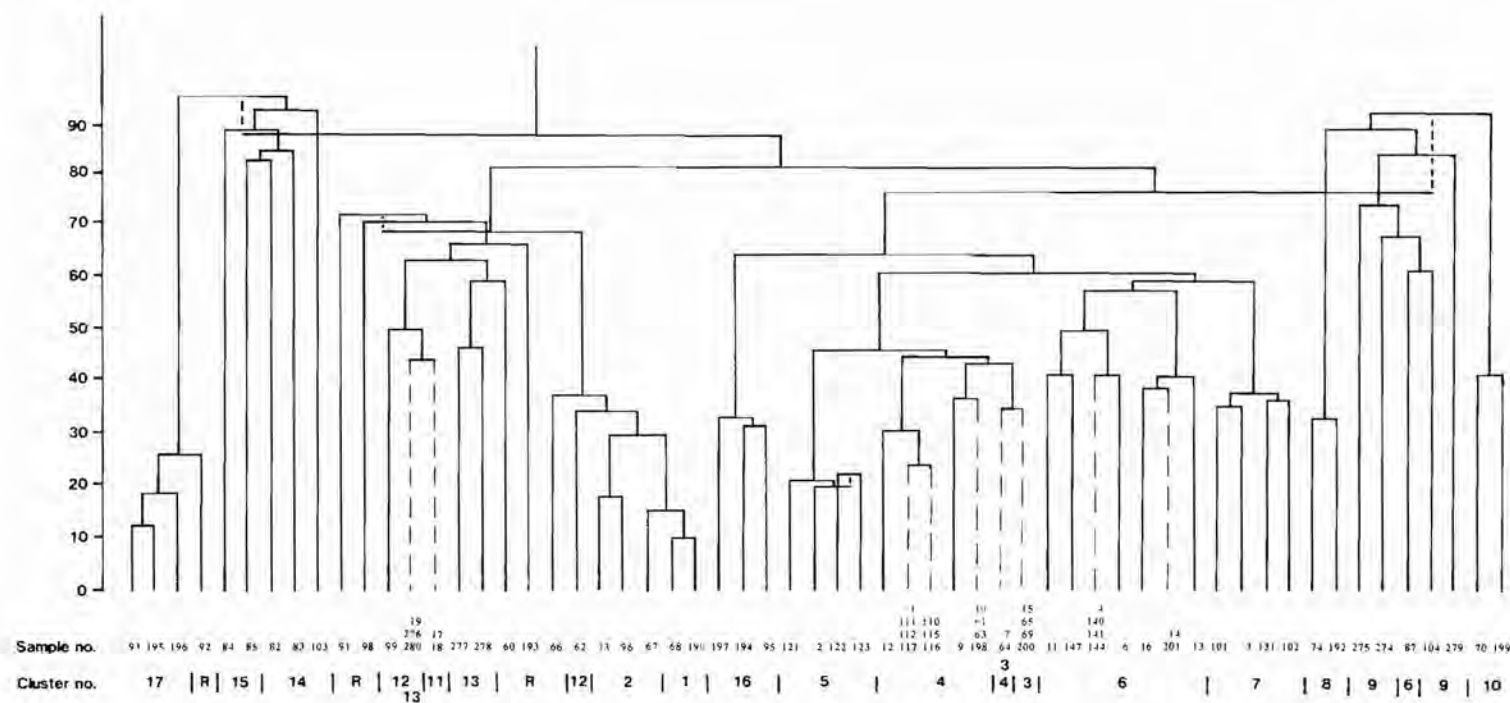


Fig. 5.2.3

TWINSpan dendrogram for 78 samples of mire and spring vegetation at Sølendet. Nine levels of division are indicated; the remaining clusters that still comprised more than one sample are shown by dashed lines. The full data set included 80 samples, nos. 71 & 89, from ombrotrophic stands, were omitted from the dendrogram; they formed a distinct cluster split off from the rest by the first division. The ordinate scale indicates the degree of heterogeneity within the clusters. Cluster no. refers to the 18 TABORD clusters M1-18 (Table 5.2.1). R = residual sample.

### 5.2.3 Ordination

Figures 5.2.4-6 are the DCA diagrams for the samples along axes 1 & 2 and 1 & 3 in three different trials. Figure 5.2.4 shows the result of a downweighting of rare species (cf. comments in 4.4.3), and forms the obverse to figure 5.2.5, without such downweighting. The ordinations referred to include the entire data set of 80 samples. Figure 5.2.6 shows the ordination of 59 of these samples after the omission of "outliers" (just these 59 samples are also dealt with in section 6, and included in the ordination diagrams of Fig. 6.3.4-5). The 21 "outliers" represent bog, swamp and spring communities, and fen margin communities transitional to damp grasslands.

The DCA-ordination results of some species scores along the three first axes are shown in table 5.2.2 for these same three trials. Figure 5.2.7 is the DCA diagram of the species for the 59 sample set (diagrams of the species for the 80 sample sets are not included).

#### 5.2.3.1 The 80 samples ordination, with downweighting of rare species (Fig. 5.2.4 and Table 5.2.2 A)

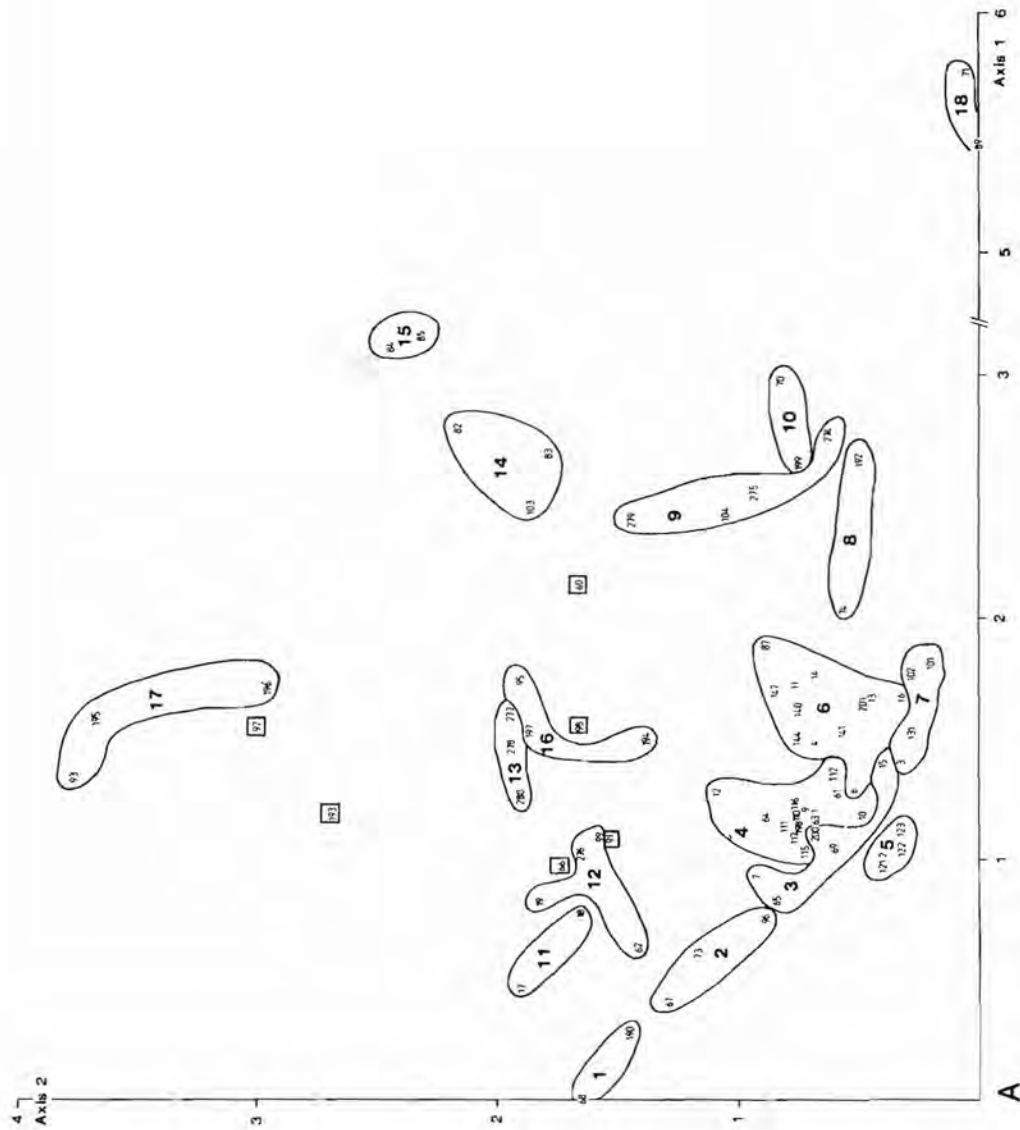
The first axis (eigenvalue 0.41, length 5.8 s.d.) represents a gradient from mud bottom communities (low values) to carpets, further to lawns/springs and swamps; the bog hummock vegetation is separated off at very high values. Ecologically it is mainly a wet-dry gradient. *Carex limosa*, *Scorpidium scorpioides* and other mud bottom/carpet species show low values (cf. Table 5.2.2 A, additional species: *Utricularia minor* -1.2, *Calliergon trifarium* -0.7). The highest values along the first axis belong to species indicative of dry habitats, e.g. the values for all three *Vaccinium* spp. exceed 5.5. *Sphagnum fuscum* (occurring in only two samples) has the highest value, 7.2.

In the phytosociological literature on mire vegetation (cf. section 8, e.g. Table 8.3.1 column no. 6) different stages/levels are separated within the rich fens, characterized by the dominant species of the bottom layer. The position of these species (for the first axis in Table 5.2.2 A) follows that order, viz: *Scorpidium scorpioides*-(*Meesia triquetra*-*Cinclidium stygium*)-*Drepanocladus revolvens*-*Campylium stellatum*-*Homalothecium nitens*-*Sphagnum warnstorffii*-*Sphagnum fuscum*. It can be stated that the gradient of the first axis is the main vegetational gradient for the mire and spring vegetation samples of Sørendet; cf. also comments to the cluster groups in section 5.1.

The second axis (eigenvalue 0.33, length 3.8 s.d.) shows bog hummock and lawn communities with low values, further to wetter types of fens/*Sphagnum warnstorffii*-dominated types. The *Drepanocladus*-*Meesia* communities and swamp communities show higher values; open spring vegetation is grouped uppermost. Of the taxa occurring in at least five samples, *Carex flava* x *C. hostiana* (-1.7) and *Carex hostiana* have the lowest values, then follows a number of species requiring dry conditions, e.g. *Ditrichum flexicaule*. At median values a

**Table 5.2.2** The species scores (in standard deviation units) for chosen species along the three first axes of the DCA-ordination of mire and spring vegetation at Sølendet. Seven species (marked with \*) are included in all nine lists, the remainder (i.e. eight species in each list) are frequent species with high or low values along at least one axis. A. Species scores in the ordination of 80 samples, with downweighting of rare species (sample ordination in Fig. 5.2.4). B. Species scores in the ordination of 80 samples (sample ordination in Fig. 5.2.5). C. Species scores in the ordination of 59 samples (sample ordination in Fig. 5.2.6, species ordination diagram in Fig. 5.2.7).

First axis (ranked)		Second axis (ranked)		Third axis (ranked)	
<b>A:</b> Eigenvalue: 0.410		Eigenvalue: 0.326		Eigenvalue: 0.147	
<i>Empetrum hermaphroditum</i>	6.3	<i>Petasites frigidus</i>	4.5	<i>Juncus castaneus</i>	3.5
<i>Vaccinium uliginosum</i>	5.9	<i>Philonotis font./toment.</i>	4.3	<i>Saxifraga aizoides</i>	3.3
<i>Eriophorum vaginatum</i>	5.4	<i>Caltha palustris</i>	3.7	<i>Cratoneuron commutatum</i>	3.0
* <i>Sphagnum warnstorffii</i>	3.1	<i>Cratoneuron commutatum</i>	3.6	<i>Carex atrofusca</i>	2.8
<i>Homalothecium nitens</i>	2.6	* <i>Meesia triquetra</i>	2.9	<i>Crepis paludosa</i>	2.5
* <i>Molinia caerulea</i>	1.2	* <i>Scorpidium scorpioides</i>	2.2	* <i>Molinia caerulea</i>	1.6
* <i>Campylium stellatum</i>	1.0	* <i>Drepanocladus revolvens</i>	1.5	* <i>Scirpus cespitosus</i>	0.9
* <i>Scirpus cespitosus</i>	0.7	* <i>Sphagnum warnstorffii</i>	1.4	* <i>Campylium stellatum</i>	0.6
* <i>Drepanocladus revolvens</i>	0.3	* <i>Campylium stellatum</i>	1.0	* <i>Drepanocladus revolvens</i>	0.3
<i>Cinclidium stygium</i>	-0.2	* <i>Scirpus cespitosus</i>	0.0	* <i>Sphagnum warnstorffii</i>	0.0
* <i>Meesia triquetra</i>	-0.3	* <i>Molinia caerulea</i>	-0.4	* <i>Scorpidium scorpioides</i>	-0.1
<i>Carex heleonastes</i>	-0.7	<i>Dactylorhiza pseudocord.</i>	-0.9	<i>Carex heleonastes</i>	-1.1
* <i>Scorpidium scorpioides</i>	-0.9	<i>Kobresia simpliciuscula</i>	-1.1	<i>Calliergon giganteum</i>	-1.7
<i>Eleocharis quinqueflora</i>	-1.0	<i>Ditrichum flexicaule</i>	-1.5	* <i>Meesia triquetra</i>	-1.7
<i>Carex limosa</i>	-1.3	<i>Carex hostiana</i>	-1.6	<i>Potentilla palustris</i>	-2.2
<b>B:</b> Eigenvalue: 0.652		Eigenvalue: 0.399		Eigenvalue: 0.263	
<i>Empetrum hermaphroditum</i>	6.2	<i>Chiloscyphus</i> sp.	4.0	<i>Petasites frigidus</i>	3.7
<i>Vaccinium uliginosum</i>	5.9	<i>Pellia neesiana</i>	3.8	<i>Plagiomnium ellipticum</i>	3.0
<i>Eriophorum vaginatum</i>	4.7	<i>Geum rivale</i>	3.8	<i>Geum rivale</i>	3.0
* <i>Sphagnum warnstorffii</i>	3.6	* <i>Sphagnum warnstorffii</i>	2.6	* <i>Sphagnum warnstorffii</i>	2.4
<i>Homalothecium nitens</i>	3.3	* <i>Meesia triquetra</i>	2.4	* <i>Drepanocladus revolvens</i>	1.7
* <i>Molinia caerulea</i>	2.1	<i>Cratoneuron commutatum</i>	2.4	* <i>Campylium stellatum</i>	1.6
* <i>Scirpus cespitosus</i>	1.7	* <i>Scorpidium scorpioides</i>	1.4	* <i>Scirpus cespitosus</i>	1.0
* <i>Campylium stellatum</i>	1.7	* <i>Drepanocladus revolvens</i>	0.7	* <i>Molinia caerulea</i>	1.0
* <i>Drepanocladus revolvens</i>	1.2	* <i>Campylium stellatum</i>	0.5	* <i>Meesia triquetra</i>	0.8
<i>Cinclidium stygium</i>	0.7	* <i>Scirpus cespitosus</i>	0.0	* <i>Scorpidium scorpioides</i>	0.0
<i>Eleocharis quinqueflora</i>	0.6	* <i>Molinia caerulea</i>	-0.1	<i>Saxifraga aizoides</i>	-0.4
* <i>Scorpidium scorpioides</i>	0.5	<i>Dactylorhiza pseudocord.</i>	-0.2	<i>Cratoneuron commutatum</i>	-0.5
* <i>Meesia triquetra</i>	0.3	<i>Kobresia simpliciuscula</i>	-0.4	<i>Carex limosa</i>	-0.5
<i>Carex heleonastes</i>	0.2	<i>Carex hostiana</i>	-0.5	<i>Juncus castaneus</i>	-0.9
<i>Petasites frigidus</i>	-0.4	<i>Ditrichum flexicaule</i>	-0.8	<i>Philonotis font./toment.</i>	-1.0
<b>C:</b> Eigenvalue: 0.403		Eigenvalue: 0.229		Eigenvalue: 0.133	
<i>Empetrum hermaphroditum</i>	4.5	<i>Viola palustris/epips.</i>	3.8	<i>Listera ovata</i>	3.4
<i>Vaccinium uliginosum</i>	4.1	<i>Potentilla palustris</i>	3.8	<i>Galium boreale</i>	2.7
* <i>Sphagnum warnstorffii</i>	3.3	<i>Aulacomnium palustre</i>	3.8	<i>Eleocharis quinqueflora</i>	2.5
<i>Gymnadenia conopsea</i>	3.3	<i>Carex heleonastes</i>	3.3	<i>Crepis paludosa</i>	2.5
<i>Eriophorum vaginatum</i>	3.2	* <i>Meesia triquetra</i>	3.2	* <i>Molinia caerulea</i>	2.2
<i>Homalothecium nitens</i>	3.2	* <i>Sphagnum warnstorffii</i>	2.8	* <i>Scorpidium scorpioides</i>	2.1
* <i>Molinia caerulea</i>	2.3	* <i>Campylium stellatum</i>	1.6	<i>Carex heleonastes</i>	2.0
* <i>Campylium stellatum</i>	1.4	* <i>Scirpus cespitosus</i>	1.4	* <i>Scirpus cespitosus</i>	1.2
* <i>Scirpus cespitosus</i>	1.2	* <i>Molinia caerulea</i>	1.1	* <i>Campylium stellatum</i>	1.2
* <i>Drepanocladus revolvens</i>	0.4	* <i>Drepanocladus revolvens</i>	1.1	* <i>Drepanocladus revolvens</i>	0.8
<i>Cinclidium stygium</i>	-0.3	<i>Vaccinium uliginosum</i>	0.6	* <i>Meesia triquetra</i>	-0.6
<i>Eleocharis quinqueflora</i>	-0.7	<i>Ditrichum flexicaule</i>	0.5	* <i>Sphagnum warnstorffii</i>	-0.5
* <i>Scorpidium scorpioides</i>	-0.8	<i>Eleocharis quinqueflora</i>	-0.5	<i>Caltha palustris</i>	-1.3
* <i>Meesia triquetra</i>	-1.1	* <i>Scorpidium scorpioides</i>	-1.0	<i>Geum rivale</i>	-1.4
<i>Carex heleonastes</i>	-1.2	<i>Carex limosa</i>	-1.6	<i>Empetrum hermaphroditum</i>	-1.4



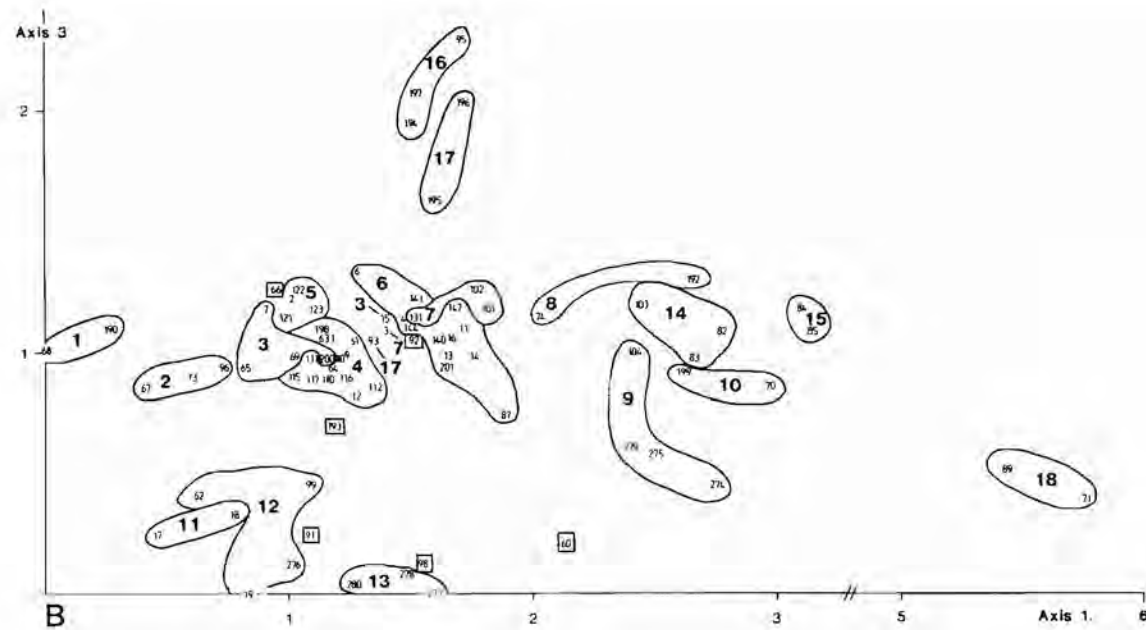


Fig. 5.2.4

DCA-ordination diagrams of 80 samples of mire and spring vegetation at Sølendet with downweighting of rare species. A: axes 1 & 2; B: axes 1 & 3. Eigenvalues of the axes: 1: 0.410; 2: 0.326; 3: 0.147. The 18 clusters used for classification (Table 5.2.1) are outlined. Quadrangles indicate the 6 residual samples.



mixture of carpet, lawn and hummock species occurs (e.g. *Sphagnum fuscum* has the value 1.5, the same as *Drepanocladus revolvens*). The spring margin species have median values, e.g. *Saxifraga aizoides* (1.4); swamp species and open spring species show the highest values, e.g. *Petasites frigidus* and *Caltha palustris*.

The gradient is complex, but certainly also includes elements of a dry-wet gradient, with increasing spring influence at high values.

Axes 1 and 2 both have relatively high eigenvalues, and the samples are spread out fairly evenly over the diagram (Fig. 5.2.4); exceptions are the samples of bog hummock (cluster 18, far to the right of the diagram) and the open spring vegetation (cluster 17 and samples 92 and 193, at the top of the diagram). The "chain" of samples/clusters from mud bottom (cluster 1) to carpets (cluster 2) and lawns (expanse, in clusters 3-5, marginal communities in clusters 6-7), and further to transitional types between lawn and hummock (clusters 8-10) are nicely shown in the diagram. This "chain" can also be characterized by the typical dominant bryophytes, as listed under the description of axis no. 1. The second "chain" includes clusters 11-13, further clusters 14-15 may be added. As commented earlier, these separations have formed the basis for the classification system of mires at Sølendet.

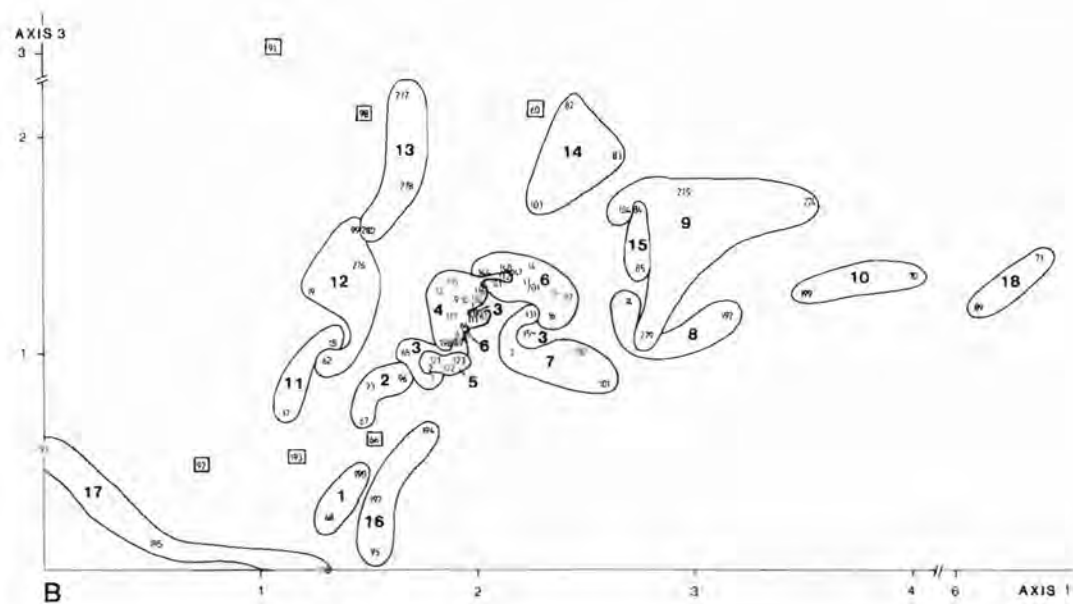
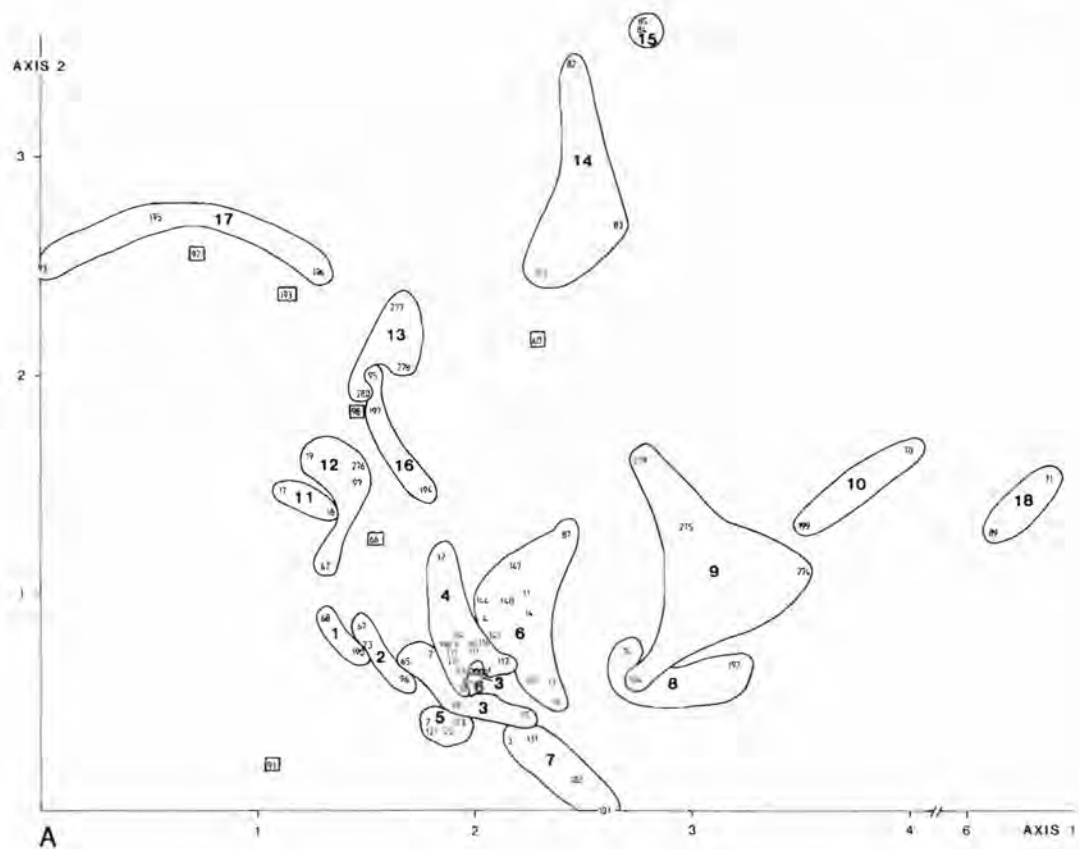
The third axis (eigenvalue 0.15, length 2.4 s.d.) has the *Drepanocladus-Meesia* communities/species well separated with low values, the typical mud bottom-carpet-lawns are all gathered at the centre of the axis, and the spring margin communities (*Saxifraga aizoides*-*Cratoneuron commutatum*) represent the highest value. The axis is not so easy to characterize in terms of a single vegetational gradient, but it is nevertheless important, e.g. because it separates the *Cratoneuron* spring communities from the fen communities.

The fourth axis (eigenvalue 0.10, length 2.8 s.d.; when the most peripheral sample, no. 91, is excluded the length is only 1.7 s.d.) This axis has not been presented in any of the diagrams or tables shown. It certainly represent a complex gradient, with a mixture of mud bottom, carpet and hummock samples with the lowest values, willow swamps represent the highest values.

#### 5.2.3.2 The 80 samples ordination, without downweighting (Fig. 5.2.5 and Table 5.2.2 B)

The first axis (eigenvalue 0.65, length 6.4 s.d.) represents a gradient from open springs (low values) to *Drepanocladus-Meesia* carpets/mud bottoms and *Scorpidium* carpets, further to lawns and fen margins/swamps; the extremely high values represent the bog hummocks. Apart from the start of the gradient (the low values), the gradient is similar to that described for axis 1 of the preceding subsection.

Fig. 5.2.5 DCA-ordination diagrams for the 80 samples of mire and spring vegetation at Sølendet. Analogous to figure 5.2.4 without downweighting of rare species. Eigenvalues of the axes: 1: 0.652; 2: 0.399; 3: 0.263.



The **second axis** (eigenvalue 0.40, length 3.6 s.d.) also shows its main features in common with the second axis of the preceding ordination. However, the willow swamp samples/species (e.g. *Salix pentandra* shrub 4.0, *Filipendula ulmaria* 3.5) all have high values.

The **third axis** (eigenvalue 0.26, length 3.4 s.d.; when the most peripheral sample, no. 91, is excluded the length is 2.2 s.d.) represents a gradient from spring/mud bottom communities to carpets and lawns; the swamp communities (*Salix pentandra* shrub 3.5) show the highest values. The axis represents elements of a habitat humidity gradient, from wet to dryer types; however, the gradient is complex.

The **fourth axis** (eigenvalue 0.17, length 3.3 s.d.) has not been presented in any of the diagrams shown. In contrast to the foregoing axis, the samples of the mud bottom/carpets show the lowest values, those of the springs the highest values.

#### 5.2.3.3 The 59 samples ordination (Figs. 5.2.6-7 and Table 5.2.2 C)

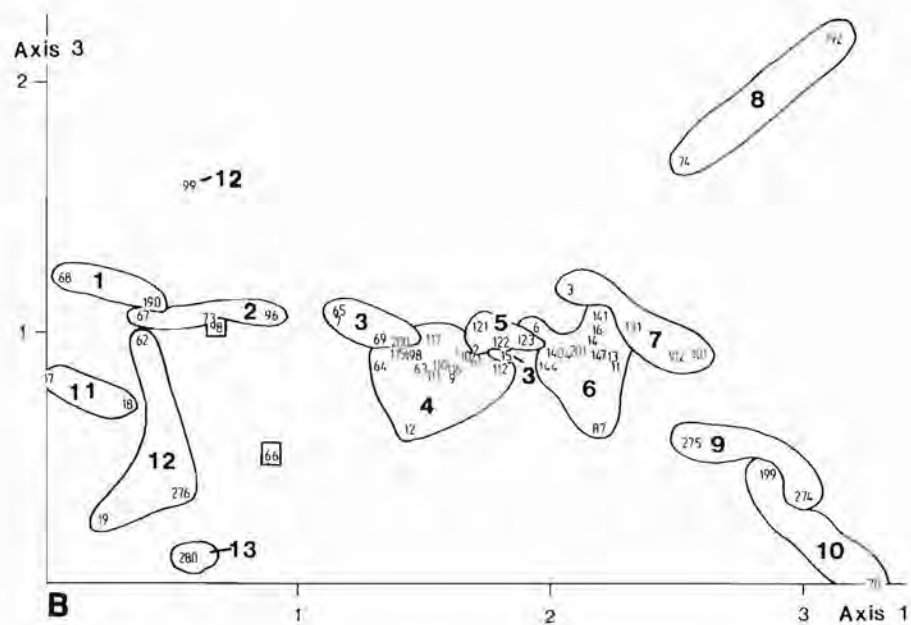
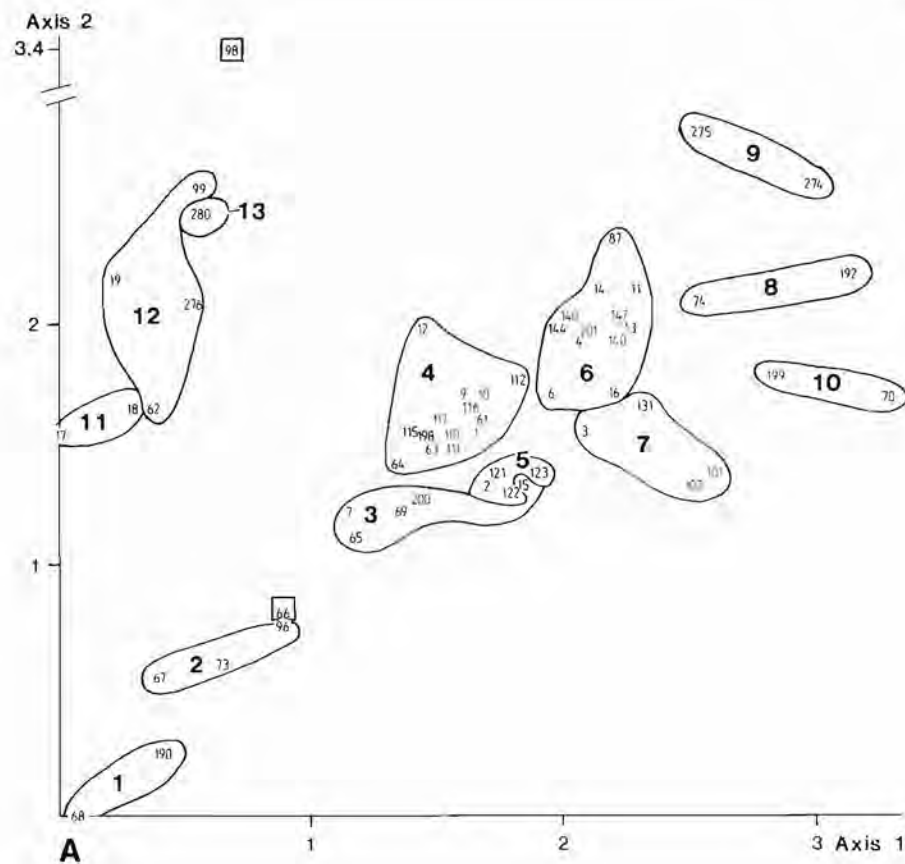
The **first axis** (eigenvalue 0.40, length 3.3 s.d.) mainly represents the mud bottom-carpet-lawn-(low) hummock gradient, as described in subsection 5.2.3.1. However, the *Cinclidium-Meesia* carpets show lower values than the mud bottoms.

The **second axis** (eigenvalue 0.23, length 3.4 s.d.) also has elements of the above-mentioned gradient, with the mud bottoms at lowest values. However, the low-growing, mire margin communities of cluster 7 also show rather low values (e.g. the typical species *Tortella tortuosa*, with -0.1; cf. also *Ditrichum flexicaule* etc. in Table 5.2.2).

Axes 1 and 2 both have relatively high eigenvalues, and the samples and the species are spread out over the diagrams. The sample ordination shows very nicely the two previously described "chains". The first "chain" forms the diagonal of the diagram, from mud bottom to carpets and lawns, and also separate the expanse types (clusters 3-5) and the marginal types (nos. 6-7) dominated by *Campyllum*, thereafter the *Sphagnum warnstorffii* types (nos. 8-10). Clusters 11-12 form a separate group on the upper left in the diagram.

The species diagram (Fig. 5.2.7 A) shows the "*Scorpidium* species" located in the left hand bottom corner, and the "*Drepanocladus-Meesia*" species at the left hand top corner of the diagram. The species of low-growing and dry lawn margins are placed at the right hand bottom corner, and the "*Sphagnum warnstorffii* species" at the right hand top corner. The typical lawn species are to find in the centre of the diagram.

Fig. 5.2.6 DCA-ordination diagrams of 59 samples of fen vegetation at Sølendet. (The same samples as in Figs. 5.2.4 & 5, after the omission of 21 "outliers".) A: axes 1 & 2; B: axes 1 & 3. Eigenvalues of the axes: 1: 0.403; 2: 0.229; 3: 0.133.



The third axis (eigenvalue 0.13, length 2.3 s.d.; when the most peripheral sample, no. 192, is excluded the length is 1.7 s.d.) shows the *Sphagnum warnstorffii* communities/species and the *Drepanocladus-Meesia* communities/species with the lowest values; in the ordination diagrams (also including axis no. 1, see Figs. 5.2.6-7 B) the communities/species referred to above are situated at the right-hand and left-hand bottom corners, respectively. The *Scorpidium* communities/species are located in the left-hand upper part of the diagram. Axis no. 3 does not differentiate well between the samples of the clusters 1-7, in the ordination diagram, a majority of the samples are located along a line nearly parallel to axis no. 1. Axis no. 3, however, distinctly separates the two samples of cluster 8 from the rest of the fen margin communities. The species typical of the low-growing marginal communities (e.g. *Betula nana*, *Galium boreale*) occur in the right-hand upper part of the species ordination diagram.

The fourth axis (eigenvalue 0.08, length 1.7 s.d.; when sample no. 66 is excluded, the length is only 1.2 s.d.) is less important, and thus has not been presented in any of the diagrams shown.

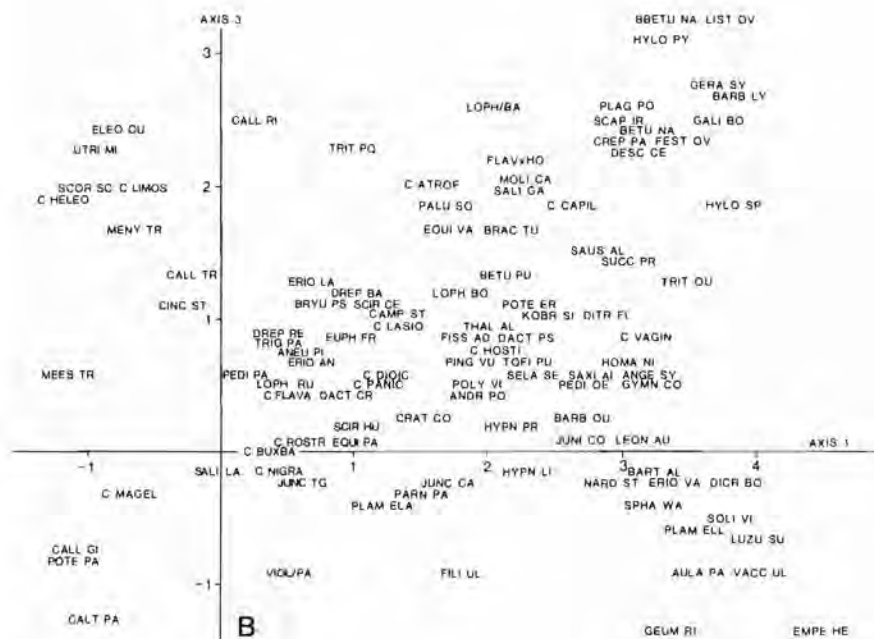
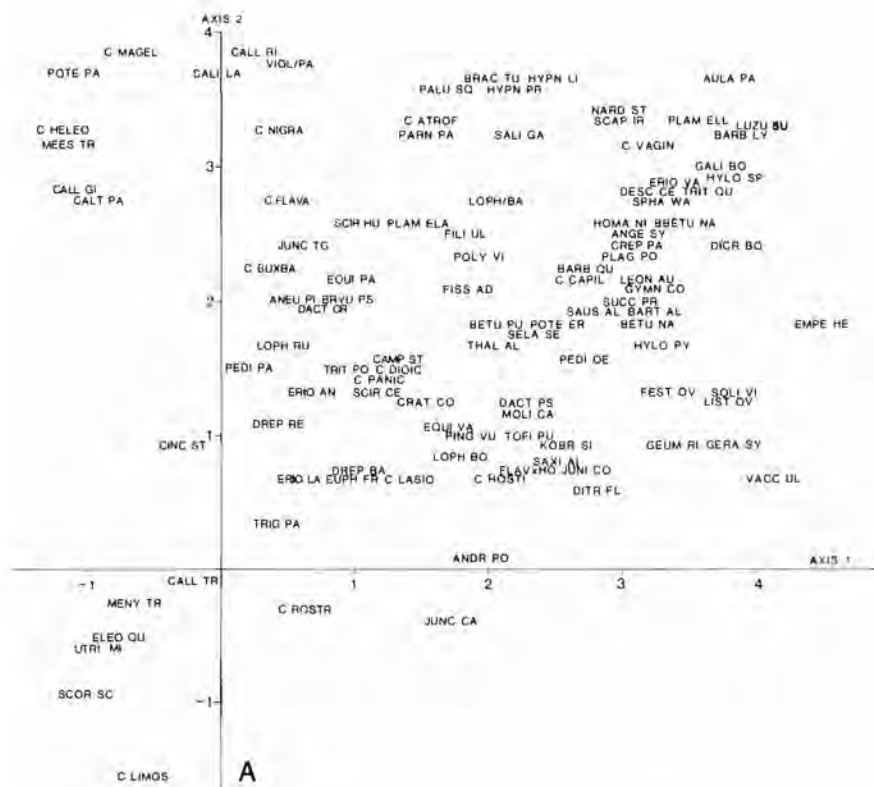
#### 5.2.3.4 Conclusion

The DCA diagrams show much the same structural framework for all the trials, but there are also marked differences. The samples forming the clusters (especially in the peripheral parts) of the heterogeneous data set of 80 samples are not so spread out when the downweighting of the rare species was carried out (Fig. 5.2.4) as when downweighting was not done. The downweighting of rare species would seem to be a very relevant procedure for this very heterogeneous data set, and the clustering of the samples accords better with the classification results and with the ordinations of the more homogeneous data sets. For the data set presented in figures 5.2.6 and 6.2.4, downweighting of the rare species yielded only small differences, these diagrams have not therefore been presented here. It is a well-known fact (cf. e.g. Gauch 1982, Eilertsen & Pedersen 1988) that downweighting of rare species, and omission of outlying samples yields the best structured framework for heterogeneous data.

The descriptions of the 18 types are based on the tables and the figures referred to above, to which no further mention will be made. The DCA diagram shown in figure 5.2.4 should be regarded as the main diagram, but, in addition, the other DCA diagrams, especially that shown in figure 5.2.6, are of value in relation to the structural framework of the samples related to clusters 3, 4, 5, 6 and 7.

Fig. 5.2.7 DCA-ordination diagrams of the taxa of fen vegetation at Sørendet, the same sample set and axes as shown in figure 5.2.6 (i.e. the 59 sample set). 107 entries are included, i.e. all species occurring in five or more samples. *Betula nana* is entered twice (B prefix indicates presence in the shrub layer); one hybrid (x) is included. A: axes 1 & 2; B: axes 1 & 3. Abbreviations: Appendix F.





### 5.3 ECOLOGICAL DATA AND FIELD LAYER PRODUCTION

The methods used in the field and the laboratory are described in section 4.5. The tables of Appendices A and C (nos. 1 and 2) list details of the ecological data for the mire stands. Appendix E shows the productivity data from scything.

A survey of ecological data and field layer production data for the mire types is given in tables 5.3.1-2; figure 5.3.1 shows the changes in field layer production of four communities when scythed every year and every second year. The ecological data and the values for field layer production for the communities are described and commented on under the heading for each cluster group in section 5.4. Comparisons with the ecological data in the literature are given in section 8.4.

### 5.4 THE VEGETATIONAL TYPES (=CLUSTERS M1-18) AND THEIR ECOLOGY

#### 5.4.1 Rich fen, *Scorpidium* communities

##### 5.4.1.1 The clusters M1-2

- M1. *Carex rostrata-Scorpidium scorpioides* (mud bottom) type  
2 samples (68 & 190) in cluster 1.

Mud bottom communities of rich fens cover only minor areas of Sølendet, but are widespread as small patches in flat fens and flarks. *Carex rostrata*, *C. lasiocarpa*, *Eleocharis quinqueflora*, *Eriophorum angustifolium*, *Calliergon trifarium*, *Drepanocladus revolvens* and *Scorpidium scorpioides* are constant species. Bare mud bottom accounts for most of the area of each quadrat, and the field layer is very sparse.

The within-cluster similarity is 0.58. The cluster is most similar to no. 2 (between-cluster similarity: 0.50).

- M2. *Eleocharis quinqueflora-Scorpidium scorpioides-Drepanocladus revolvens* type  
3 samples (67, 73 & 96) in cluster 2.

A rich carpet vegetation that covers some areas on the flat fens and also occurs as smaller patches all over the reserve in the flarks. *Scorpidium scorpioides* is dominant in the bottom layer, together with *Campylium stellatum* and *Drepanocladus revolvens* as additional dominants.

In the sparse field layer, *Scirpus cespitosus* is the only dominant species. Characteristic and common species of mud bottoms and carpet vegetation of rich fens (i.e. clusters 1, 2, 11 & 12) are: *Menyanthes trifoliata*, *Eleocharis*

Table 5.3.1 Summary of ecological data (mean value and standard deviation) for the localities of the 18 mire and spring types described in section 5. Details for the stands are listed in table 2 of Appendix C and in App. A. The "sum of groundwater-levels" represent the 4 values of 1982, viz. June 10, July 17, Aug. 6 and Oct. 5. n = number of samples, listed when different from the no. of localities.

Cluster number and name	No. of loc.	Slope in g	Depth of peat cm	pH in peat	pH in water	K <sub>20</sub> in $\mu$ S/cm	Sum of 4 groundw.-levels cm
M1 C rostrata-Scorp scorp	2	1±1	35±21	6.6±0.2	7.3±0.5 (n=4)	152±35	-3±3
M2 Eleochea-Scorp-Drep rev	3	1±1	43±12	6.4±0.5 (n=4)	7.1±0.3 (n=6)	162±62 (n=4)	19±15
M3 C lasio-Camp ste-Drep rev	4	3±1	36±22	6.6±0.2 (n=8)	7.3±0.2 (n=15)	136±32 (n=11)	63±33
M4 C las-Pote ere-Camp ste	7	5±1	42±17	6.6±0.2 (n=12)	7.2±0.4 (n=25)	128±55 (n=21)	70±20
M5 Scirpus-C host-Camp ste	1	5	35	6.2±0.2 (n=3)	7.0±0.1 (n=6)	87±28 (n=6)	78
M6 Molinia-Succ-Camp ste	7	4±1	22±10	6.4±0.3 (n=14)	7.0±0.3 (n=23)	109±47 (n=23)	99±29
M7 Molinia-Kobresia-Camp ste	3	5±0	15±0	6.5±0.2 (n=4)	6.7±0.2 (n=6)	84±7 (n=6)	119±4
M8 Betula-Molinia-Camp ste	2	6	11±8	6.0±0.1	-	-	129 (n=1)
M9 Saussurea-C vag-Sph warnst	4	2±1	14±4	5.9±0.5 (n=5)	-	-	102±31 (n=3)
M10 C rostrata-Sph warnst	1	1	50	6.4±0 (n=2)	6.1±0.3 (n=4)	74±33 (n=2)	85
M11 Menyanthes-C heleon-Cincl	2	0	78±4	6.5±0.1 (n=4)	7.2±0.1 (n=6)	87±34 (n=6)	14±4
M12 C heleon-Drep rev-Meesia	4	0±1	75±23 (n=3)	6.3±0.4 (n=5)	7.1±0.2 (n=5)	97±31 (n=5)	45±12
M13 Salix-Equisetum-Drep rev	3	0	62±10	6.7±0.3 (n=7)	7.0±0.1 (n=5)	149±26 (n=5)	65±9
M14 Salix-Filipendula-Plagiag ellipt	3	3±2	60±46	6.2±0.2 (n=5)	6.7±0.3 (n=4)	91±30 (n=4)	-
M15 Salix-Caltha-Pellia	2	2±0	4±1	5.3±0.1	5.8 (n=1)	80 (n=1)	-
M16 Saxifraga-Cratoneuron	3	-	9±1	-	7.7±0.1 (n=9)	166±16 (n=9)	-
M17 Epilobium-Cratoneuron	3	1	92±10	-	7.8±0.1 (n=5)	197±6 (n=5)	-
M18 Betula-Sph fuscum	2	0	120±28	4.0±0.1	3.9±0.1	-	-

**Table 5.3.2** Survey of the field layer production of the mire types of Sälendet. The production values are given in g/m<sup>2</sup> of dry matter (at 80°C) from scything ca. August 1 of quadrats (usually 12,5 m<sup>2</sup> in size). The "first scything" refers to that first done after cessation ca. 25 years ago. When calculating the values for "scything every second year" and "scything every year" the two first, respectively the four first, values in the series were omitted. The table shows the mean values and the s.d. for the localities representing the clusters. Details for the localities are listed in Appendix E-table 1.

Cluster number and name	The first scything			Scything every second year			Scything every year		
	No. of loc.- samples	Mean g/m <sup>2</sup> ± s.d.	Litter in %	No. of loc.- samples	Mean g/m <sup>2</sup> ± s.d.	Litter in %	No. of loc.- samples	Mean g/m <sup>2</sup> ± s.d.	Litter in %
M2 Eleocharis-Scirpus-Dryas rev	1-1	76	ca. 30	1-5	70(±12)	ca. 25	-	-	-
M3 C. lasiocarpus-Campylopus-Dryas rev	4-7	164±27	43	4-19	87±17	25	-	-	-
M4 C. lasiocarpus-Potentilla-Campylopus ste	7-9	216±61	32	7-57	135±16	17	2-9	70±11	5
M5 Scirpus-Campylopus-Campylopus ste	1-6	135(±27)	32	1-18	87(±19)	20	1-10	44(±10)	10
M6 Molinia-Succisa-Campylopus ste	6-11	156±31	26	7-42	115±41	17	1-8	75(±14)	6
M7 Molinia-Kobresia-Campylopus ste	2-5	100±8	21	1-16	50(±14)	15	1-9	24(±11)	8
M8 Betula nana-Molinia-Campylopus	1-1	88	-	1-2	100(±8)	ca. 15	-	-	-
M10 C. rostrata-Sphagnum warnst	1-1	81	40	1-4	103(±20)	ca. 15	-	-	-
M11 Menyanthes-C. heleon-Cinclidium	2-2	69±15	-	2-9	90±5	15	2-8	74±16	7
R66 Residual	1-1	257	-	1-2	163(±59)	ca. 20	1-3	88(±11)	14

*quinqueflora*, *Calliergon trifarium*, *Cinclidium stygium* and *Scorpidium scorpioides*. All species mentioned under the description of type 1 are also constants for type 2, and in addition a number of species typical of rich lawn communities of mire expanse (i.e. type 3-5) are constants: *Andromeda polifolia*, *Euphrasia frigida*, *Pedicularis palustris*, *Carex dioica*, *Eriophorum latifolium* and *Lophozia rutheana*.

The within-cluster similarity is 0.75, indicating a cluster with a high homogeneity. The greatest resemblance of the cluster is to no. 3 (0.66). The DCA diagrams show that clusters 1 and 2 are not distinct, dense clusters, since the samples 68 to 96 are arranged along a continuous gradient.

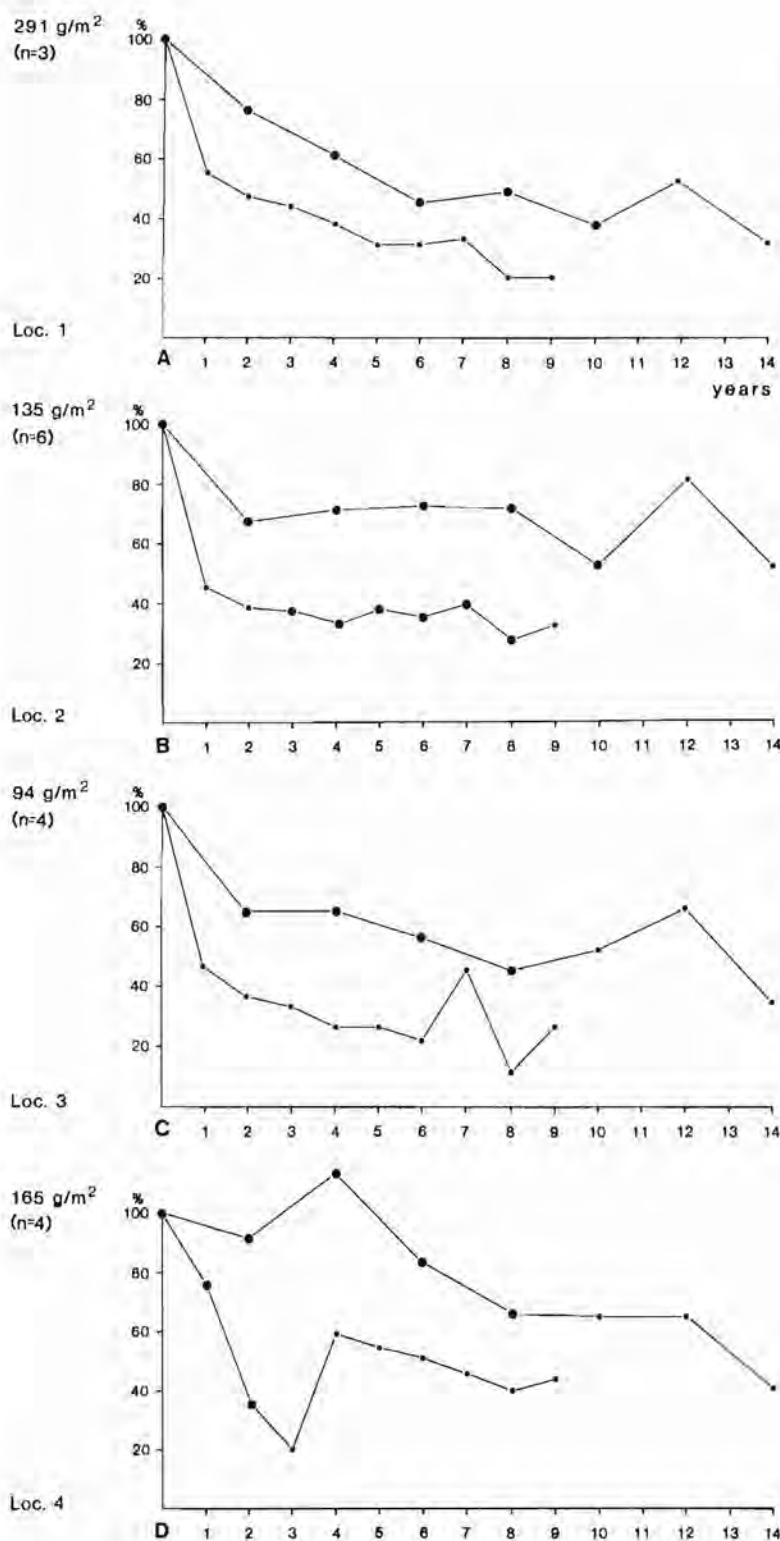


Fig. 5.3.1

A-D. The field layer production on the permanent quadrats of the four fen localities (nos. 1-4), scythed either every other year (upper curve) or every year (lower curve). The values are expressed as a percentage of the value recorded for the first year after the recommencement of scything (litter included). The latter value (in g/m<sup>2</sup> dry matter) is shown for each locality. Small dots represent values for single quadrats only, large dots are mean values for 2 or more quadrats. Further details in table 1 of Appendix E.



#### 5.4.1.2 Habitat conditions, field layer production

All the sample quadrats of clusters 1 and 2 are situated on flat fens (0-1% of slope), the peat layer varies from 20 cm to 50 cm. The two stands of cluster 1 (nos. 68 and 190, mud bottom community) are situated in the soaks from eustatic springs, ca. 250 m and 100 m, respectively, away from the outlets. It seems reasonable to assume that the open cover of these community is maintained by the mechanical effect of springwater irrigation, including the effect of ice in wintertime. The quadrats nos. 67 and 73 of cluster 2 are localized close to nos. 68 and 190, respectively.

The **groundwater-level** of the quadrats of cluster 1 is at or above the ground level throughout the summer. The quadrats of cluster 2 also have a groundwater-level near the surface; during the dry period in August 1982 the water-levels were 2 cm, 10 cm and 20 cm below the surface, respectively, at the three localities.

The mean pH values of the peat of vegetational types 1 and 2 were determined as 6.6 and 6.4. In the fen water, the pH/specific conductivity values were 7.3/152 and 7.1/162, respectively.

The **field layer production** of the mud bottom communities is generally low, but on patches dominated by the tall sedges (*Carex rostrata*, *C. lasiocarpa*) production is greater. Scything of quadrats for productivity estimates was done in localities 67 (photo in Fig. 5.4.1) and 73. In the quadrats of locality 67, the "every second year" mean value was 70 g/m<sup>2</sup>. The production values for the six quadrats of locality 73 are somewhat higher, but production has only been measured once in each quadrat (with mean value of 95 g/m<sup>2</sup> for four quadrats in 1982, which had been scythed once before, in 1980).

#### 5.4.2 Rich fen expanse, *Campyllum* communities

##### 5.4.2.1 The clusters M3-5

The communities represent a rich lawn type of open fen, that covers large areas at Sølendet. All these three types have a strong resemblance to each other, and *Scirpus cespitosus* predominates in the field layer and *Campyllum stellatum* in the bottom layer. *Drepanocladus revolvens* is also dominant in all these clusters, and *Thalictrum alpinum*, *Carex panicea* and *Molinia caerulea* are constants with characteristic cover values of 2-3. Another group of species are constants in all three clusters: *Dactylorhiza cruenta*, *Equisetum palustre*, *E. variegatum*, *Selaginella selaginoides*, *Carex dioica*, *Eriophorum angustifolium*, *Bryum pseudotriquetrum*, *Fissidens adianthoides* and *Lophozia borealis*. *Carex lasiocarpa* is also a dominant in clusters 3 and 4. Flowering *Eriophorum latifolium*, in some years, can give a distinctive character to some stands (see photos, Figs. 1.1.1 and 5.4.3). Further photos in figures 5.4.2 & 4.



Fig. 5.4.1. The flat fen area of Floen, with scattered occurrences of tall sedges (e.g. *Carex lasiocarpa*); *Scorpidium scorpioides* is dominant in the bottom layer. Reindeer are visible in the background. Localities 67 & 68. 19770807.



Fig. 5.4.2 Early summer at locality no. 1, before recommencement of scything of the Blautmyra area. The area outside the scythed quadrats is characterized by a heavy litter layer and some scrub. 19790613.



Fig. 5.4.3 *Eriophorum latifolium* is a dominant species on Knutmyra. This sloping fen area is fed by springwater from eustatic springs, their outflows are ca. 500 m distant. Locality 63. 19770806.



Fig. 5.4.4 Locality no. 2 after scything of quadrats. The hay-crop of quadrat 2A is shown on the right, the larger "haycock" of 2C in the centre of the photo. 19770718.

- M3. *Carex lasiocarpa*-*Campylium stellatum*-*Drepanocladus revolvens* type  
5 samples (7, 15, 65, 69, 200) in cluster 3.

Cluster 3 is best separated from nos. 4 & 5 by the occurrence of some carpet species (*Eleocharis quinqueflora*, *Calliargon trifarium*, *Cinclidium stygium*) and by the absence of some of the dry-site lawn species (e.g. *Polygonum viviparum*).

Within-cluster similarity is high (0.76) and the resemblance to cluster 4 is very high (0.81). Both the TABORD and TWINSpan procedures unite the samples of cluster 3, although in the TWINSpan diagram sample 64 (of cluster 4) is included with the samples forming cluster 3.

The DCA diagrams show that the samples are spread over quite a distance, and no. 15 is somewhat separated from the rest, lying nearest to the samples of clusters 4, 6 & 7. Measured with the similarity ratio, sample 15 shows the greatest similarity to cluster 3 (0.75), but has nearly the same affinity to the other clusters mentioned above (e.g. 0.74 to cluster 4).

- M4. *Carex lasiocarpa*-*Potentilla erecta*-*Campylium stellatum* type  
14 samples (1, 9, 10, 12, 61, 63, 64, 110-112, 115-117, 198) in cluster 4.  
7 samples are derived from the same locality (= stand s.lat.), viz. locality 1.

A rich lawn community, like that described under type 3 (cf. also type 2), but including some of the "dry" lawn species that are absent from type 3, e.g. the constants: *Polygonum viviparum*, *Potentilla erecta*, *Saussurea alpina*, *Carex flava*, *Sphagnum warnstorffii*. The dominants in field layer are *Carex lasiocarpa* and *Scirpus cespitosus*.

Within-cluster similarity is high (0.78), and there is a great resemblance to clusters 3 (0.81), 6 (0.73) and 5 (0.71). Sample 12 is the most "outlying" one, with a similarity to the rest of the cluster of 0.67. It occupies a rather isolated position on most of the DCA diagrams. Sample 6 of cluster 6 is very close to cluster 4 (cf. description under cluster 6).

- M5. *Scirpus cespitosus*-*Carex hostiana*-*Campylium stellatum* type  
4 samples (2, 121-123) in cluster 5. All the samples come from the same locality (= stand s.lat.).

A rich lawn community as described under types 3 and 4, with the addition of *Carex flava* x *C. hostiana* as a characteristic taxon and *Saxifraga aizoides*, *Succisa pratensis*, *Carex hostiana*, *C. capillaris*, *Eriophorum latifolium* and *Kobresia simpliciuscula* among the constants. *Dactylorhiza pseudocordigera* and *Pedicularis oederi* are also constants, a number of plants flowering each year. These same 2 species are also very common in some of the localities of type 4, and are constants in a few of the following types.

Within-cluster similarity is very high (0.88). This is readily explainable, because the cluster is composed of samples all from the same locality. It is most similar to clusters 4 (0.71), 7 (0.68), 3 (0.65) and 6 (0.65).

#### 5.4.2.2 Habitat conditions, field layer production

**Inclination and depth of peat.** The slope aspect of the sample quadrats of all three clusters varies between S and E. The sample quadrats of cluster 3 have a slope of 2-4°, mean value 3°; the quadrats of the two other clusters have a slope of 3-7°, mean value 5°.

The depth of the peat varies between 15 cm and 60 cm for the 12 localities represented in clusters M3-M5, mean values for the three clusters were 35 cm-42 cm.

The groundwater-level on a selected date varied much from one locality to another, mean values of the sum of the values for the four dates in 1982 (cf. text in Table 5.3.1) were 63 cm, 70 cm and 78 cm for the clusters M3, M4 and M5, respectively. Throughout the summer, the groundwater-level varies very much in most of the localities. In springtime and during periods of high precipitation (e.g. in autumn) the groundwater-level usually remains close to the surface in all the quadrats. On June 11, the records showed a rather high water-level, varying from 0-12 cm for the localities of the three clusters. On July 17, a typical summer situation was recorded, the surface of most of the localities was ca. 25-30 cm above the groundwater-level. After another dry period, the level had sunk (on Aug. 8) to more than 35-40 cm in most of the localities. In the rather dry autumn situation (on October 5) the groundwater-level lay 2-8 (-20)cm below the ground surface.

The ecological effects of the groundwater-fluctuations in sloping fens will be further discussed in section 8.4.3.5. In the stands showing the described variation in groundwater-level throughout the summer, the aeration of the peat is good. In the quadrats nos. 61 and 63 of cluster M4, the groundwater-level is not far below the ground surface, even in dry periods. Both these quadrats have a marked slope (5 °) and they are influenced by springwater. In this way, it seems reasonable to assume that the peat is rather well aerated. Locality no. 7, however, is situated in an area of 2 ° slope and the groundwater-level is close to the surface the whole summer (the sum of the four water-level values in 1982 was 15 cm!). This quadrat (and also no. 6 of cluster M6 lying nearby) is situated in an area of springs and more diffuse groundwater-outflows, so that the supply of oxygen may be satisfactory. In addition, locality no. 7 had a lower groundwater-level on Oct. 5 (viz. 8 cm) than the other quadrats of the cluster (the same situation as for no. 6). It seems reasonable to assume that in late summer/autumn the general groundwater-level of the area has fallen, and during this part of the year the groundwater-level is rather low; the late summer situation compensates for the earlier period of a higher water-table.



**pH in peat, water analyses.** The pH values of the peat varied from 6.1-6.9, with mean values of 6.6 for the clusters M3 and M4, 6.2 for cluster M5. The mean value for the pH of the fen water exceeds 7 at all the localities of clusters M3-5, except no. 1, where the mean value is 6.4 (5 values: 6.1, 6.1, 6.4, 6.7 & 6.9, the three first values cited are from the period 1974-1976). The specific conductivity varied from 64 to 195 in the 12 samples, the lowest recorded values being for locality 1.

**Field layer production.** A large number of the quadrats for clusters M3-5 have been scythed for estimation of the field layer production.

Scything every other year in quadrats of type 3 gave 87 g/m<sup>2</sup> as the mean value, including 25% of litter. The first scything gave a mean value of 164 g/m<sup>2</sup> for four localities, the litter fraction exceeded 40%.

Scything every other year in quadrats of type 4 gave a mean value of 135 g/m<sup>2</sup> (for 7 localities, 57 samples in all), including 17% litter. The first year of scything gave 216 g/m<sup>2</sup> as the mean value, with 32% of litter. In locality 1 (photo in Fig. 5.4.2), scything every year gave 81 g/m<sup>2</sup> as the mean value (5% litter); in this locality scything every other year gave a mean value of 140 g/m<sup>2</sup> (20% litter), and for the first year of scything the value was 291 g/m<sup>2</sup> (36% litter) (see Fig. 5.3.1).

Locality 2 (photo in Fig. 5.4.4) of cluster 5 yielded the following mean values: 87 g/m<sup>2</sup> (20% litter) when scythed every other year; 44 g/m<sup>2</sup> (10% litter) when scythed every year; and 135 g/m<sup>2</sup> (32% litter) for the first year of scything.

### 5.4.3 Rich fen margin, *Campyllum* communities

#### 5.4.3.1 The clusters M6-7

The rich lawn communities of the fen margin cover large areas of the Sølendet reserve and types 6 & 7 represent the main types covering large, continuous areas (photos in Figs 5.4.5-8). In addition, types 8, 9 and 10 represent fen margin communities occurring more scattered. Types 6 & 7 have their main dominants in common, viz. *Succisa pratensis*, *Thalictrum alpinum*, *Molinia caerulea*, *Scirpus cespitosus* and *Campyllum stellatum*. A number of other species, mainly fen margin/grassland species that are absent from the foregoing types, are also either constants or common species in types 6 and 7 (and often also in types 8, 9 and 10) e.g.: *Angelica sylvestris*, *Crepis paludosa*, *Gymnadenia conopsea*, *Leontodon autumnalis*, *Carex vaginata*, *Deschampsia cespitosa*, *Nardus stricta* and *Barbilophozia quadriloba*.

M6. *Molinia caerulea*-*Succisa pratensis*-*Campylium stellatum* type

12 samples (4, 6, 11, 13, 14, 16, 87, 140, 141, 144, 147, 201) in cluster 6. 5 of the samples are derived from the same locality (= stand. s.lat.), viz. no. 4.

Type 6 is very species-rich, with a number of extremely rich fen species with a high frequency, viz.: *Dactylorhiza pseudocordigera*, *Equisetum variegatum*, *Gymnadenia conopsea*, *Carex atrofusca*, *C. capillaris*, *Juncus triglumis*, *Kobresia simpliciuscula*, *Cratoneuron commutatum*, *Fissidens adianthoides* and *Lophozia rulheana*.

Most of the above-mentioned species, together with *Carex dioica* and *Carex flava*, which are very numerous in these types, thrive best under a scything regime (cf. section 13.4.2). The vegetational composition of types 6 and 7 changes rapidly after the cessation of regular scything, *Molinia caerulea*, *Betula nana* and other trivial species becoming more abundant.

Within-cluster similarity is 0.76, and the type is most similar to nos. 4 and 7 (between-cluster similarity of 0.73 to both).

Sample 87, with *Sphagnum warnstorffii*, *Homalothecium nitens* and *Hypnum lindbergii* as the dominant species in the bottom layer, tends to be an outlier, with only a rather low (0.61) similarity to the rest of the samples in the cluster.

In the TWINSpan classification this cluster is well-defined, except for sample 87, which is grouped among the samples of cluster 9. The DCA diagrams show that cluster 6 is rather widely dispersed, and that sample 87 occupies a peripheral position.

Sample 6 is classified to cluster 6 by the TABORD and TWINSpan classifications, but the sample is very close to clusters 4 and 7 as shown in the DCA diagrams (cf. also the description of type 7).

M7. *Molinia caerulea*-*Kobresia simpliciuscula*-*Campylium stellatum* type

4 samples (3, 101, 102, 131) in cluster 7. The four analysed stands come from the same fen, situated near to each other.

A rich lawn community of the fen margin, with *Betula nana* invading the community after regular scything ceases. *Ditrichum flexicaule* and *Tortella tortuosa* are characteristic species and *Festuca ovina* is constant species. *Kobresia simpliciuscula* has its main occurrence at Sølendet in this type. Other species belonging to this type are listed under the description of type 6, (q.v.). The within-cluster similarity is as high as 0.80, and its greatest resemblance is to types 6 (similarity 0.73) and 5 (0.68). The TWINSpan diagram separates the samples in cluster 7 as a well-defined group lying nearest to those of cluster 6.



Fig. 5.4.5 The *Crepis paludosa*-*Molina caerulea*-dominated fen margin community at locality no. 4. 19770801.



Fig. 5.4.6 A spring-influenced fen margin community with *Eriophorum latifolium*. Locality no. 6. 19760804.



Fig. 5.4.7      Locality no. 3 represents a typical *Kobresia simpliciuscula* lawn, a species-rich community dominated by low-growing graminoids and herbs. 19770802.



Fig. 5.4.8.      *Betula nana* has colonised areas of fen margin that were previously open. Locality no. 101. 19820802.

Parallel to the clustering of section 6 (clusters k and l), samples 6 and 16 could have been grouped together with samples 3 and 131, and samples 101 and 102 could make a separate cluster. However, samples 6 and 16 have closer links to cluster 6 than to an initial cluster of samples 3 and 131. The TABORD classification is followed, and in addition samples 101 and 102 (representing a dry subtype) are grouped together with samples 3 and 131 to avoid having too many small clusters.

#### 5.4.3.2 Habitat conditions and field layer production for the marginal types (M6-10)

Ecological data concerning the samples of the rich fen margin types, M6-10, (including the *Sphagnum warnstorffii* communities described in next subsection) are dealt with here.

**Inclination and depth of peat.** The quadrats of cluster 6 are situated in areas of 2-5 ° of slope (mean value 4 °), facing between S and E. The peat layer is 10-35 cm thick, mean value of 22 cm.

The quadrats of clusters 7 and 8 have an inclination of 5-6 ° to the S and SE; the peat layer depth was recorded as about 15 cm in all the localities, except no. 192 where it was only 5 cm (that sample is regarded as transitional to the damp grassland vegetation of section 9.7).

The four stands of cluster 9 also represent transitional types between fen margin and damp grassland vegetation, with a thin humus-like peat layer (mean depth 14 cm). The stands are situated on the margins of soaks, in nearly flat areas, stands 274, 275 and 279 are from the Vassdalen area, cf. section 7.3.4.

The two quadrats of locality 70, forming cluster 10, are situated in a flat area at the margin between lawn-dominated rich fen and poor/intermediate fen. The peat layer is 50 cm deep.

**Groundwater-level.** The "sum value" for four dates in 1982 exceeded 100 cm for six of the seven localities of cluster 6, and for all the localities of clusters 7 and 8. The localities referred to were fairly dry down to a depth of more than 30 cm on July 17 and Aug. 8, and even on June 10 and Oct. 5 most of the localities had a groundwater-level 10 cm or more below the surface. The mean values of the "sum of 4 dates" were 99 cm (when locality 6 is excluded, the mean for the other 6 localities was  $110 \pm 4$  cm), 119 cm and 129 cm for clusters 6, 7 and 8, respectively. Locality 6 recorded the very low value of 33 cm, and even during the dry summer period the groundwater lay close to the surface (9 cm on Aug. 6). The records of the groundwater-levels in spring and summer most resemble those of the carpet communities of cluster M2 and of locality 7 (of cluster M3) situated close to locality 6. On Oct. 5, however, locality 6 had the lowest groundwater-level (viz. 18 cm) of all the localities of cluster 6. As already commented upon



under "habitat conditions" for cluster M3, localities 6 and 7 exhibited remarkable changes in groundwater-level compared to the other localities of the clusters to which they belong. The influence of springwater, and the late summer/autumn dryness in locality 6 (and 7) seem to give good aeration in the upper layer of the peat. In all the other stands of clusters 6, 7 and 8, the changing position of the groundwater-level, and the low level in dry periods, certainly gives a good aeration, compared to most of the other mire sites.

The groundwater-level conditions of the three stands of cluster M9 (situated in Vassdalen) are dealt with in section 7.3. Quadrats 274-275 had rather high groundwater-levels during the summer, no. 279 was drier ("sum of 4 dates": 80 cm, 89 cm and 138 cm respectively).

In locality 70 the groundwater is rather far from the surface in summertime, but the level is never very deeply depressed (the locality is situated in a flat fen rather close to an eustatic spring). The "sum of 4 dates" was 85 cm.

**pH in peat, water analyses.** The pH in the peat of the quadrats of clusters M6-10 varied between 6.0 and 6.8, except for nos. 274 and 275 of cluster 9 (pH values 5.5 & 5.8, respectively). The mean values for the 5 clusters were: 6.4, 6.5, 6.0, 5.9 and 6.4.

The pH of the fen water of locality 70 (cluster 10) was 6.1 (mean of four water analyses varying from 5.7 to 6.3). The mean pH of cluster 6 was 7.0; the pH of cluster 7 was 6.7.

The specific conductivity of the water differed considerably from one locality to another representing the same cluster, and it also varied rather much within some of the localities. It is known (e.g. Persson 1962) that the values are generally higher in autumn than in spring. Water analyses were made on samples from localities for three of the clusters, the mean values were: M6:109 (the sample values varied between 58 and 157); M7:84; M10:74.

It is also well known (e.g. Persson 1962) that the pH of fen water is usually somewhat higher than that of fen peat. At Sølendet, the water analyses usually yielded values 0.2-0.8 units higher than the peat analyses. For locality 70 the situation was the opposite; the explanation seems to be that the water was collected from the surface by applying weak pressure, whereas the peat was collected ca. 2 cm below the *Sphagnum warnstorffii* cushions. Locality 70 represents a fen type which seems to be rapidly changing to more oligotrophic conditions by peat growth.

Of all the localities represented in clusters M6-10, no. 6 showed the highest recorded values for pH (in peat 6.8, water 7.4) and specific conductivity (154).

**Field layer production.** Field layer production was recorded at 6 localities of cluster 6, 2 localities of cluster 7 and 1 locality for each of the clusters 8 & 10.

Mean production for the quadrats of cluster 6 was 115 g/m<sup>2</sup> (including 17% of litter) in the quadrats scythed every other year (mean of 7 localities, 42 samples). Production in the first year of scything was 156 g/m<sup>2</sup> (26% litter). For locality 4, scything every year gave a mean value of 75 g/m<sup>2</sup> (6% of litter), scything every other year gave a value of 106 g/m<sup>2</sup> (11% litter) and in the first year of scything one of 165 g/m<sup>2</sup> (26% of litter), see figure 5.3.1.

The field layer production of locality 3 represents cluster 7. Scything every other year gave a mean value of 50 g/m<sup>2</sup> (15% of litter), the first year of scything value being 94 g/m<sup>2</sup> (21% of litter), and scything every year gave a mean of 24 g/m<sup>2</sup> (8% of litter), see figure 5.3.1.

Quadrat 74A of cluster M8 was cleared in 1980 (see the photo, Fig. 3.5.5). The mean value of two trials for scything every other year was 100 g/m<sup>2</sup>.

Quadrat 70A of cluster M10 has been scythed every other year from 1977 to the present day, with a mean production value of 103 g/m<sup>2</sup> (photo of scythed quadrat in Fig. 5.5.9).

#### 5.4.4 Rich fen, *Sphagnum warnstorffii* communities

The habitat conditions for the stands of the three clusters are summarized in the previous subsection.

##### M8. *Betula nana*-*Molinia caerulea*-*Campylium stellatum* type

2 samples (74, 192) in cluster 8. Samples from two stands at the same locality s.lat.

A transitional type between fen and grassland vegetation. After cessation of scything about 4 decades ago, shrub species have spread, and at the time the vegetational analyses were made, *Betula nana* dominated in both the shrub and field layers, together with *Molinia caerulea* and *Saussurea alpina*. *Salix nigricans*, *Listera ovata*, *Hylocomium pyrenaicum* and *Pleurozium schreberi* are constants only in this particular type of mire (photo in Fig. 3.5.5).

A number of species of both fen and grassland vegetation (e.g. *Geranium sylvaticum*) grow together here. Sample 192, in particular, shows certain characters of grassland vegetation (cf. also the description of cluster O3 of open grassland vegetation in section 9.7).

Within-cluster similarity is 0.62. The greatest similarity is to cluster 7 (0.47). The samples form a distinct cluster in the TWINSpan classification. All the DCA diagrams show the samples spread for quite a distance along the first axis (the gradient from wet mire types to drier types and more grassland types of vegetation), and small differences along the other axis.

M9. *Saussurea alpina*-*Carex vaginata*-*Sphagnum warnstorffii* type

4 samples (104, 274, 275, 279) in cluster 9. Three of the samples come from the profile in Vassdalen.

A rich fen community of fen margin type, with *Sphagnum warnstorffii* covering some sizeable patches, most often in the transitional areas between open fen and grassland or heathland vegetation. Both types 9 and 10 include representatives of these fen margin communities, with very wide ranges of species occurring. The dominants in type 9 are: *Saussurea alpina*, *Succisa pratensis*, *Thalictrum alpinum*, *Carex vaginata*, *Nardus stricta* and *Sphagnum warnstorffii*. Constants only in this particular type are *Rhinanthus minor*, *Agrostis capillaris*, *Anthoxanthum odoratum*, *Paludella squarrosa* and *Rhizomnium pseudopunctatum*. *Luzula sudetica* and *Aulacomnium palustre* are typical species of both clusters 9 and 10.

Within-cluster similarity is only 0.58, and the cluster is most similar to nos. 6 (similarity 0.49), and 10 (0.45). As seen in the DCA diagrams, sample 87 of cluster 6 does not lie far away from the samples of cluster 9, and as seen in the TWINSpan dendrogram, sample 87 is classified to cluster 9 (cf. further comments under description of cluster 6).

M10. *Carex rostrata*-*Sphagnum warnstorffii* type

2 samples (70 and 199) in cluster 10. The samples come from a single locality and represent one stand s.lat.

A rich fen community of marginal type, with *Sphagnum warnstorffii*, as described under type 9 (photo in Fig. 5.4.9).

*Sphagnum warnstorffii* and *Carex rostrata* are the dominants and even *C. lasiocarpa* is very common. A number of species are constants and are in common with those of the ombrotrophic hummock communities (type 18), e.g.: *Empetrum hermaphroditum*, *Oxycoccus microcarpus*, *Vaccinium myrtillus*, *V. uliginosum*, *Eriophorum vaginatum*, *Dicranum angustum*, *Pohlia nutans*, *Cephalozia lunulifolia* coll. Constants only in this type are *Dicranum bonjeanii* and *Barbilophozia kunzeana*. The type includes a long list of species, representing a mixture of poor fen and rich fen species.

Within-cluster similarity is 0.69, and the greatest similarity is to cluster 9 (0.45).

#### 5.4.5 Rich fen, *Drepanocladus*-*Meesia* communities

##### 5.4.5.1 The clusters M11-13

Types 11-13 represent rich fen carpet communities, with *Drepanocladus revolvens*, *Calliergon giganteum*, *Cinclidium stygium* and *Meesia triquetra* as the



Fig. 5.4.9      The *Sphagnum warnstorffii* community at locality no. 70, after the scything of quadrat A. 19770801.



Fig. 5.4.10      Gråmyra, a flat fen dominated by *Carex heleonastes*-*Cinclidium stygium* carpets. *Carex appropinquata* dominates the small hummocks. Localities 17,18 & 60. 19760804.

typical and often dominant species in the bottom layer. These types cover some parts of the flat fens near springs, or in other areas influenced by well-oxygenated, calcium-rich, seepage water. In addition to the four moss species mentioned above, a number of other plant species are constants in all these types (or in at least two of them), e.g.: *Salix lapponum*, *Caltha palustris*, *Dactylorhiza cruenta*, *Equisetum palustre*, *Pedicularis palustris*, *Polygonum viviparum*, *Potentilla palustris*, *Thalictrum alpinum*, *Carex dioica*, *C. flava*, *C. heleonastes*, *C. nigra*, *C. panicea*, *Eleocharis quinqueflora*, *Eriophorum angustifolium*, *Bryum pseudotriquetrum*, *Campylium stellatum*, *Scorpidium scorpioides*.

M11. *Menyanthes trifoliata*-*Carex heleonastes*-*Cinclidium stygium* type

2 samples (17 & 18) in cluster 11. The analysed stands come from the same fen, sited near to each other.

Type 11 is the wettest type of the three (photo in Fig. 5.4.10), with typical species such as: *Menyanthes trifoliata* (dominant), *Triglochin palustre*, *Utricularia minor* and *Carex limosa*. Dominants are also: *Calliergon giganteum*, *Cinclidium stygium* and *Drepanocladus revolvens*.

The within-cluster similarity is 0.63, and the greatest similarity is to cluster 12 (0.63). These indices, the result of the TWINSpan classification, showing a strong relationship to the sample members of cluster 12, and also the picture provided by the DCA diagrams (the samples in the cluster spaced out rather far apart), all indicate a close relationship to type 12.

M12. *Carex heleonastes*-*Drepanocladus revolvens*-*Meesia triquetra* type

4 samples (19, 62, 99, 276) in cluster 12.

A rich fen carpet community with dense moss cushions. It is more lawn-like than no. 11, including such constant species as *Parnassia palustris*, *Scirpus cespitosus* and *Campylium stellatum* (dominant). *Drepanocladus revolvens* is the predominant species. Constant species in this particular type are the following: *Carex heleonastes* (also type 11), *C. magellanica*, *Juncus triglumis* and *Moerckia hibernica*. Among the plant species found more infrequently on Sølendet, *Carex saxatilis* and *C. stenolepis* occur in this type. *Salix hastata*, *S. myrsinites*, *S. pentandra*, *Scirpus hudsonianus*, *Calliergon richardsonii* and *C. sarmentosum* are common species of this type, and, though they occur rather frequently on Sølendet, they are not constants in any of the types.

Within-cluster similarity is 0.68. The cluster has its greatest resemblance to clusters 13 (similarity 0.64) and 11 (0.63); the next is the resemblance to cluster 2 (0.49).



The TWINSpan procedure classifies sample 62 closest to the samples of cluster 2, and sample 280 of cluster 13 lies along the same branch as samples 19 and 276 of the present cluster. The DCA diagrams show the cluster samples spread over rather a large area, with sample 62 situated closest to the samples of cluster 2. Sample 280 occupies a transitional position in relation to the other samples of cluster 13.

**M13. *Salix* spp.-*Equisetum palustre*-*Drepanocladus revolvens* type**

3 samples (277, 278, 280) in cluster 13. All stands come from the profile in Vassdalen, where no. 277 includes the area of a small stream that shrinks to an underground trickle in dry periods. Nos. 278 and 280 represent the areas next to the stream, and they are also flooded in wet periods, cf. section 7.3 (photos in Figs. 7.3.2-3).

A rich fen margin community with dense moss cushions and scattered shrubs. *Salix pentandra* occurs in an old tree layer in stand 277, and shrubs (mainly *S. pentandra* and *S. phylicifolia*) had spread after the cessation of scything ca. 20 years before the quadrats were analysed. The main structure of the vegetation is described under type 11 (cf. also 12). Type 13 represents the driest type of this kind. Some fen margin/grassland species are constants here, e.g. *Filipendula ulmaria* (dominant), *Angelica sylvestris* and *Deschampsia cespitosa*. Other dominants are: *Equisetum palustre*, *Carex nigra*, *Campylium stellatum*, *Drepanocladus revolvens* and *Calliergon giganteum*. *Cardamine pratensis* coll. and *Plagiomnium elatum* (constant) are characteristic species of this type.

The within cluster similarity is 0.68, and the closest resemblance for cluster 13 is to cluster 12 (0.64). Sample 280 is close to the samples of cluster 12 (cf. description under the latter).

#### 5.4.5.2 Habitat conditions, field layer production

**Inclination and depth of peat.** All the quadrats dealt with are situated in flat fens, the mean depths of the peat layer are 62-80 cm. The communities are all situated in areas influenced by well-oxygenated, calcium-rich, seepage water. The Gråmyra area, including the two quadrats of M12, has a groundwater-level close to the surface throughout the year (maximum 12 cm below the surface during the dry period in Aug. 1978). This flat fen is fed by a strong eustatic spring. The quadrats of clusters 12 (except sample 99) and 13 are situated in Vassdalen; in dry periods during summer the groundwater-level is rather far from the surface. The mean values for the sum of the groundwater-levels of the quadrats of clusters M11-13 are: 14 cm, 45 cm and 65 cm, respectively.

pH values in the peat for the quadrats of clusters 11-13 varied between 6.2-6.8, one peat sample had pH = 5.7. The pH values of the water were 7.0-7.2 for all localities except one (pH = 6.8); the specific conductivity values varied

between 67 and 185. The habitat conditions for the Vassdalen stands are discussed further in section 7.3.4.

Scything of quadrats for estimating the **field layer production** was done only for two localities of cluster 11. Scything every other year gave a mean value of 90 g/m<sup>2</sup>, scything every year gave 74 g/m<sup>2</sup>, the litter proportions were estimated to be 15% and 7%, respectively. The first year of scything showed low values (mean of 69 g/m<sup>2</sup>, two quadrats scythed in 1976). The greater differences in the production values from one year to another in the quadrats of localities 17 and 18 in relation to the values for other fen localities may be explained by the existence of more sources of error in this wet community (difficulties when scything, the spot tests unrepresentative, etc.). Also, the low first year scything value may be explained in this way. However, the production in these spring-influenced stands (the water temperature is low) may be more sensitive to changes in the air temperature than other stands, cf. the very wide annual differences in the field layer production found for the spring vegetation in Denmark (Warncke 1980).

#### 5.4.6 Rich fen, *Salix* communities

##### 5.4.6.1 The clusters M14-15

Communities transitional between rich scrubby fen vegetation and damp scrubby grassland vegetation occur quite commonly at Sølendet, as represented by types 14 and 15. The samples in these clusters are also dealt with under cluster W11 of the woodland vegetation and under cluster O5 of the open grassland vegetation.

Clusters 14 and 15 represent *Salix*-dominated samples (see Figs. 5.4.11 and 9.6.8) with a number of species in common, e.g. the following ones, occurring as constants only in these types of the 18 clusters dealt with (those marked d are dominants in no. 14): *Salix glauca*, *Alchemilla* spp. (d; mainly *A. glabra* & *A. glomerulans*), *Rumex acetosa*, *Calamagrostis purpurea*, *Chiloscyphus pallescens* and *Pellia neesiana* (d). More widespread species are also constants in both types, e.g.: *Angelica sylvestris*, *Crepis paludosa* (d), *Epilobium palustre*, *Filipendula ulmaria* (d), *Geranium sylvaticum*, *Geum rivale* (d), *Saussurea alpina*, *Deschampsia cespitosa* and *Sphagnum warnstorffii* (d).

M14. *Salix* spp.-*Filipendula ulmaria*-*Plagiomnium ellipticum* type  
3 samples (82, 83, 103) in cluster 14.

Cluster 14 represents the most fen-like community of the two, with a common occurrence of fen species such as: *Equisetum palustre*, *Carex nigra* (d), *Eriophorum angustifolium*, *Luzula sudetica* and *Bryum pseudotriquetrum*. Two of the three samples are dominated by *Salix pentandra* both in the tree and shrub layers. *Plagiomnium ellipticum* is a dominant and *Ranunculus acris* and



Fig. 5.4.11 *Salix pentandra* forms a 5 m high, dense tree layer in the tall-herb community. Locality no. 83. 19780809.

*Hierochloa odorata* are constants only in cluster 14 of all the clusters dealt with.

Within-cluster similarity is 0.52. Cluster 14 is most similar to no. 15 (similarity 0.48).

M15. *Salix glauca*-*Caltha palustris*-*Pellia neesiana* type  
2 samples (84 & 85) in cluster 15.

A number of species are exclusive constants for this type compared to the other types of the multivariate analyses, e.g.: *Cicerbita alpina*, *Equisetum sylvaticum*, *Stellaria calycantha*, *Trientalis europaea*, *Harpanthus flotowianus* and *Lophozia obtusa*. Dominants are: *Salix glauca*, *Alchemilla* spp., *Caltha palustris*, *Filipendula ulmaria*, *Geranium sylvaticum* and *Pellia neesiana*.

Within-cluster similarity is 0.52, and greatest similarity is to cluster 14 (0.48).

#### 5.4.6.2 Habitat conditions

No measurement of groundwater-level or field-layer production were made in the localities of clusters M14-15.

Stand 103 of cluster 14 is situated in a gently-sloping, small soak (close to stand 104), the mull-like peat layer is rather thin (ca. 10 cm). Stand 82 is situated in a nearly flat area at the upper margin of the largest fen area of Sølendet (only a few metres away from poor and dry heathland), in an area influenced by groundwater seepage; the peat depth is 1 m. Stand 83 also occurs in the same part of Sølendet, the slope is 3 ‰, and the peat depth is 70 cm.

The two stands of cluster M15 are situated at the margin of a rich fen (Floen) bordering poor heathland vegetation. The surface has a slope of 2 ‰, the peat/mull layer is only ca. 4 cm. The two stands are regarded as mineral ground vegetation (cf. section 11.3.6.7).

ph mean values in peat and water of clusters M14 and 15 were 6.2-6.7 (M14) and 5.3-5.8, respectively. The specific conductivity values were ca. 90 and 80, respectively.

#### 5.4.7 Rich spring, *Cratoneuron* communities

Spring vegetation is very common at Sølendet, since there are a large number of both eustatic, strong springs and more diffuse springs present over the entire area (see Fig. 3.2.4). Clusters 16 and 17 describe the two main types (cf. further section 7). *Cratoneuron commutatum* is a common dominant in both types.

Habitat conditions are described in section 7.2.1.

M16. *Saxifraga aizoides*-*Cratoneuron* spp. type  
3 samples (95, 194, 197) in cluster 16.

Dominants in type 16 are: *Saussurea alpina*, *Saxifraga aizoides*, *Cratoneuron commutatum* and *C. decipiens*, with *Carex atrofusca* and *Philonotis calcarea* as characteristic constants. *Crepis paludosa*, *Thalictrum alpinum*, *Carex dioica*, *Deschampsia cespitosa* and *Bryum pseudotriquetrum* are also constants in this type.

Some other typical species of this community, e.g. *Juncus triglumis* and *Lophozia bantriensis*, were recorded in two of the three samples.

Within-cluster similarity is 0.60, between-cluster similarity to cluster 17 is as low as 0.23. The greatest resemblance is to cluster 6 (0.31).

In the DCA diagrams with downweighting of rare species (cf. Fig. 5.2.4) the clusters 16 and 17, and even the samples in the clusters, are widely separated along axis 2; the samples are rather close together along the other axes.

M17. *Epilobium alsinifolium*-*Cratoneuron* spp. type

3 samples (93, 195, 196) in cluster 17. All the samples come from the same spring area, sample 93 situated in the middle of the spring and the other 2 not far away (no. 195 closest to no. 93).

Constant species in all three samples are: *Caltha palustris*, *Epilobium alsinifolium*, *Equisetum arvense*, *E. palustre*, *Carex rostrata*, *Cratoneuron commutatum* (dominant), *Philonotis fontana* coll.

Within-cluster similarity is 0.62, and the greatest similarity is to no. 16 (comments made under the description of that type).

#### 5.4.8 Bog hummock, *Sphagnum fuscum* communities

M18. *Betula nana*-*Sphagnum fuscum* type

2 samples (71, 89) in cluster 18.

Ombrotrophic hummock communities that cover some of the mires in the north of Sølendet (analysis no. 71) and, in addition, some smaller hummocks in other parts of the reserve (e.g. no. 89, photos of the two referred localities in Figs. 3.2.9-10).

The material is too sparse for a full description to be given of the ombrotrophic vegetation. Dominants are: *Betula nana*, *Empetrum hermaphroditum* and *Sphagnum fuscum*. *Polytrichum strictum*, *Calypogeia sphagnicola*, *Cephalozia pleniceps* and *Mylia anomala* are typical constants.

Within-cluster similarity is low (0.50), and the type shows a very low degree of resemblance to any of the other types (0.19 to cluster 10). In the ordination diagrams the samples are well separated off, a great distance away from the other clusters that lie along the first axis.

#### Habitat conditions

The two stands of cluster 18 are situated on flat mires, the peat depths are 1.4 m and 1.0 m, respectively. Analyses of peat and water samples from no. 71 yielded pH values 4.0 and 3.9, respectively; i.e. extremely low values.

The groundwater-level (no exact measurements are available) is always a few dm below the surface. The hummock areas of the open mires have a thin snow cover, mainly due to strong winds on the wide open areas, and the raised position of the hummocks. There is deep frost penetration into the hummock peat, and the ground remains frozen for a long period. No precise observations were made, but frozen peat in hummocks has been observed as late as in August (in 1979).



#### 5.4.9 Residual samples

For six of the 80 samples dealt with, the similarity value was lower than 0.45 to any of the 18 clusters; these samples are therefore not included in the clusters of the TABORD classification. Full phytosociological tables of the small quadrats of these samples are included in tables 11 (samples 60, 66, 91, 98) and 12 (samples 92, 193) of Appendix C. The samples are included in the TWINSpan dendrogram and the DCA-ordination diagrams.

**Sample 60.** *Carex appropinquata*-*Sphagnum warnstorffii* community (Table 11, quadr. 23-27). The community covers small areas and occurs as protuberances in carpets of the *Menyanthes-Carex heleonastes-Cinclidium stygium* type (i.e. cluster 11). The *Carex appropinquata*-dominated sample represents an outlier in the multivariate treatment. The TWINSpan dendrogram shows that sample 60 is connected closest to samples of cluster 13, cf. also the DCA-ordination diagrams, showing sample 60 as an isolated sample, closest to samples of clusters 9, 13 and 14. Ecological data for the root level are the same as those described for the surrounding stands 17 and 18 (cf. cluster 11).

**Sample 66.** *Carex rostrata*-*Cratoneuron* spp. mud bottom community (Table 11, quadr. 28-32) is dominated by tall-growing *Carex rostrata*. The TWINSpan diagram shows sample 66 to be included in the branch forming clusters 1, 2 and sample 62 of cluster 12. The DCA-ordination diagrams show that sample 66 is an outlier, situated closest to the samples of clusters 2 and 12 mentioned above.

The stand is situated in a soak, just where the spring-fed stream from a strong eustatic spring spreads water over the fen surface. A transect across this spring-fed stream is described in section 7.2.2; stand 66 is situated 250 m from the outlet of the spring. Spring water floods the surface of the locality throughout the year. Even in the dry August of 1982, the groundwater-level lay close to the surface. Erosion caused by stream water, ice, etc., explains the sparsity of the bottom layer. The pH in the peat was 6.9; the highest of all recorded values. The pH of the water was 7.4 and the specific conductivity 148. The field layer of this *Carex rostrata*-dominated community has a high productivity. The few records for one quadrat show values of 163 g/m<sup>2</sup> when scythed every other year, of 88 g/m<sup>2</sup> when scythed every year.

**Sample 91.** *Salix phylicifolia*-*Tortella tortuosa*-*Lophozia borealis* community (Table 11, quadr. 33-36) occurs in Vassdalen, in the depressions flooded by a stream in wet periods. This is a unique community, covering small areas; cf. further description under section 7.3.2.1. The TWINSpan and DCA diagrams also show sample 91 to be an outlier, closest connected to samples of clusters 11-13.

**Sample 98.** *Carex stenolepis*-*Calliergon richardsonii* community (Table 11, quadr. 37-38) occurs as a marginal community of a flat fen. Stands 98 and 99 repre-

sent the flat fens of the upper parts of Sølendet; these types of rich fens cover small areas inside the reserve. In the multivariate treatment, sample 98 is an outlier, closest connected to samples of clusters 12-13.

**Samples 92 and 193.** Spring communities (Table 12, quadr. 21-22 and 26-27, respectively). The stands represent two different types of spring carpet communities from the same spring, cf. description in section 7.2.1.1. Only a few stands of spring vegetation were analysed, and samples 92 and 193 represent outliers, no. 92 with closest resemblance to the other spring samples (in cluster 17). The TWINSpan-procedure classifies sample 193 closest to the samples of cluster 13.

## 6 MULTIVARIATE ANALYSES OF THE RICH FEN SAMPLES, INCLUDING GAARE'S ANALYSES

### 6.1 THE DATA SET

The complete data set comprises 97 samples of rich fen vegetation present at Sølendet, of which 59 were investigated by myself and 38 by E. Gaare (made during the summers 1959-62, as his cand. real thesis, cf. Gaare 1963). The latter have never been published, so initially an account of this work will be given; this is followed by an account of the full data set, the classification and ordination of the samples and a description of the 15 clusters (a-o) yielded by the analyses. A summary of the classification system of Gaare is given in section 6.4, including comparisons with the results of the multivariate analyses (Table 6.1.1).

#### 6.1.1 Gaare's analyses

##### 6.1.1.1 Cover scale and species list

Gaare used the Hult-Sernander scale for degree of cover, but extended it by subdividing class 5 into 4 degrees. This has simplified the transformation of his data to the 6-degree scale that I used. In addition, Gaare used the + symbol to signify scattered occurrences of a few individual plants of a species. This is equivalent to my cover designation "s".

Use of a data set that includes data from more than one observer always runs the risk of introducing a noise factor into the subsequent analyses. The results of analyses of any homogeneous plant community by more than one botanist will not be identical, because of differences in the experience and individual biases involved in the sampling strategy used (e.g. quadrat size, stand selection and homogeneity etc.), in the estimation of degree of cover (especially in

Table 6.1.1 Details of the 38 samples of rich fen vegetation analysed by Gaare (1963) and used here in the data set dealt with in section 6. "Stand no. in Gaare" refers to his nine tables (A-I, the stands included in the tables (I-IV) and the small quadrats analysed (= q)). The altitudes and grid references (UTM) for his localities are approximations.

Cluster no.	Sample no.	Stand no. in Gaare	No. x size in m <sup>2</sup> of quadrats	m above s.l.	UTM grid system zone 32V,PQ	Inclination		Communities in Gaare (1963)
						Aspect	Slope in g	
k	901	AI q1-5	5x1	730	456,538	S0	4	A. Trichophorum - variant
k	902	AI q6-10	5x1	730	456,538	S0	4	
l	903	AII q11-12	2x1	740	457,542	0	3	
j	904	AII q13-17	5x1	740	457,542	0	3	
j	905	AIII q18-22	5x1	740	457,542	0	3	B. Succisa - variant
l	906	BI q1-5	5x1	730	456,538	S0	4	
l	907	BI q6-10	5x1	730	456,538	S0	4	
l	908	BII q11-13	3x1	740	455,540	S0	5	
l	909	BII q14-16	3x1	740	455,540	S0	5	
l	910	BIII q17-19	3x1	740	455,540	-	-	
l	911	BIV q20-24	5x1	720	455,535	S0	5	
l	912	BIV q25-29	5x1	720	455,535	S0	5	
k	913	CI q1-5	5x1	750	454,541	0S0	5	C. Kobresia - variant
k	914	CI q6-10	5x1	750	454,541	0S0	5	
k	915	CII q11-15	5x1	760	453,541	0S0	5	
k	916	CII q16-20	5x1	760	453,541	0S0	5	
k	917	CIII q21-25	5x1	710	448,527	SS0	5	D. Pedicularis - variant
j	918	DI q1-5	5x1	750	452,538	S0	5	
j	919	DII q6-10	5x1	760	443,536	S	4	
j	920	DIII q11-12	2x1	760	443,536	S	4	
j	921	DIV q13-15	3x1	740	457,542	0	3	
j	922	DIV q16-18	3x1	740	457,542	0	3	E. Sphagnum - variant
i	923	E q1-5	5x1	720	455,534	S0	6	
i	924	E q6-10	5x1	720	455,534	S0	6	F. Carex panicea-Campylium stellatum-Drepanocladus intermedius-sociation
e	925	FI q1-5	5x1	700	454,529	S0	1	
e	926	FI q6-10	5x1	700	454,529	S0	1	
e	927	FII q11-15	5x1	700	454,529	S0	1	
e	928	FII q16-20	5x1	700	454,529	S0	1	
e	931	HI q1-5	5x1	720	457,537	S0	1	H. Thalictum alpinum-Eriophorum latifolium-Drepanocladus intermedius-Campylium stellatum-sociation
e	932	HII q6-7	2x1	710	455,534	S0	2	
e	933	HIII q8-12	5x1	710	455,534	S0	2	
e	934	HIII q13-17	5x1	710	455,534	S0	2	
e	935	HIV q18-22	5x1	720	455,534	S0	6	
e	936	HIV q23-27	5x1	720	455,534	S0	6	
R	937	I q1-5	5x1	780	451,545	0	1	I. Carex lasiocarpa-Scorpidium s.-sociation
g	938	GI q1-3	3x1	740	453,537	S0	3	G. Carex rostrata-Thalictum alpinum-Campylium stellatum-sociation
g	939	GI q4-6	3x1	740	453,537	S0	3	
g	940	GII q7-11	5x1	740	455,541	S0	4	

vegetation that includes many sclerophyllous graminoid species), and in the listing of the species present. The majority of such divergences have to be accepted and only a certain number of possible mistakes can subsequently be rectified.

Because of the intensive study made over the years of the vascular plant and bryophyte flora at Sølendet (species lists and distribution maps, as well as ecological studies), I have considered certain modifications to Gaare's (1963) tables to be in order, so as to bring more homogeneity into the full data set. For example, Gaare (1963) listed the bryophyte *Camptothecium* (= *Homalothecium*) *lutescens*, which is a southern, warmth-demanding species, in a number of his rich fen lawn samples. This is certainly due to a faulty species identification. It should be *Brachythecium turgidum*, a typical rich fen species, but one not included in any of Gaare's lists. I have therefore altered it in all the tables concerned. Where Gaare has listed *Brachythecium* sp., I have similarly changed this to *B. turgidum*. Another example of a probable species mis-identification concerns *Fissidens osmundoides*, the only taxon of this genus noted by Gaare. In my experience, *F. adianthoides* is by far the most common *Fissidens* species present in the rich fen lawns of Sølendet. I have therefore altered the entries in his tables accordingly. Additional species changes made among Gaare's plant listings include the following:

*Angelica archangelica* ssp. *norvegica* changed to *Angelica sylvestris*  
*Equisetum arvense* changed to *Equisetum pratense*  
*Bryum* sp. changed to *Bryum pseudotriquetrum*  
*Dicranella heteromalla* changed to *Ditrichum flexicaule*  
*Dicranum scoparium* changed to *Dicranum bonjeanii*  
*Hypnum cupressiforme* changed to *Hypnum lindbergii*  
*Orthothecium chryseum* changed to *Brachythecium turgidum*  
*Thuidium tamariscinum* changed to *Thuidium recognitum*

In some determinations to genera, (e.g. *Cladonia* sp.) I have omitted these records from his tables. It should also be noted that he included no hepatics in his tables.

#### 6.1.1.2 Sample syntheses and sample no. 937

Gaare analysed 24 stands, employing 2-10 quadrats (each of 1 m<sup>2</sup>) for each stand. In all cases where Gaare's data are the result of more than 5 quadrats per stand I have split the data to form 2 samples. As a result I have 38 samples in place of Gaare's 24 (cf. Table 6.1.1 for further details). Each of these 38 samples was then converted into a synthesis sample, using the SCANTAB program (cf. section 4.4). The synthesis samples with full species lists are shown in table 4 of Appendix C, with the exception of a residual sample (no. 937), which was included in the numerical analyses but is not tabulated. The full species list and degrees of cover for sample 937 are as follows: *Andromeda polifolia* s; *Oxycoccus microcarpus* s; *Menyanthes trifoliata* +; *Pedicularis*

*palustris* 21; *Thalictrum alpinum* s; *Triglochin palustre* +; *Carex chordorrhiza* s, *C. lasiocarpa* 2, *C. limosa* +, *C. rostrata* 1, *Eriophorum latifolium* s, *Scirpus cespitosus* 1, *Campylium stellatum* u, *Drepanocladus badius* u, *Scorpidium scorpioides* 3; Mud bottom coverage 6.

### 6.1.2 The full data set

This data set comprises 97 samples, of which nos. 901-928 and 931-940 are the 38 samples from the 24 stands described by Gaare (1963). These samples each represent synthesised samples from (2)-3-5 quadrats (each 1 m<sup>2</sup>) making a total of 172 quadrats (cf. Table 6.1.1).

The 59 samples investigated by myself have already been discussed in section 5. The results of the DCA ordination of these 59 on their own are shown in figures 5.2.6-7. These 59 samples are synthesised ones constructed from the results of the small quadrats: 32 are syntheses of 5 quadrats (each 0.25 m<sup>2</sup>); 21 are from 2-3 quadrats (each 0.25 m<sup>2</sup>); 6 are from (1)-2-3 larger quadrats. In all, therefore, the 59 samples represent the data from 224 quadrats.

Before carrying out the data analyses, the cover value for each of the small quadrats was standardised on a 6-degree scale, whereafter the cover values for the synthesised samples were, in turn, standardised to the 9-degree scale adopted. All hepatics were omitted from the sample data before making the multivariate analyses, because Gaare had not included hepatics in his vegetation samples.

## 6.2 THE MULTIVARIATE ANALYSES

Data sets of differing magnitude were used in preliminary trial analyses, e.g. one set of 111 samples that included all the samples of rich fen vegetation (i.e. including those for vegetation transitional to rich grassland). These different data sets were subjected to trial runs of the TABORD and TWINSpan classifications and to DCA ordination. The evaluation of the results of these trials, and of those discussed in section 5, was of fundamental importance with regard to the final choice and the clustering and ordination results presented here. All the 97 samples included in the full data set are shown in the TWINSpan dendrogram and the DCA-ordination diagrams (Figs. 6.2.3-4), the three residual samples are omitted in figures 6.2.1-2.

### 6.2.1 The TABORD classification

Three samples have been omitted from the TABORD and the FLEXCLUS tables (Appendix C-Table 4 and Table 6.2.1), viz. nos. 66, 98 and 937. These three samples were consigned to the residual group by the TABORD classification



Table 6.2.1 Synoptic table of the rich fen vegetation at Salsendet, including Gaare's analyses. The table shows frequency values and characteristic degrees of cover for the species (hepatics omitted) in the 15 clusters (including 94 samples). Only species occurring as constants (limit 70%) in at least one cluster are included. I., Constant species of one or two neighbouring clusters. II., Constant species of other clusters. A: tree layer; B: shrub layer.

Cluster no.	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o
No. of samples	2	3	2	5	10	5	17	4	3	16	11	10	2	2	2
I Menyanthes trifoliata	50-1	100-u	100-3		60-4	40-2	6-2								
Caltha palustris			100-u	60-1	20-s					6-0					
Epilobium palustre			100-u	20-u											
Potentilla palustris			100-u	60-u											
Triglochin palustre	50-s	33-s	100-u	40-u		60-s	29-u	50-u		19-s	9-s	10-u	50-s		
Utricularia minor		67-u	100-u	20-u											
Carex limosa	50-1	67-3	100-2			40-u									
Carex heleocharis			100-1	100-1	30-u										
Calliergon giganteum			100-3	80-2			6-u								
Meesia triquetra			100-2	100-2											
Carex magellanica				80-u	20-u					67-s					50-0
Calliergon richardsonii				40-1	80-u		6-u			33-s	38-u				
Drepanocladus badius		33-s			80-u	20-s	24-u			13-s					
Carex flava x C. hostiana								100-1			18-s			50-0	
Carex hostiana								100-2			36-s	20-0			
Dactylorhiza maculata										100-u	13-1	18-u	60-s		
Scirpus hudsonianus		67-s		40-u	20-s	20-0	18-u			100-s	13-s	27-s	30-u		50-u
Calliergon stramineum					20-s		6-s			100-u					50-1
Ditrichum flexicaule						20-s	18-s	50-u		44-u	82-u	80-1			
Juniperus communis					20-s			50-u		19-u	45-s	80-u			
Tortella tortuosa											9-1	90-2			
Pleurozium schreberi										13-u		80-u	100-u		50-u
Betula nana - B				20-u								20-2	100-5		50-1
Salix nigricans coll. - B													100-s		
Salix nigricans coll.				20-0										100-s	
Geranium sylvaticum					20-s		6-s		33-0	25-u		20-u	100-1		50-u
Listera ovata										19-0	18-s	60-s	100-u		
Hylocomium pyrenaicum							12-s		67-s	13-u	18-u	40-u	100-1		
Rhinanthus minor															100-1
Viola palustris / epipsila		50-0	60-u				6-u			6-s					100-1
Agrostis capillaris															100-1
Plagiomnium ellipticum										25-u					100-1
Rhizomnium pseudopunctatum							6-u		33-s	6-1					100-2
Eriophorum vaginatum					20-s	53-s			33-0	31-s	45-u	20-u			100-1
Luzula sudeetica													50-0		100-1
Empetrum hermaphroditum												10-u			100-2
Oxycoccus microcarpus					40-s	6-s						20-u			100-2
Vaccinium myrtillus															100-u
Vaccinium uliginosum										13-u		50-u			100-u
Geum rivale				20-u				33-0							100-u
Listera cordata															100-u
Solidago virgaurea										19-u		20-s			100-1
Dicranum angustum															100-1
Dicranum bonjeanii									33-u	25-s	9-s	40-u	50-u		100-1
Pohlia nutans														50-1	100-1
II Carex lasiocarpa	100-1	100-1				100-3	76-3		33-u	31-1	18-u		50-u		100-2
Carex rostrata	100-2	100-1			50-u	60-u	82-2			19-s	18-s	10-0			100-3
Eleocharis quinqueflora	100-1	100-2	100-1	60-1		60-1	6-s								
Eriophorum angustifolium	100-1	100-u	100-u	100-2	100-1	100-u	100-1	100-u	100-1	81-u	91-u	40-s	50-1	50-1	100-1
Calliergon trifarium	100-1	100-1	50-u	100-u	50-s	60-u	18-u	75-u		6-u	18-s				
Drepanocladus revolvens	100-1	100-4	100-4	100-5	100-4	100-4	100-3	100-3	100-u	100-1	100-2	100-2			50-0
Scorpidium scorpioides	100-2	100-4	100-3	100-2	20-s	20-2									
Andromeda polifolia		100-u		20-s		80-1	18-u				27-u	70-u			100-1
Euphrasia frigida		100-s				80-s	41-s	50-1	100-s	25-u	9-0				
Pedicularis palustris		100-u	100-1	100-1	100-u	80-u	94-u		33-u	13-u					
Carex dioica	50-1	100-1	100-1	100-1	90-1	100-1	100-1	100-1	100-2	94-1	100-1	70-u	50-1	100-2	100-2
Eriophorum latifolium		100-1	100-s		80-1	80-u	65-2	100-2	67-1	50-u	55-1				
Scirpus cespitosus		100-3		80-2	100-2	100-3	100-3	100-4	100-1	100-3	82-3	100-3	50-u		
Campylium stellatum		100-3	50-2	100-2	100-4	100-5	100-5	100-6	100-2	100-5	100-5	100-4	100		
Cinclidium stygium		100-u	100-3	100-2	100-u	80-u	65-u				6-s	18-s			
Salix lapponum			100-u	100-u	40-1		6-u		67-u	13-u					
Dactylorhiza cruenta			100-0	60-u	60-u	80-u	65-u	75-u		67-u	73-u				
Equisetum palustre		67-u	100-2	100-2	100-1	80-u	94-1	100-1		100-u	100-u				
Equisetum variegatum	50-u	33-s	100-1	20-1		100-1	88-1			100-1	6-1				
Polygonum viviparum			100-1	100-1	90-1	20-s	6-s			100-1	100-1	100-u			
Carex flava			100-1	100-2	100-1					100-1	100-1	100-u			
Bryum pseudotriquetrum		33-u	100-2	100-2						100-1	100-1	100-u			
Parnassia palustris					20-s					100-1	100-1	100-u			
Thalictrum alpinum					60-2	10-s									
Carex nigra					20-s										
Carex panicea															
Juncus triglumis					60-u	30-s									
Selaginella selaginoides					20-u	20-s									
Molinia caerulea															
Dactylorhiza octodes															
Pedicularis aizoides															
Saxifraga pratensis															
Succisa capillaris															
Succisa simpliciuscula															
Agrostis sylvatica															
Kobresia alpina															
Angitia paludosa															
Crepis paludosa															
Filipendula ulmaria															
Filipendula borealis															
Gymnadenis conopsea															
Gallium vaginatum															
Deschampsia cespitosa															
Nardus stricta															
Aulacomnium palustre															
Paludella squarrosa															
Leontodon autumnalis															
Luzula ovina															
Mnium splendens															



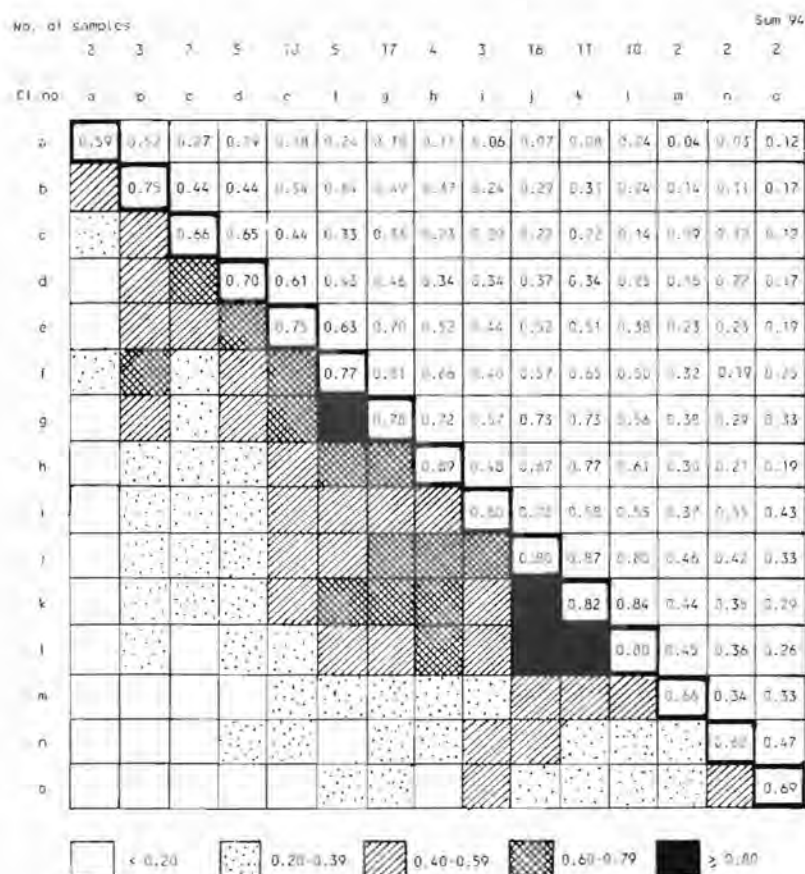


Fig. 6.2.1

Resemblance between the 15 clusters (97-sample data set, 3 residual samples omitted) of fen vegetation at Sølandet, calculated from the "similarity ratio" values. The diagonal shows the within-cluster similarity.

procedure, with 15 clusters and threshold and fusion levels of 0.55 and 0.87, respectively. These particular levels were selected so as to separate the clusters, as far as possible, in a similar way to that achieved in section 5. At a fusion level of ca. 0.70, most of the samples forming the clusters f-l became united into a single large cluster (63 samples). At a fusion level of ca. 0.80, two large clusters (22 samples of clusters f and g; 37 samples of clusters j-l) and a number of smaller ones emerged.

Figure 6.2.2 shows how the 15 clusters (a-o) agglomerate when no iterations were allowed to arise during the agglomerative process, the threshold and fusion levels then both being zero. At a similarity level of ca. 0.35, all the 94 samples become gathered together to form a single cluster.

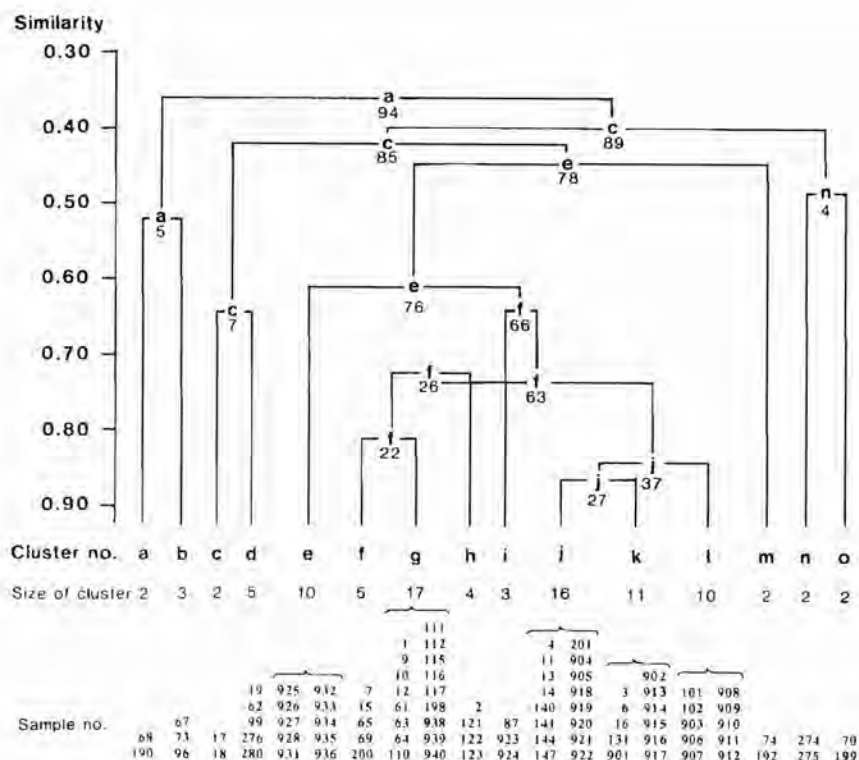
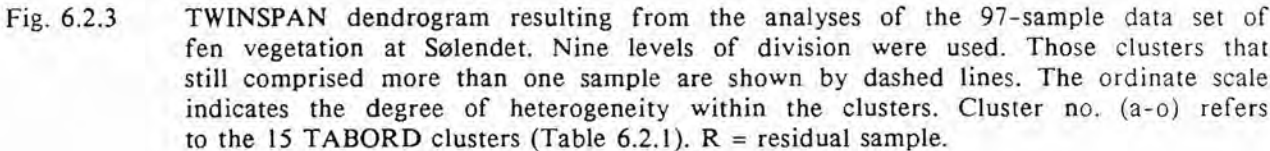


Fig. 6.2.2

TABORD dendrogram of the 15 clusters (97-sample data set, 3 residual samples omitted) of fen vegetation at Sølendet. The initial clusters are the TABORD ones for threshold and fusion levels of 0.55 and 0.87, respectively. The dendrogram shows how the 15 clusters then agglomerate at the respective zero levels, with no sample relocation allowed during the agglomerative process. Index: similarity ratio.

Figure 6.2.1 shows the within- and between-cluster similarities of the 15 TABORD clusters. The greatest internal homogeneity is shown by the "central" clusters (f-l), for which the values vary from 0.77 to 0.82, except for cluster h with a value as high as 0.89 (all the samples in this cluster were derived from a single locality). Most of these clusters comprise a large number of samples, with high between-cluster similarities as well. The following pairs of samples show resemblance values above 0.8: f & g, j & k, k & l, and even for the pair j & l the value is 0.80.

The smaller "peripheral" clusters (a-e and m-o) show less internal homogeneity and have rather low between-cluster resemblances. The high value adopted for the fusion level (0.87) ensured the absence of cluster fusion, e.g. the clusters j & k have a resemblance of nearly 0.87. The relatively low threshold value (0.55) ensured that no further samples were omitted.





By adopting the above-mentioned procedure, the grouping of the samples in the initial clusters had an important bearing on the final result. Nevertheless, it must be emphasized that each sample is to be found in the cluster with which it shows the closest linkage. The clusters are identical with those given by the TABORD classification; and the TWINSpan classification and the DCA ordination (see Figs. 6.2.3-4), thus provided a valuable independent check on the validity of the clusters distinguished.

The phytosociological table (Table 4 of Appendix C) is the result of the arrangement given by the FLEXCLUS program, with the clusters in a subjectively chosen order and a polar ordination of the samples in each cluster. A synoptic survey, the frequencies and characteristic degrees of cover, are given in table 6.2.1 and include only species that occurred as constants in at least one cluster.

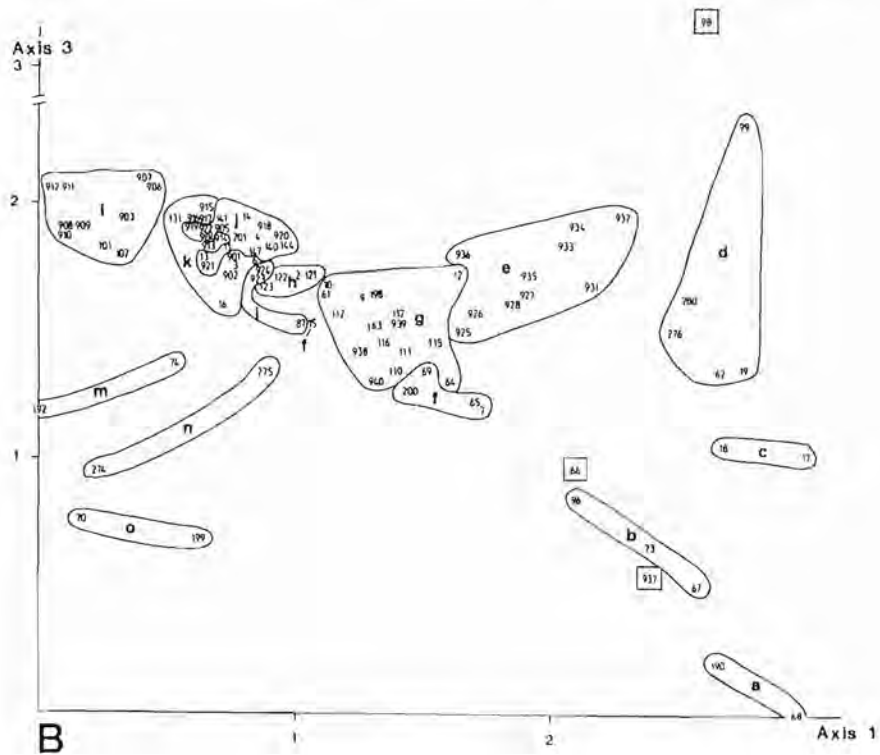
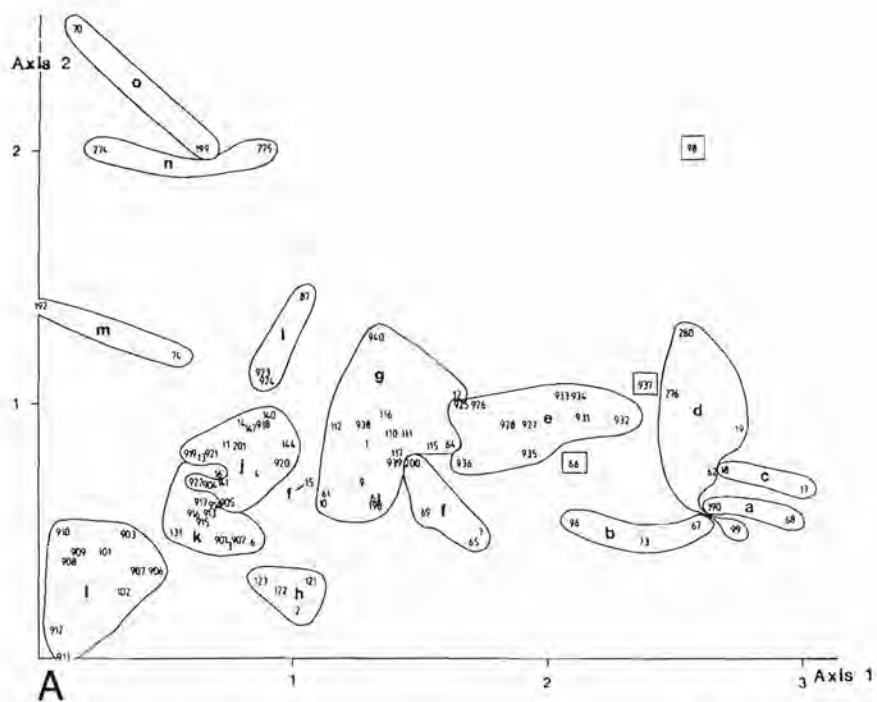
### 6.2.2 The TWINSpan classification

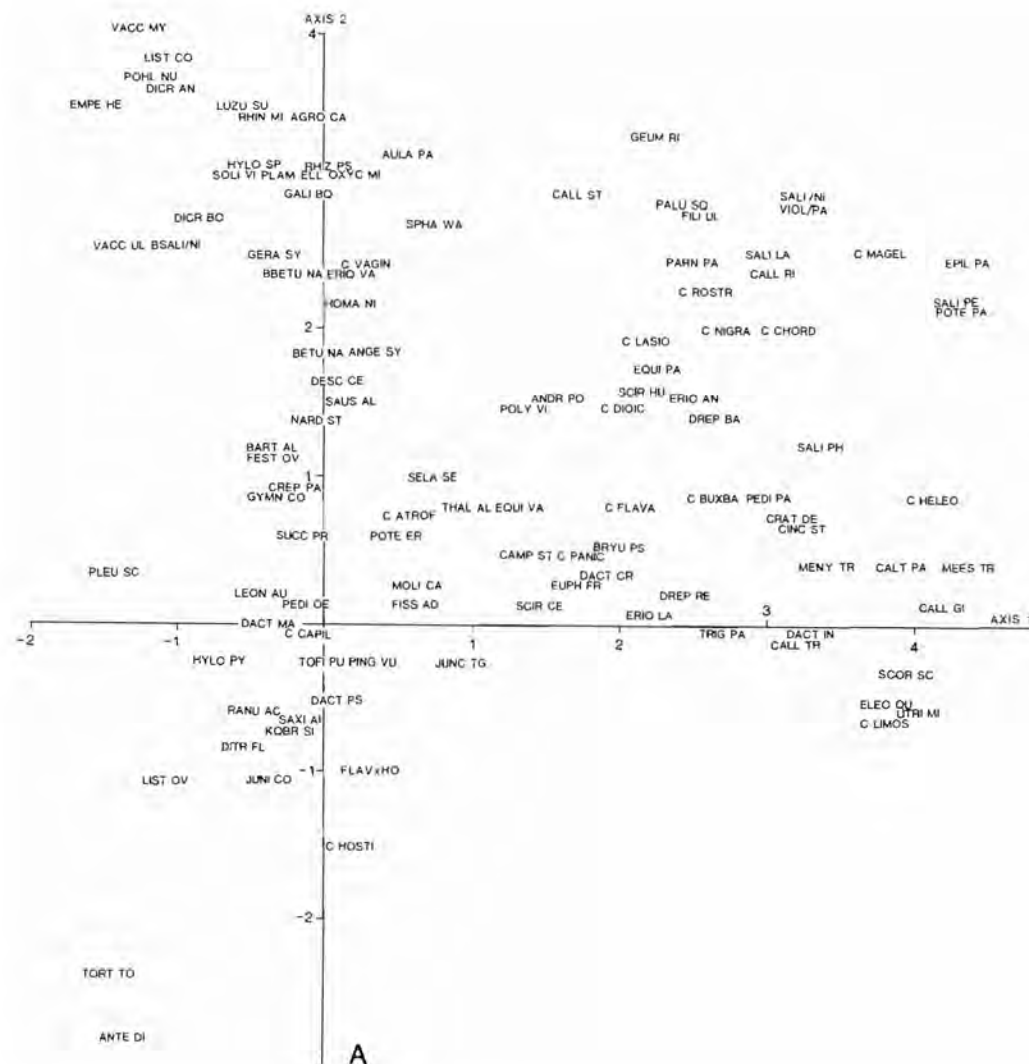
The TWINSpan dendrogram for the 97 samples data set is shown in figure 6.2.3. Nine "pseudospecies" cut levels were used. The weightings used for these pseudospecies' levels were the same as those already described in section 4.4.2. The dendrogram shows the results down to the 9<sup>th</sup> level, separated down to a single or to two samples. The resultant TWINSpan classification, as the dendrogram shows, agrees very well with TABORD classification. The classification produced by the TWINSpan program in some cases involved the TABORD clusters being split, but the samples are always then grouped together with the samples of neighbouring clusters. Further comments are given under the descriptions of the different types.

### 6.2.3 The DCA-ordination

The DCA-ordination diagrams for the 97 samples, grouped along the axes nos. 1 & 2 and 1 & 3, are shown in figure 6.2.4. The sample clusters (a-o) are indicated, together with the residual samples. All the species of the 97 samples were included in the DCA-ordination (altogether 180 "taxa"), the diagrams (see Fig. 6.2.5) included 110 taxa, i.e. constants of at least one cluster, together with the following 8 species (occurring in 50-70% of at least one cluster), viz. *Salix pentandra*, *S. phylicifolia*, *Antennaria dioica*, *Dactylorhiza incarnata*, *Ranunculus acris*, *Carex atrofusca*, *C. buxbaumii* and *C. chordorrhiza*.

Fig.6.2.4 DCA-ordination diagrams for the 97 samples of fen vegetation at Sølendet; the same 59 samples as in figure 5.2.6, plus 38 samples investigated by Gaare. A: axes 1 & 2; B: axes 1 & 3. Eigenvalues of the axes: 1: 0.381; 2: 0.250; 3: 0.147. The clusters formed by the samples shown in table 6.2.1 are outlined. The quadrangles are the 3 residual samples.





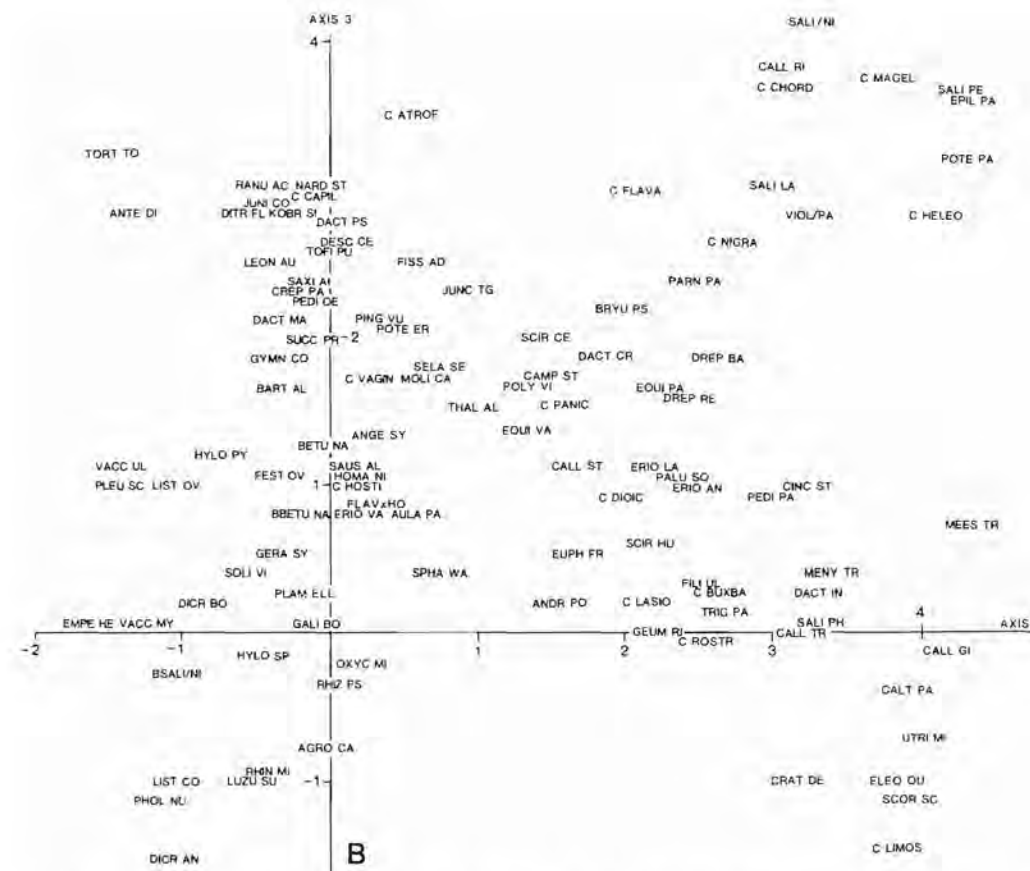


Fig. 6.2.5

DCA-ordination diagrams of the species (all the constant species of any cluster, plus 8 others; cf. details in text) for the same sample set and the same axes as figure 6.2.4. (A: axes 1 & 2; B: axes 1 & 3.) Two species are entered twice, once in the shrub layer (with B prefix) and once in the field layer (no prefix), and one hybrid is included (x), i.e. the 110 entries represent 107 species. Abbreviations: Appendix F.

The first axis (no. 1; eigenvalue 0.381, length 3.0 s.d.) represents a gradient from dry communities with low values to wet communities with high values. For example the following species recorded low values (minus) in the species ordination, in ascending order along axis 2: *Antennaria dioica*, *Tortella tortuosa*, *Ditrichum flexicaule*, *Hylocomium pyrenacium*, *Pleurozium schreberi*, *Festuca ovina* and *Vaccinium* spp. Species with high values along the 1st axis arranged in ascending order along axis 2 are e.g.: *Carex limosa*, *Eleocharis quinqueflora*, *Scorpidium scorpioides*, *Calliergon giganteum*, *Meesia triquetra*, *Carex heleonastes*, *Potentilla palustris* and *Salix pentandra*. The first-mentioned group obviously includes species belonging to dry types of fen and grassland habitats and the second group those belonging to mud bottom, carpet and swamp communities.

The second axis (no. 2; eigenvalue 0.250, length 2.5 s.d.) distinguishes between open, low-growing communities transitional to damp grassland vegetation (low values) and those of fen margins and rather hummocky lawns (high values) seen on the left-hand side of figure 6.2.4 A. The species list referred to above, in ascending order (*Antennaria* etc.) shows typical species arranged along this gradient. Most of the samples falling on the right-hand side of figure 6.2.4 A, those with high axis 1 values, i.e. wet-communities, show less separation along axis 2, from fen expanse to more marginal communities. The second species list referred to (*Carex limosa* etc.) arranges typical species along the axis 2 gradient.

The third axis (no. 3; eigenvalue 0.147, length 3.3 s.d.; when sample 98 is excluded, however, the length is only 2.3) yields the best separation of the different kinds of wet habitat communities, from mud bottoms and carpets on the fen expanse to those on the fen margins. *Carex limosa* and *Scorpidium scorpioides* have low values and *Carex heleonastes*, *Potentilla palustris* and *Salix pentandra* have high values. There is less separation of the samples clustering on the left-hand (dry) side of the ordination diagram, although there is a distinction between scrub-covered, fen margin communities (e.g. with species such as *Luzula sudetica* and *Oxycoccus microcarpus* with low values) and low-growing communities of dry habitats (e.g. *Vaccinium* spp., *Kobresia simpliciuscula* and *Carex capillaris*) with high values.

Since axes 2 and 3 serve to separate off different parts of the samples arranged along axis 1, they are therefore both important in their own right.

The fourth axis (no. 4; eigenvalue 0.099, length 2.1 s.d.; when sample 66 is excluded, however, the length is only 1.3) has not been presented in any of the diagrams shown. Wet fen margin communities (with species such as *Carex chordorrhiza* and *Menyanthes trifoliata*) show the lowest values, followed by mud bottom, carpet, lawn, mire margin and spring-flush communities in ascending order (with the species *Salix pentandra*, *Juncus castaneus* and *Cratoneuron* spp. showing the highest values).



### 6.3 THE 15 TYPES OF FEN VEGETATION (= CLUSTERS a-o)

#### 6.3.1 Rich fen, *Scorpidium* communities

- a. *Carex rostrata*-*Scorpidium scorpioides* (mud bottom) type  
2 samples (68 & 190) - the same as cluster M1 of section 5.
- b. *Eleocharis quinqueflora*-*Scorpidium scorpioides*-*Drepanocladus revolvens* type  
3 samples (67, 73 & 96) - the same as cluster M2 of section 5.

#### 6.3.2 Rich fen, *Drepanocladus*-*Meesia* communities

- c. *Menyanthes trifoliata*-*Carex heleonastes*-*Cinclidium stygium* type  
2 samples (17 & 18) - the same as cluster M11 of section 5.
- d. *Carex heleonastes*-*Drepanocladus revolvens*-*Meesia triquetra* type  
5 samples (16, 62, 99, 276, 280).

The first four samples mentioned constituted cluster M12 of section 5; and sample 280 was there included in cluster M13. The within-cluster similarity for cluster d (0.70) is about the same as that for cluster M12 of section 5.

- e. *Carex panicea*-*Campylium stellatum*-*Drepanocladus revolvens* type  
10 samples (925-928, 931-936), all of which are Gaare's.

The two bryophytes that designate this cluster are the only dominants in this type, which is a lawn community that is transitional to carpet and fen margin vegetation types. *Calliergon richardsonii* and *Drepanocladus badius* are constant species only in this particular type. *Thalictrum alpinum*, *Carex panicea* and *Scirpus cespitosus* are constants with high cover values, and a large number of rich fen lawn species are constants.

*Menyanthes trifoliata* is the dominant species in four of the samples (927, 928, 931, 932) and *Carex chordorrhiza* in three of the samples (932, 933, 934). Both these species are absent from most of the other samples and they are not constants in the type as a whole. The predominance of the two above-mentioned species and of *Drepanocladus revolvens* in some of the samples, and the occurrence of species such as *Carex heleonastes*, *Calliergon trifarium*, *Cinclidium stygium* and *Scorpidium scorpioides* indicate a carpet-like vegetation. The common occurrence in some samples of *Salix* spp. and *Festuca rubra*, together with a number of scattered occurrences of species typical of grassland/fen margin (e.g. *Angelica sylvestris*, *Geranium sylvaticum*) indicate fen margin communities.

All the stands included in this cluster are found in the lower-lying parts of Sølendet, in areas where the main watercourse (the Vassdal) originates. There is a constant seepage of groundwater through these areas, especially in the springtime, which partially explains the mixture of species, indicating different habitats, mentioned above. In addition, it seems reasonable to assume that some

of Gaare's stands were not as homogeneous as the stands I myself analysed. Use of even 1 m<sup>2</sup> quadrats can lead to difficulties when investigating vegetation that has a small-scale mosaic pattern. I also assume that the heterogeneity of these samples explains to some extent why the cluster consists exclusively of Gaare's samples.

Gaare (1963) separated the stands of this cluster into two sociations: F. the *Carex panicea*-*Campyllum stellatum*-*Drepanocladus revolvens*-sociation and H. the *Thalictrum alpinum*-*Eriophorum latifolium*-*Drepanocladus revolvens*-*Campyllum stellatum*-sociation. Sociation F included samples 925-928 (from four stands) with an internal homogeneity (similarity ratio) of 0.85. Sociation H included samples 931-936 (from four stands) with a similarity ratio of 0.77. The between-cluster similarity of these two mini-clusters is 0.71. When these mini-clusters were considered as representing distinct initial clusters (all options and other parameters unchanged) the TABORD classification accepted them as stable clusters; i.e. Gaare's grouping was quite acceptable and the choice of the initial clusters determined the size of the final clusters. As seen in figure 6.2.1, the within-cluster similarity of cluster e is 0.75, i.e. very little lower than the similarity values for the mini-clusters. The results of the TWINSpan classification and DCA-ordinations (see below) were decisive as regards the inclusion of 10 samples in cluster e.

The TWINSpan dendrogram (Fig. 6.2.3) shows that, at the first division, the samples of cluster e separated along two different branches. Samples 925 and 936 are grouped along one main branch, close to the samples forming cluster g, the remaining samples being grouped on another branch, which in its turn bifurcates to separate samples 926-928 along one minor branch and the rest along another.

The DCA-ordination diagrams show that the samples forming cluster e cover a rather large area, and samples 925-928 do not form a distinct, natural group. Samples 925 and 936 (which fall along a separate branch in the TWINSpan dendrogram) are situated closest to the samples of cluster g. Some of the other samples of cluster e (e.g. nos. 931 & 932) are situated quite close to the samples forming cluster d. Cluster e in its entirety most resembles clusters g (0.70), f (0.63) and d (0.61).

### 6.3.3 Rich fen expanse, *Campyllum* communities

- f. *Carex lasiocarpa*-*Campyllum stellatum*-*Drepanocladus revolvens* type  
5 samples (7, 15, 65, 69, 200) - the same as cluster M3 of section 5.
- g. *Carex lasiocarpa*-*Thalictrum alpinum*-*Campyllum stellatum* type  
17 samples (1, 9, 10, 12, 61, 63, 64, 110, 111, 112, 115, 116, 117, 198, 938, 939, 940).

This cluster includes all 14 samples of cluster M4 of section 5, and in addition three of Gaare's samples (those of his sociation G, the *Carex rostrata*-*Thalictrum alpinum*-*Campyllum stellatum*-sociation). In addition to the species

that designate this type, *Scirpus cespitosus* and *Drepanocladus revolvens* are also present as dominants, and *Potentilla erecta* and *Molinia caerulea* are constants, both with high cover values.

Within-cluster similarity is high (0.78) and there are high resemblances to clusters f (0.81), j (0.73), k (0.73), h (0.72) and e (0.70). On the TWINSpan dendrogram the samples of cluster g are all situated along one main branch, together with some of the samples of clusters e and f. The DCA-ordination diagrams show a similar proximity of the samples of cluster g, with the samples constituting clusters f and e, respectively.

- h. *Scirpus cespitosus*-*Carex hostiana*-*Campyllum stellatum* type  
4 samples (2, 121, 122, 123) - the same as in cluster M5 of section 5.

#### 6.3.4 Rich fen margin, *Campyllum* communities

In general, the clusters of types i-o represent rich fen margin communities, or communities transitional between lawn and mire margin; they include a number of fen margin species that are either absent from or found only seldom in the previously described types, e.g. some shrubs and dwarf-shrubs, and the species *Angelica sylvestris*, *Crepis paludosa*, *Gymnadenia conopsea*, *Leontodon autumnalis*, *Carex vaginata*, *Deschampsia cespitosa* and *Festuca ovina*. Cluster i is described in the next subsection, together with clusters m, n and o.

- j. *Carex flava*-*Thalictrum alpinum*-*Campyllum stellatum* type  
16 samples (4, 11, 13, 14, 140, 141, 144, 147, 201, 904, 905, 918, 919, 920, 921, 922).

These samples include the 9 samples forming cluster M6 of section 5 together with 7 of Gaare's samples, viz. two samples of variant A (*Trichophorum cespitosum*-var.) and five samples of variant D (*Pedicularis oederi*-var.) of his *Thalictrum alpinum*-*Kobresia simpliciuscula*-*Campyllum stellatum*-sociation.

As well as the three species that designate this type, *Succisa pratensis* and *Scirpus cespitosus* are also dominants. A number of fen margin species that also occur as constants in this cluster type, have already been listed.

The within-cluster similarity is 0.80, and there is a strong resemblance to clusters k (0.87) and l (0.90) and even to cluster g (0.73) and i (0.72). In the TWINSpan dendrogram the samples of this cluster are to be found along different branches. A number of the samples are situated on their own sub-branches with others being grouped together with the samples forming clusters k and i, and even l (i.e. sample 922). On the DCA-ordination diagrams, which likewise reveal that a great similarity exists between the samples of the above-mentioned clusters, some of the samples forming clusters j and k in particular are even intermixed.

The conclusion drawn is that clusters j and k lie very close together and some transitional samples exist. The main reason for separating these samples into two clusters (j and k) is the desire to build homogeneous clusters for the main rich fen types of vegetation at Sølendet, and preferably not to have to include the stand samples of the "basic" localities, i.e. nos. 3 (samples 3 & 131) and 4 (samples 4, 140, 141, 144, 147) in one and the same cluster. The initial clusters, and the fusion level, were chosen so as to achieve a separation of the samples of these localities. The TABORD clustering was therefore followed very consequently, even though some of the samples (e.g. nos. 904, 905, 922 of cluster j) in fact show a closer relationship with those in cluster k in the TWINSpan dendrogram and/or the DCA-ordination diagrams.

k. *Kobresia simpliciuscula*-*Thalictrum alpinum*-*Campylium stellatum* type  
11 samples (3, 6, 16, 131, 901, 902, 913-917).

These samples include two of the samples in cluster M6 (i.e. nos. 6 & 16) and two in cluster M7 (i.e. 3, 131) of section 5 together with two samples (nos. 901-902) of variant A (the *Trichophorum cespitosum*-var.), and all five samples of variant C (the *Kobresia simpliciuscula*-var.) of Gaare's *Thalictrum alpinum*-*Kobresia simpliciuscula*-*Campylium stellatum*-sociation.

The three species that designate this type, together with *Scirpus cespitosus*, are dominants. *Diurichum flexicaule* is a characteristic species of both this cluster and of cluster l. A large number of rich fen lawn and fen margin species occur as constants.

The cluster has a high degree of internal homogeneity (0.82), especially when the facts that the cluster comprises 11 samples from 7 localities, that were analysed by two different people in two different decades, are taken into consideration. There is a high resemblance to clusters j (0.87) and l (0.84) and a somewhat lower resemblance to clusters h and g (0.77 to both).

The TWINSpan classification groups most of these samples together, although nos. 901 and 902 are split off and grouped together with two samples of cluster j. On the DCA-ordination diagrams some of the samples in cluster k occupy an intermediate position in relation to cluster j, e.g. sample 16 along the first two axes. Both the TABORD and TWINSpan classifications, however, agree in their treatment of this sample.

l. *Succisa pratensis*-*Campylium stellatum*-*Tortella tortuosa* type  
10 samples (101, 102, 903, 906-912).

The samples include two of those in cluster M7 of section 5 with one sample of the variant A (the *Trichophorum cespitosum*-var.) and all seven samples of variant B (the *Succisa pratensis*-var.) of Gaare's *Thalictrum alpinum*-*Kobresia simpliciuscula*-*Campylium stellatum*-sociation.

The dominant species in this type are: *Succisa pratensis*, *Thalictrum alpinum*, *Molinia caerulea*, *Scirpus cespitosus* and *Campylium stellatum*, whilst *Tortella tortuosa* and *Diurichum flexicaule* (also constant species of cluster k) are char-



acteristic species. The trivial species *Juniperus communis* and *Pleurozium schreberi* are constants only in this particular type of rich fen vegetation dealt with in section 6. *Eriophorum latifolium*, a species that occurs as a constant, or is at least common, in most of the foregoing cluster types, is absent from types l-o.

A typical feature of type l is the dominance of *Succisa pratensis* (characteristic degree of cover 4) and of other low-herb species and graminoids, and the common occurrence of *Betula nana*. The last-mentioned species, together with e.g. *Molinia caerulea*, has expanded at Sølendet after the cessation of scything. The rather low cover-degree values (even absence in two samples) recorded for this species, as well as the scarcity of dwarf-shrubs in general (e.g. *Calluna vulgaris*, *Vaccinium* spp.), in some of Gaare's samples can be explained by the fact that Gaare made his analyses only a few years after regular scything had ceased.

The within-cluster similarity is 0.80. It has a great resemblance to cluster k (0.84), and quite a high one to j (0.80), but to all the other clusters the values are below 0.65.

All the samples in cluster l are situated along a single branch of the TWINS-PAN dendrogram, only sample 922 of cluster j being intermixed. The DCA-ordination diagrams also show that this is a fairly distinct cluster, only samples 911 and 912 are somewhat isolated, lying at, or near, the extremities of all three ordination axes (see also the TWINS-PAN dendrogram, where these same two samples are also separated off from the remainder). Both these samples are characterized, amongst other things, by a very sparse bottom layer and the occurrence of some species that are mainly restricted to mineral soils, e.g. *Melampyrum sylvaticum*.

### 6.3.5 Rich fen, *Sphagnum warnstorffii* communities

- i. *Saussurea alpina*-*Sphagnum warnstorffii*-*Homalothecium nitens* type  
3 samples (87, 923, 924).

Sample 87 was included in cluster M6 in section 5. The other two samples are those that Gaare placed in his variant E (*Sphagnum warnstorffii*-var.) of his *Thalictrum alpinum*-*Kobresia simpliciuscula*-*Campylium stellatum*-sociation.

*Sphagnum warnstorffii* is the only dominant species in this type, and *Dactylorhiza maculata*, *Scirpus hudsonianus* and *Calliergon stramineum* are constants only in this particular type.

Bryophytes, such as *Aulacomnium palustre*, *Homalothecium nitens*, *Hypnum lindbergii* and *Paludella squarrosa* are species more typical of this type than of most of the other types of rich fen vegetation, as are also some herbs, e.g. *Filipendula ulmaria*, *Galium boreale* and *Saussurea alpina*. Most of the above-mentioned species are preferential species of fen margin communities.



Cluster i has a within-cluster similarity of 0.80 and its greatest resemblance is to cluster j (0.72), whilst its resemblance to other clusters is low (e.g. 0.58 to cluster k and 0.55 to cluster n). In the TWINSpan classification, sample 87 is grouped together with the samples forming cluster n, the two other samples are situated along another branch, separated from the samples of cluster j. In the DCA-ordination diagrams, too, sample 87 is somewhat isolated from the two other samples of this cluster type, which lie closer to the samples constituting cluster j.

- m. *Betula nana-Molinia caerulea* type  
2 samples (74, 192) from a single stand - the same as cluster M8 of section 5.
- n. *Saussurea alpina-Carex vaginata-Sphagnum warnstorffii* type  
2 samples (274, 275) from Vassdalen - these samples are included in cluster M9 of section 5.
- o. *Carex rostrata-Sphagnum warnstorffii* type  
2 samples (70, 199) from a single stand - the same as cluster M10 of section 5.

#### 6.4 GAARE'S CLASSIFICATION SCHEME IN RELATION TO CLUSTERS a-o

Gaare classified one of his stands (sociation I, sample no. 937; cf. Table 6.1.1) to the alliance *Stygio-Caricion limosae*. The remaining 23 stands were classified as belonging to the *Caricion atrofuscae-saxatilis*, within which alliance he separated four different sociations. The largest of the four, the *Thalictrum alpinum-Kobresia simpliciuscula-Campyllum stellatum* sociation (15 stands), he subdivided into 5 variants A-E (with 3, 4, 3, 4, and 1 stands, respectively; samples 901-924). The other 3 sociations were:

- F *Carex panicea-Campyllum stellatum-Drepanocladus intermedius*-sociation (two stands, subdivided into two variants; samples 925-928).
- G *Carex rostrata-Thalictrum alpinum-Campyllum stellatum*-sociation (two stands; samples 938-940).
- H *Thalictrum alpinum-Eriophorum latifolium-Drepanocladus intermedius-Campyllum stellatum*-sociation (four stands, subdivided into four variants; samples 931-936).

In the TABORD classification, sample 937 (Gaare's *Stygio-Caricion limosae*) was consigned to the residual group, i.e. those with a low degree of similarity to any of the other samples of both A. Moen and E. Gaare.

The multivariate analyses resulted in the other 37 of Gaare's samples falling into the following clusters: g (10 samples, including all the stands of his sociations F and H), g (3 samples, all the stands in his sociation G), i (2 sam-

ples, the only stand of type E of the *Thalictrum-Kobresia-Campylium*-sociation), **i** (7 samples, representing two stands of type A and four stands of type D of the *Thalictrum-Kobresia-Campylium*-sociation), **k** (7 samples, representing one stand of type A and three stands of type C of the *Thalictrum-Kobresia-Campylium*-sociation) and **l** (8 samples, representing one stand of type A and four stands of type B of the *Thalictrum-Kobresia-Campylium*-sociation). Table 6.1.1 provides fuller information on these points.

As can be seen, Gaare's phytosociological units (A-H) agree in the main with the resultant clusters; the only one of his units to become split up between different clusters is that of the samples comprising type A of the *Thalictrum-Kobresia-Campylium*-sociation, the *Trichophorum cespitosum* var. In another case, two of Gaare's sociations became united into a single cluster in the multivariate analyses, viz. sociations F (the *Carex panicea-Campylium-Drepanocladus* sociation) and H (the *Thalictrum-Eriophorum latifolium-Drepanocladus-Campylium*-sociation), both of which fall into cluster **e**. The samples comprising both of these sociations show a high degree of internal similarity and, if the sociations of Gaare are used as initial clusters, then they are accepted as separate clusters by the TABORD program (cf. further comments under the description of cluster **e**).

## 7 THE VEGETATION OF SPRINGS AND SPRING STREAMS, INCLUDING THE VASSDALEN AREA

### 7.1 INTRODUCTION

The hydrology of the Sølendet springs is described in section 3.2.4. More than 50 spring outflows have been mapped inside the nature reserve, one half of them being characterised as strong springs. Figure 7.1.1 shows the hydrological structure and the main localities described here.

Eight stand samples of the spring vegetation at Sølendet, together with the mire samples, are included in the multivariate analyses of section 5. Section 7.2.1 gives a survey of the spring vegetation, including a description of the habitat conditions.

The pattern of the spring vegetation gradually changes from the centre to the margins of the springs (as shown for the three stands of cluster M17). A number of the fen stands described in section 5 are directly influenced by spring water, cf. e.g. stand no. 66, situated just beneath the outlet of a spring stream; the stand has a spring-like fen vegetation (described in section 5.4.9). These types of spring-fed fen vegetation are not further dealt with in section 7 (cf., however, the description of the Vassdalen area). Spring-fed streams and stream margins are occupied by spring-like vegetation for an appreciable distance from the outflow of the stronger eustatic springs. The vegetation of the margins

of spring streams is very species-rich; two localities are described, one of them along a belt transect, in section 7.2.2.

Comparisons between the spring vegetation of Sølendet and those described in the literature are given in section 7.2.3, cf. also tables 8.2.5 and 8.3.1 and figures 8.2.1-2, all of which show the vegetational types of mires and springs in relation to different classification systems.

The vegetation of Vassdalen is described in section 7.3, i.e. the drainage "valley" across the flat, sandy areas more than 1000 m away from the outflows of the springs, but still influenced by the calcareous water.

## 7.2 SPRINGS AND SPRING STREAMS

### 7.2.1 The vegetation and habitat conditions of springs

#### 7.2.1.1 Phytosociological analyses, clusters M16-17

Phytosociological analyses were made for 4 springs (localities 92-95); table 12 of Appendix C shows all the 27 small quadrats (representing 9 samples) of the spring vegetation.

In the main section dealing with the vegetation of mires and springs (section 5), two spring types were described and two samples were grouped as residuals. The *Saxifraga aizoides*-*Cratoneuron* spp. type (no. M16) are species-rich communities represented by 3 stands from three different springs. This type represents spring vegetation covering a large part of the spring area itself as well as on the margins of spring-fed streams. The *Epilobium alsinifolium*-*Cratoneuron* type (no. M17) includes 3 stands from a single spring, a total of 11 quadrats. This type of spring, on deeper peat, is uncommon on Sølendet.

Stands 92 and 193 (both from complex-locality 92) are grouped as residual samples in the account given in section 5. "Locality" no. 92 comprises a complex of several springs, and stands 92 and 193 represent types found on a single, level stretch ca. 10 m away from the outflow. In both stands the water-level lies at the surface; the field layer is sparse and sporadic bryophytes are predominant: *Jungermannia excertifolia* and *Philonotis fontana* in stand 92, *Caliergon giganteum* in no. 193.

Locality 94 represents the vegetation cover along the margins of a spring-fed stream and is described in section 7.2.2.

#### 7.2.1.2 Habitat conditions

The max.-min. temperatures of the water in the middle of the spring were recorded at localities nos. 93 and 95 over a two-year period (Sept. 1985 - July

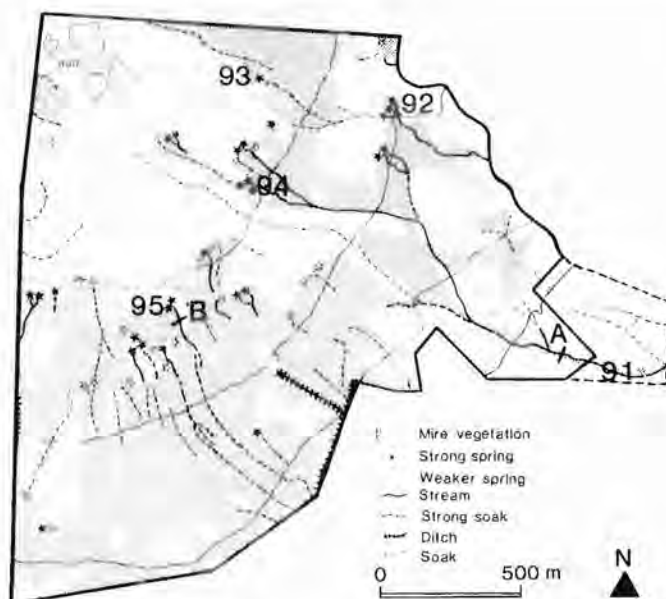


Fig. 7.1.1 The hydrological features of Sølendet (based on Fig. 3.2.4); showing the localities for the spring vegetation analyses (nos. 92-95), the locality for stream-bed vegetation (no. 91), the Vassdalen transect (A) and the transect of the spring stream (B).

1987). The rather simple and imprecise thermometers used nevertheless gave readings, indicating that, throughout the year, the water temperature does not fall below ca. 2°, nor does it rise above ca. 5°C.

The stands of the *Saxifraga aizoides*-dominated type (no. M16) are localized at the margins of main spring outflows and along the margins of spring-fed streams, in areas with a thin peat cover. The three stands of cluster M16 have 8-10 cm of dark-coloured peat mixed with mineral grains, sand and stones to the surface.

The stands of cluster M17 represent the gradient from the outflow (stand 93) to the more fen-like spring vegetation (stands 195-196) situated ca. 2 m and ca. 5 m, respectively, from the outflow. The spring occurs in a nearly flat, fen-dominated area, the peat is 0.8-1 m thick. The outflow has patches of mud bottom.

Analyses of spring water (cf. Table 2 of Appendix C and the summary for the mire and spring clusters in Table 5.3.1) show that pH at the investigated localities varied between (7.3)7.6-7.9(8.0), the mean for 16 water samples was 7.7.

The specific conductivity for the same water samples varied between 127–204  $\mu\text{S}/\text{cm}$ ., with a mean value of 180. These data show that the spring water is weakly alkaline, with a high content of electrolytes.

### 7.2.2 The spring streams

Small streams, fed mainly by spring water, can be found all over Sølendet (see Fig. 7.1.1). The vegetation of Vassdalen, including that along the stream, is described in section 7.3.

Phytosociological analyses of the marginal vegetation of small, spring-fed streams were made at locality 94 and at transect B close to locality 95. The main aims of these analyses were to elucidate the species composition of this marginal ecotope and to obtain a few quadrats to document some very special plant communities that are seldom analysed. The material is nevertheless too restricted to allow full descriptions of the plant communities to be given.

#### 7.2.2.1 Three small quadrats at locality 94

The data for locality 94 (three small, ca.  $0.1 \text{ m}^2$  quadrats) are shown as quadrats nos. 23–25 in Appendix C-Table 12. The small quadrats were taken on rather homogeneous cushions of bryophytes on the north- and east-faces of boulders, and on gravel, ca. 4–15 cm above the stream water-level (pH in water ca. 8.0), at a distance of ca. 10 m from the main outflow of the eustatic spring. As seen in the table, the species composition of the three quadrats differs widely, and they are in reality descriptions of three different stands. Even where the greatest possible homogeneity is stressed, the numbers of species are large (27–38 in each of the three small quadrats), the most numerous being bryophytes.

A mixture of spring and rich fen species occurs in the field layer, e.g. *Saxifraga aizoides*, *Carex atrofusca* and *Juncus* spp. are typical. Species typical of rich fens and springs are dominant in the bottom layer, e.g. *Bryum pseudotriquetrum*, *Campylium stellatum*, *Cratoneuron commutatum*, *Drepanocladus revolvens* and *Philonotis* spp. In addition, a number of species that most often occur on the margins of springs and near small streams etc. are to be found, e.g. *Dicranella palustris*, *Meesia uliginosa*, *Tayloria lingulata* and *Hygrobiella laxifolia*. Also, some species that mainly grow on rocks and boulders close to streams are present, e.g. *Andreaea rupestris*, *Blindia acuta*, *Dicranoweisia crispula* and *Racomitrium aciculare*. At Sølendet the last-mentioned species is

Fig. 7.2.1 Profile and species lists with cover values for the belt transect (B), across the stream fed by the eustatic spring (further details in text).





only found in the area of locality 94, on north-facing boulders close to the spring-fed stream, at a level at which the moss is subject to periodic submersion. Other bryophyte species found in the *Racomitrium aciculare*-cushions are: *Dicranoweisia crispula*, *Andreaea rupestris*, *Cephaloziella* sp., *Odontoschisma elongatum* and *Scapania irrigua*.

#### 7.2.2.2 Belt transect (B) close to locality 95

The transverse profile of the belt transect, running from north to south across the stream ca. 30 m from the strong outflow of the eustatic spring, is shown above in figure 7.2.1, see also figures 7.2.2-3. The transect was 0.5 m in width and 2.34 m in length, comprising the seven quadrats and the open water stretch. The vertical intervals from the stream-bed to the furthest edges of the transect are 40.0 cm and 41.3 cm respectively.

The vegetation of quadrats 3-5 is directly influenced by the calcareous (pH: ca. 7.8) spring-water throughout the year, and the areas are submerged at certain times of year. These three quadrats parallel the three quadrats of locality 94, described above; the field layers contain a number of species in common, e.g. *Saxifraga aizoides*, *Carex atrofusca* and *Juncus* spp.. *Philonotis fontana* and *Rhizomnium pseudopunctatum* occur in all the strongly spring-water influenced quadrats, and predominate in nos. 3 and 4 respectively. *Brachythecium rivulare*, a rare species at Sølendet is the dominant in quadrat 5. In addition, a large number of other bryophytes occur, e.g. all three *Cratoneuron* species in all the quadrats. The following spring/stream margin species have more scattered occurrences in these three quadrats: *Amblydon dealbatus* (a rare species at Sølendet, with its typical habitat in quadrat 5), *Meesia uliginosa*, *Onchophorus virens*, *Philonotis calcarea*, *Pohlia wahlenbergii*, *Tayloria lingulata* and *Lophozia bantriensis*.

Quadrat 6 represents a typical community that occurs in shaded areas near springs, streams etc., *Harpanthus flotovianus* is the dominant. *Epilobium lactiflorum* is also a typical species. In addition, a number of damp grassland and rich fen species occur, e.g. *Crepis paludosa* and *Tritomaria* spp.

Since the vegetation across the entire transect is somewhat influenced by calcareous water, calciphilous species, such as *Thalictrum alpinum* and *Carex capillaris*, are present throughout. All the quadrats are species-rich, the total number of species varies from 28 to 51 for the 7 quadrats.

The composition of quadrats 3-5 lies closest to the typical vegetation of springs. The vegetation of quadrats nos. 1, 2 & 7 is transitional between rich fen and grassland vegetation; that of no. 7 even includes some heathland species (e.g. dwarf-shrubs and *Barbilophozia lycopodioides* as a dominant). Species that occur in all the above-mentioned three quadrats are: *Saussurea alpina*, *Selaginella selaginoides*, *Solidago virgaurea*, *Carex vaginata*, *Eriophorum angustifolium*, *Molinia caerulea*, *Sphagnum warnstorffii* and *Marchantia polymorpha*. *Aulacomnium*



Fig. 7.2.2 The spring-fed stream in the area covered by the belt transect (Fig. 7.2.1), quadrat 1 on the left. The tape measure marks quadrat 5. Photo taken looking downstream. 19821005.



Fig. 7.2.3 The same locality as above, viewed upstream. The extensive, marginal vegetation-free areas (dark coloured) are due to heavy vole grazing during wintertime. 19850607.

*palustre* and *Plagiomnium ellipticum* are common in quadrats 1 & 2, *Nardus stricta* and *Hylocomium pyrenaicum* in no. 7.

The data from the quadrats of the transect have not been included in any of the multivariate analyses.

#### 7.2.2.3 Grazing by voles

The areas on the margins of spring-fed streams and flushes are subject to heavy grazing by voles during years of peak rodent populations. The voles live in the subnival region, beneath the winter snow cover and, because the spring water supply never freezes, the streambanks do not freeze either during the wintertime. The field layer of the vegetation along the stream margins is in this way totally destroyed in some years, for a distance of a few cms. to about 1 m away from the stream, see the photos (Figs. 3.2.5 and 5.2.3) taken in the springs of 1977 and 1985. This influence is certainly of importance in preventing trivial species, both of grasses (e.g. *Molinia caerulea*) and of herbs, from becoming dominants in the field layer. This periodic destruction of the plant cover (at ca. 7-year intervals) is undoubtedly important in enabling weakly-competitive, alpine species to occupy the habitat along the margins of such spring-fed streams, together with the good mineral supply, and the erosive effect of water/ice.

### 7.2.3 Comparisons with similar types of spring vegetation elsewhere

#### 7.2.3.1 Synsystematic survey

The spring vegetation is by most authors classified in one class and one order (*Montio-Cardaminea*, *Montio-Cardaminetalia*, respectively), cf. e.g. Dahl (1957, 1987), Oberdorfer (1977, 1983), Moravec et al. (1983). Spring vegetation is most often differentiated into two main types (usually at alliance level), one including the vegetation of soft water, the other the vegetation of hard (calcareous) water (cf. e.g. Nordhagen 1936, 1943, Dahl 1957, Oberdorfer 1977, 1983). The alliance names are: *Cardamino-Montion* and *Cratoneurion commutali* (cf. Table 8.2.5).

The Central European classification system, in accord with the Tüxen tradition, classified the communities into broad-based associations and alliances, mainly based on the vascular plants (cf. comments in section 8.2 regarding the classification of mire vegetation). Oberdorfer (1977, 1983) differentiated between 8 associations of spring vegetation in the two alliances (the *Cratoneurion* alliance included three associations).

In parallel to the classification system for mires (cf. section 8.2), Czechoslovakian authors also use narrower units of spring vegetation. Moravec et al. (1983) divided the spring order into three alliances and 10 associations for

Czechoslovakia. Later, Hadač (1983) in his survey of the plant communities of "springs and mountain brooks in Czechoslovakia" differentiated between 6 alliances, including 22 associations. Hadač also differentiated at the level of order between soft water and hard water spring vegetation. The latter order was separated into two alliances, including altogether 6 associations. In addition Hadač included another 6 associations in an "intermediate" alliance (*Cratoneuro filicini-Calthion laetae*). Hadač (1983: 360) concluded that "besides the geological substrate the temperature is the deciding factor for the character of spring communities". He found that some of the associations and alliances occur at low altitudes, some other units in alpine areas.

Nordhagen (1936, 1943) and Dahl (1957, 1987) classified the upland spring vegetation of Fennoscandia into two alliances, viz. the *Montio-Epilobion hornemannii* Nordh. 36 (= *Mniobryo-Epilobion hornemannii* Nordh. 43) and the *Cratoneuro-Saxifragion aizoidis* Nordh. 36. Nordhagen (1943: 417) pointed out the close relationships to the two Central European alliances, he suggested a differentiation, at the suballiance level, between lowland and upland types. As a consequence of the rules of priority (Barkman et al. 1986) the Central European names should then be used (as done here, cf. Table 8.2.5, cf. also Vevle 1983, 1986).

The vegetation of eustatic springs differs, compared with other vegetational types, rather little in different vegetational regions, cf. e.g. the spring communities of the nemoral region of Denmark, which includes a large number of the species of boreal and alpine springs. As also stated by Warncke (1980: 260), the plant communities of springs belong among the most stable and unchangeable communities of all types of vegetation. It therefore seems logical to find spring alliances in common between Fennoscandia and Central Europe.

Nordhagen (1943: 419) published analyses from 6 stands from North Norway, all of which were included in one association, the *Cratoneureto-Saxifragetum aizoidis*. Dahl (1957) included three analyses from Rondane in the same association. At the moment, this is the only described association of calcareous spring vegetation in Norway; the spring vegetation of Sølendet has to be included in that association.

The vegetation of springs and spring-fed streams varies widely in Norway as elsewhere. A lot of work certainly remains to be done in this respect, in future. I think new formal units, at association and even at alliance level, will be defined (as mentioned for Czechoslovakia).

#### 7.2.3.2 Further comments on the literature

Resvoll-Holmsen (1920: 177) described (without giving phytosociological analyses) spring vegetation from a number of localities in eastern Norway, e.g. *Cratoneuron* vegetation from Knutshø in Dovre. Mork & Heiberg (1937: 661) included three analyses of a very species-poor *Epilobium alsinifolium*-*Cratoneuron commutatum* type from the Hirkjølen area.



The *Cratoneureto-Saxifragetum aizoidis* analyses of Nordhagen (1943) and Dahl (1957: 211, *Cratoneuron decipiens* in bottom layer) mentioned above resemble the samples of cluster M16 of Sølendet. However, the stands referred to are much more species-poor than the Sølendet stands; a number of bryophytes in particular are absent.

Persson (1961, 1962) described a large number of spring communities, together with their habitat conditions, from the Torneträsk area. The *Saxifraga aizoides-Cratoneuron falcatum* community of Persson (1961: Table 20a: 1-12) is very close to the cluster M16 of Sølendet, both in regard to species composition and ecology (peat layer absent, pH in water 7-8). This *Saxifraga-Cratoneuron* community is certainly a very distinct community of the Cambro-Silurian areas of Central Norway, described e.g. in 5 stands in my cand.real. thesis work (Moen 1970: Table 30). In addition to the *Saxifraga aizoides-Cratoneuron* type, some more of Persson's (1961) samples of his *Cratoneuron* association (Tables 20a & b) resemble some of the Sølendet analyses. The *Jungermannia exsertifolia* community of Persson (1961: 141) resembles cluster M17 and stand 92 (a residual sample, also resembles the *Calliergon giganteum* types mentioned by Persson).

Descriptions of similar communities to the very species-rich mini-communities of spring-fed streams (viz. sample 94, Appendix C-Table 12; quadrats nos. 3-5 in the transect of section 7.2.2.2) are not present in the Fennoscandian literature.

### 7.3 VASSDALEN, INCLUDING THE BELT TRANSECT

#### 7.3.1 Introduction

Vassdalen is a drainage system that occupies a shallow depression in the alluvial sands in the southeast corner of Sølendet. Vassdalen's water supply comes from springs, mires and small streams (cf. the description of the hydrological systems in section 3.2.4, and Fig. 7.1.1).

The valley bottom is in places only a few metres wide, with a stream that, in some places, is more than 1 m deep. For most of its length, the Vassdalen valley is wider (up to 30-40 m), e.g. at the site of the transect. In these wider parts of Vassdalen, the stream either meanders through the area, or else there is no obvious surface drainage pattern visible, e.g. in the vicinity of the transect.

In springtime and during periods of high precipitation, Vassdalen becomes entirely flooded and the whole extent of the valley depression functions as a stream. In dry periods, however, the groundwater-level is lowered very much and it is only on some flat fens that the groundwater-level lies close to the surface. Even the deeper parts of the stream-bed dry up, indicating that the groundwater-level may fall by more than a metre for long periods.

The vegetation of Vassdalen was studied by analysing selected stands by means of small quadrats (stands nos. 19, 54, 62, 88, 91) and by investigating the transect, the profile of which is presented in figure 7.3.1. Some single transect quadrats, or the syntheses of two or three quadrats of the transect, were used as samples in the main phytosociological treatments of sections 5 and 9 (cf. survey of all samples, Appendix A-Table 1). The stands nos. 270-280 and 290-294 are all from the transect area.

### 7.3.2 The main vegetation types of Vassdalen

#### 7.3.2.1 Stream-bed vegetation, including stand 91

For long stretches of Vassdalen the stream occupies a 0.5-1 m wide bed, largely occluded by vegetation, mainly bryophytes. This type of vegetation is exemplified by stand 91 (full phytosociological data in Table 11 of Appendix C), where all the four quadrats are from the bottom of a 0.1-0.3 m deep, ca. 1 m wide, stream-bed. *Salix phylicifolia* (rooted on the stream margins) dominates the shrub layer. The very sparse field layer includes *Caltha palustris*, *Cardamine pratensis* coll., *Galium palustre* and *Veronica scutellata*; the bottom layer is dominated by *Tortella tortuosa*, *Drepanocladus revolvens*, *Jungermannia atrovirens* and *Lophozia borealis*. This is the only habitat in which large cushions of *Lophozia borealis* are known to occur (usually only scattered individual plants of *Lophozia borealis* are found, cf. Frisvoll & Moen 1980). The dominance of *Tortella tortuosa* in a wet fen community is also unique. The rare species *Drepanocladus sendtneri*, similarly, has only been found at Sølendet in the stream-beds of Vassdalen. The community represented by stand 91 covers only small areas (a ca. 200 m stretch along the 0.5-1 m wide stream in Vassdalen). In the multivariate analyses (cf. section 5) this sample separated out as an outlier/residual sample (see Figs. 5.2.4-5.2.5).

In other places in Vassdalen the stream is a more marked feature, not occluded by vegetation, and filled with water for long periods of the year. In these places, species such as *Ranunculus reptans* and *Utricularia ochroleuca* are common, in addition to the above-mentioned herbs for stand 91. Bryophytes found along the stream margin are e.g.: *Calliergon richardsonii*, *Dicranella palustris*, *Fissidens bryoides*, *Meesia triquetra*, *Tayloria lingulata*, *Moerckia hibernica* and *Pellia neesiana*, as well as some of those listed under stand 91 above; willow copses are also predominant there, e.g. *Salix phylicifolia* in stand 91 and *S. pentandra* in the main transect, the latter forming almost a "willow woodland" in places. A variety of other species of willows are also common, and locally dominate the shrub layer at sites in Vassdalen subject to wide fluctuations in groundwater-level (cf. the transect). The willows, in both the field and shrub layers, have become established after the cessation of scything. Scrub clearance and recommencement of scything was started in 1978 in part of the Vassdalen area, including the site of the main transect (see Figs. 7.3.2 & 3).

### 7.3.2.2 Mires

Wet mires are predominant on flat areas in Vassdalen except where the stream-bed is deep. Stands 19 and 62 from Vassdalen are both included in cluster M12 (i.e. the *Carex heleonastes-Drepanocladus revolvens-Meesia triquetra* type) of the multivariate analysis of mire vegetation (section 5) as is also stand 276 (quadrats 11 and 12 of the transect). This type has a high groundwater-level for most of the year and the peat layer is deep (ca. 1 m).

Quadrats 13-17 of the transect (i.e. stands 277, 278, 280) constitute cluster M13 of the analysis (i.e. the *Salix* spp.-*Equisetum palustre-Drepanocladus revolvens* type). This type includes a number of willow species, and some additional fen margin species (e.g. *Deschampsia cespitosa*).

Cluster M9 (i.e. the *Saussurea alpina-Carex vaginata-Sphagnum warnstorffii* type) includes quadrats 7-9 (stands 274, 275) and 18-20 (stand 279) of the transect. This fen margin community is transitional to damp grassland vegetation, as also indicated by the thinner peat cover (ca. 10-15 cm).

### 7.3.2.3 Damp grasslands

Damp grassland communities occur between the typical fen areas and the dry forest communities, as exemplified by quadrats (4)5-6(7-8) on the southfacing slope and nos. 18-20 (21-22) on the northfacing, shaded slope of the transect. The damp grassland areas form a narrow belt, only about 3-5 m wide on each side of the transect. The south-facing damp grassland area represents a typical habitat for *Nigritella nigra*, which occurs in quadrats nos. 5-6 of the transect, and in stand 88 situated close to these quadrats. Further down in Vassdalen, the open areas of damp grassland on the north-facing slopes form a belt 15-20 m wide. Stand 54 represents this rich grassland area and also includes *Nigritella nigra*. All the stands referred to above are grouped in cluster O2 (i.e. the *Nardus stricta-Thalictrum alpinum-Sphagnum warnstorffii* type) in the multivariate analysis of the open grasslands (cf. section 9.3).

### 7.3.2.4 Wooded areas

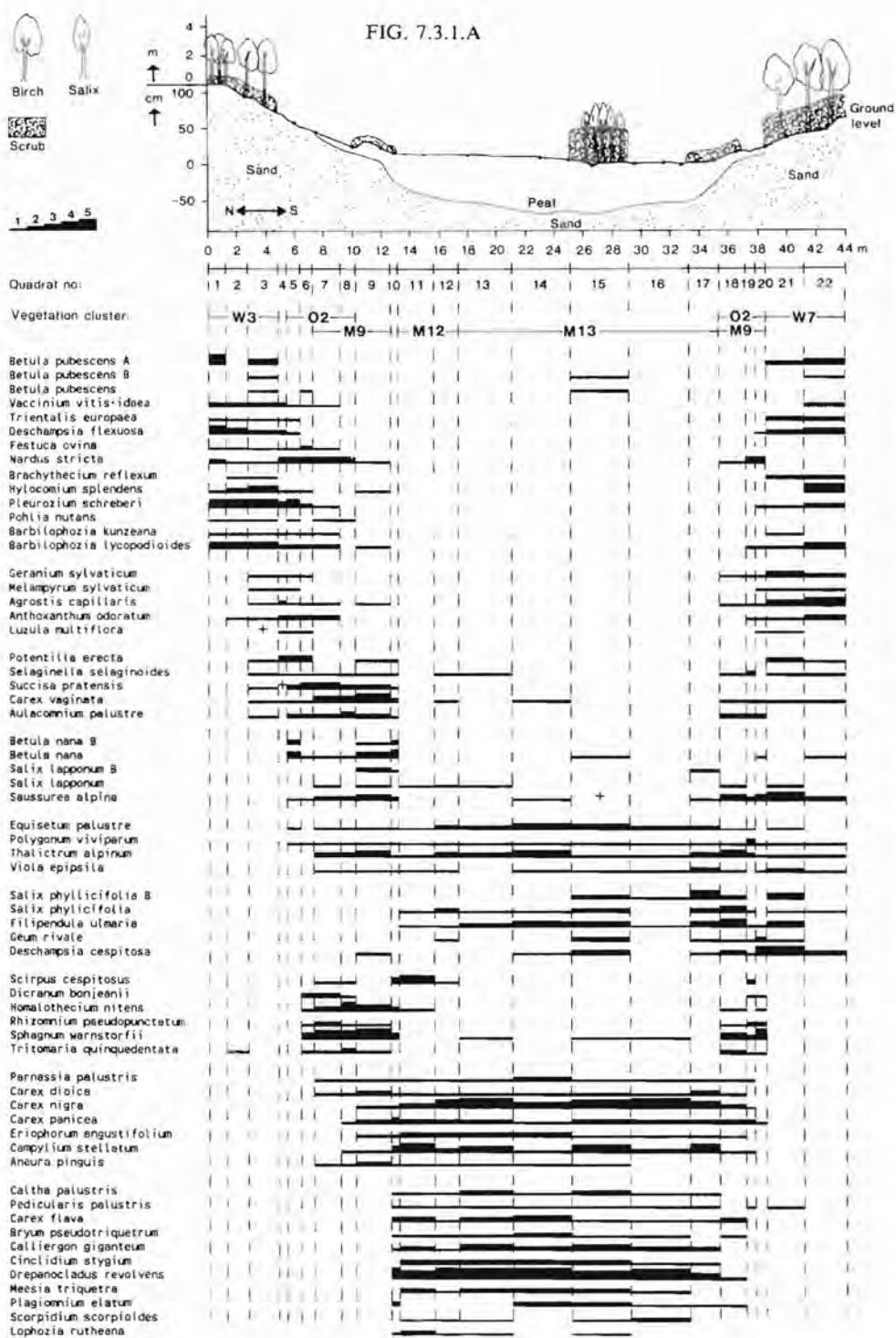
At higher altitudes, the damp grassland gives way to drier wooded grassland and heathland. The southern part of the transect ends in wooded grassland (cluster W7, i.e. the *Betula pubescens-Geranium sylvaticum-Rubus saxatilis* type), and the northern part in wooded heathland (cluster W3; i.e. the *Betula pubescens-Empetrum hermaphroditum-Pleurozium* type). Most of the flat, sandy areas in the south and east of Vassdalen are dominated by heathland (e.g. of type W3).

### 7.3.3 The Vassdalen belt transect

The plant species recorded along the transect (154 in all) are presented in three groups (Fig. 7.3.1). Part A of the figure lists the most common species, i.e. species that occurred in at least two quadrats near each end of the transect, or in at least 5-6 quadrats in the centre. Species that occurred in more than one layer (e.g. *Betula pubescens*) are listed together, with an A (tree layer) or a B (shrub layer) added after the species name. Part B of the figure lists the characteristic species of (1)2-5(6) quadrats in diagonal succession, from the first to the last quadrats along the profile from N to S. Additional species, i.e. species that occurred in only one quadrat are listed in part C.

Fig. 7.3.1 The Vassdalen belt transect and profile. A & B (next pages) present the profile, the position of each quadrat (which varied in length from 0.5 m to 4.1 m), the species lists with cover values (+, 1-5) and the ecological data. C lists additional species. The transect is 1 m wide and 44 m long, running from N to S straight across Vassdalen.

- A. The profile, showing the ground surface with sampling points, peat depths and, schematically, the wooded and scrub-covered areas. "Vegetation cluster" refers to the types resulting from the multivariate analyses of woodland (W), open grassland (O) and mire (M) samples.
- B. The same profile as in A, but showing in addition the groundwater-levels on different dates in 1982 (viz. June 11, July 17, Aug.6 and Oct.5), pH values for soil and water, and the specific conductivity values ( $K_{20}$ ) of the water.
- C. Species additional to A and B with a cover value of 1 in one quadrat: (r: reduced specimen). Quadrat nos:
  - 1: *Cladonia stellaris*, *Stereocaulon paschale*; 2: *Antennaria dioica*, *Cladonia chlorophaea*, *C. phyllophora*, *C. sulphurina*; 3: *Peltigera aphthosa*; 7: *Dicranum angustum*; 8: *Scirpus hudsonianus*; 9: *Calliergon stramineum*; 10: *C. sarmentosum*, *Hypnum lindbergii* (cover 2); 11: *Triglochin palustre*, *Eleocharis quinqueflora*; 14: *Epilobium palustre*; 15: *Galium palustre*, *Dicranella grevilleana* (r), *Distichium capillaceum*, *Fissidens bryoides* (r), *Meesia uliginosa*, *Chiloscyphus pallescens*, *Pellia neesiana*; 17: *Calamagrostis stricta*; 18: *Taraxacum* sp.; 19: *Phleum alpinum*, *Philonotis tomentella*, *Lophozia ventricosa*; 21: *Cirsium helenioides*, *Silene dioica*; 22: *Salix starkeana*, *Botrychium boreale*, *Cladonia furcata*.







### 7.3.4 Remarks on some habitat conditions

#### 7.3.4.1 Groundwater-levels

The habitat conditions in general are described in section 7.3.1 (cf. also section 3.2.4 regarding the hydrology). The groundwater-level of the valley bottom lies near the surface during most of the growing season, and Vassdalen is entirely flooded every spring and autumn (see Fig. 7.3.3).

Figure 7.3.1.B shows the situation in the spring, summer and autumn of 1982. The groundwater-level usually remains very high throughout May (1982 was a late and wet spring right up to the observation date, June 11). Even in quadrat 8 groundwater was still at the surface on June 11. Quadrats 5-7 lay ca. 10-30 cm and quadrats 3 and 4 ca. 35-50 cm above the groundwater-level at that time. At the other end of the profile, in quadrat 18, the groundwater-level lay 13 cm below the surface and even quadrats 19, 20 and the lower part of no. 21 had groundwater-levels less than 20 cm below the surface. At the time of the most intense flooding, the water-level was higher than that recorded on June 11, so it seems reasonable to assume that the groundwater-level annually lies at the surface at times in the vicinity of quadrats (7)8-18(19,20) (and that stands 19, 62 and 91 are flooded), and the deep-rooted species growing in quadrats (3)4-22 (including also stands 54 and 88) are similarly liable to flooding.

During dry periods in summer, the groundwater-level falls. The values for July 17 are representative for a rather dry period; August 8 shows the situation after a long dry period. The water-level on October 5 represents a rather dry autumn situation.

#### 7.3.4.2 Water analyses

All the pH and conductivity measurements were made on the same date, Sept. 16 in 1981. The water-level at that time was a few cm lower than on Oct. 5 in 1982. A sample of free water (little hand pressure required) was collected at each site, except for quadrat 16, where the peat had to be squeezed hard to get the sample. Quadrat 10 had pH = 6.4 and specific conductivity = 51, all the other quadrats showed higher values. Quadrat 10 represents a low, minerotrophic hummock (as also no. 9), which accounts for the (relatively) lower values. The values for quadrats 11-15 (pH = (7.0)7.1 and specific conductivity = 116-165) are fairly constant and high. The lower pH and the high specific conductivity value for quadrat 16 can be explained by the customary decrease in pH and increase in  $K_{20}$  when a water sample has to be squeezed out of the peat (cf. Persson 1962). Stand 19, which lies only 3-8 m away from the profile line and represents the same community as that analysed in quadrats 11 and 12, had pH = 7.2 (two water samples) and specific conductivity = 110 and 111 on July 22 in 1981. These values correspond very well with the values



Fig. 7.3.2 Vassdalen, shown from N to S with the area of the transect; the hummock (quadrat 9 in the transect) seen in the foreground, the *Salix pentandra* trees (quadrat 15 of the transect) in the centre. 19780809.



Fig. 7.3.3 Vassdalen, the situation in springtime with the groundwater-level lying at the surface; photo taken after scything recommenced. The same area as that shown above. The stake in the centre marks the position of quadrat 15. 19850607.

cited above, since it is a known fact that pH generally decreases between spring and autumn, whereas  $K_{20}$  is higher in autumn (cf. Persson 1962).

In conclusion, the water flowing through Vassdalen has quite a high pH (at, or a little above, the neutral point) and a fairly high specific conductivity (above 100).

#### 7.3.4.3 Soil

The depths of the peat layer are shown in figure 7.3.1.A. Very often there is a gradual change from fine sand to peat and some mineral matter is everywhere present in the peat, e.g. for quadrats 15-18 of the transect, where sand grains are common even on the surface, due to flooding. At the transition from fen to damp grassland vegetation, the peat thickness gradually diminishes, both to the north and to the south along the transect. Quadrats 8 and 9 still possess a distinct peat layer (10-20 cm), but from the surface downwards there is a gradual increase in sand content, and at 30-40 cm depth there is almost pure sand. Quadrats 5 and 6, and parts of no. 7, showed a peaty mull-like humus layer (8-15 cm), a weak bleached layer and an unsharp deposition layer, including some dark-coloured spots etc. giving evidence of gley formation (resulting from periodic high groundwater-levels). However, in my classification system, the soil in these parts of the transect are transitional between the three main soil types: peat, podsol and brown earth. Quadrats 1 and 2 show typical podsol profiles, and also quadrats 3 and 4 are classified as podsols, even though the humus layer is thin in places and the layer differentiation only weakly developed. Quadrat 22 also shows a weakly podsol profile. The other quadrats are on brown earths and peat.

The pH values of the upper 3-5 cm of humus/peat/mull of the transect are presented in figure 7.3.1.B. A pH of less than 5.0 was recorded for quadrats 2 (the lowest value of all viz., 4.6), 5 and 22. The pH values for the other 15 soil samples lay between 5.5 and 6.9. Quadrats 7 and 8, representing a vegetation transitional between rich fen margin and damp grassland, had a pH of 5.5 (similarly, the two soil samples of locality 54 had pH 5.5 and 5.6). On the low, rich fen hummocks (quadrats 9 and 10), the pH values were 5.8 and 5.6, respectively. The pH values of the peat of quadrats 11 and 12 (5.7 and 6.1, respectively) are lower than those recorded elsewhere for typical fen areas in Vassdalen (6 samples pH 6.6-6.9). Even two of the soil samples for quadrat 18 had pH values as high as 6.0 and 6.6, and the pH values for the mull of quadrat 20 were 6.1 and 6.0.

The pH gradient from quadrat 11 to quadrats 14/15, seems to be genuine, since the pH values were also lower at localities 19 and 62 and, within these stands, the measured values were lowest in the northern parts. The pH values for locality 19 were 6.4 and 6.7, for locality 62, 6.1 and 6.4, respectively, (cf. Table 2 of Appendix A). The explanation for the highest values being recorded near to the stream/central flow is probably that the supply of calcareous water is better there, together with a greater annual fluctuation in the groundwater-level.

## **8 A SYNSYSTEMATIC SURVEY OF N. AND C. EUROPEAN MIRE VEGETATION: THE SØLENDET TYPES COMPARED**

### **8.1 INTRODUCTION**

The delineation of the mire and spring communities described in this monograph has only been made by taking into account the composition of the vegetation of Sølendet, without any attempt to use classification systems conceived for related types of vegetation elsewhere, in Fennoscandia or C. Europe, or to consider the ecological conditions underlying the differentiation of the vegetation. The multivariate analysis method was used to classify the samples into clusters (M1-18 in section 5; also a-o in section 6, which in addition included Gaare's Sølendet data).

A broader synthesis of upper boreal mire vegetation is in progress (cf. comments in section 1.2) including multivariate analyses of samples from a number of other localities (mainly in Central Norway). Here, only the samples from a single area have been dealt with, which explains why no new phytosociological units, have been defined (in agreement with Recommendation 7A of Barkman et al. 1986).

The hydrological and geographical terminology used to characterise mires has already been dealt with in section 2.7. Both the vegetational types, and their ecological relationships have been described in section 5. The areal extents of the various mapped units, together with a survey in addition to the phytosociological analyses can be found in section 12.4.

The units adopted in connection with the Norwegian national plan for mire nature reserves, and the two phytosociological, hierarchical systems used, will be described briefly, with comments, in the next subsection (8.2). The former are based on the local vegetational gradients, as described by e.g. Sjörs (1948, 1950) and Malmer (1973). Comments on the Central European classification system used by Dierssen (1982) in his monograph on North European mires are made in section 8.2.2. The hierarchical system proposed for Norway (section 8.2.3) is a synthesis of Nordhagen's (1936, 1943) and Dahl's (1957) proposals, Central European systems (e.g. Rybníček et al. 1984) and personal experience of Fennoscandinavian research on mire vegetation over the past decades.

### **8.2 SOME OF THE MAIN CLASSIFICATION SYSTEMS**

#### **8.2.1 Units adopted for the mire vegetation of the nature reserves**

During the work on the Norwegian national plan for mire nature reserves, the vegetation of the mires was classified using units related to the three main vegetational gradients (after Sjörs 1948).



The units used for Norway have been described previously in the primary reports presented for each county (e.g. Moen 1983; cf. also Moen 1985a). Figure 8.2.1 provides a schematic presentation of these 25 units (including vegetation transitional to *Magnocaricetum*; and spring vegetation).

The vegetation has been divided into 5 main units on the basis of the "bog - poor fen - rich fen" vegetational gradient (the species groups shown in Table 8.2.1). Each of these main units has been subdivided into open mire vegetation (mire expanse) or tree-/scrub-covered mire vegetation (mire margin) respectively (for species groups see Table 8.2.2). The open mire vegetation has been further subdivided according to the hummock - mud bottom gradient (for species groups see table 8.2.3). The mire vegetation has in this way been divided into 22 separate units. The vegetation of the springs has yielded a further 3 units.

The above-mentioned mire vegetation units are easily related to local ecological differences on the mires, cf. e.g. Sjörs (1948, 1983), Malmer (1973, 1985).

	Ombrotrophic vegetation	Minerotrophic vegetation (fen)			
		Poor fen	Inter-mediate fen	Moderately rich fen	Extremely rich fen
Mire margin (Tree/shrub-covered mire)	Bog				
	E	K	P	T	X
Mire expanse					
Hummock	A	F	(F)	(F)	-
Lawn	B	G	L	Q	V
(Open mire) Carpet	C	H	M	R	W
Mud bottom	D	I		S	
Magnocaricetum fen		Ø		A	
Spring vegetation		Y	Z	Æ	

- |   |   |
|---|---|
| A. Open bogs, hummock                     | P. Wooded or scrub-covered intermediate fens    |
| B. Open bogs, lawn                        | Q. Open moderately rich fens, lawn              |
| C. Open bogs, carpet                      | R. Open moderately rich fens, carpet            |
| D. Open bogs, mud bottom                  | S. Open moderately rich fens, mud bottom        |
| E. Wooded bogs                            | T. Wooded or scrub-covered moderately rich fens |
| F. Open fens, hummock                     | V. Open extremely rich fens, lawn               |
| G. Open poor fens, lawn                   | W. Open extr. rich fens, carpet & mud bottom    |
| H. Open poor fens, carpet                 | X. Wooded or scrub-covered extr. rich fens      |
| I. Open poor fens, mud bottom             | Y. Poor spring                                  |
| K. Wooded or scrub-covered poor fens      | Z. Intermediate spring                          |
| L. Open intermediate fens, lawn           | Æ. Rich spring                                  |
| M. Open interm. fens, carpet & mud bottom | Ø. Poor <i>Magnocariceta</i> fen                |
|   | A. Rich <i>Magnocariceta</i> fen                |

Figure 8.2.1 Vegetational units used in the surveys made in connection with the Norwegian national plan for mire nature reserves.

Table 8.2.1 Schematic representation of the occurrences of the main plant species of the boreal mire vegetation of Central Norway, arranged according to the bog-poor fen-rich fen vegetational gradient.

Species group	Ombrotroph. vegetat.	Minerotrophic vegetation			
		Poor	Intermed.	Mod. rich	Extr. rich
1			-----		
2				-----	
3					
4					
5					
6					
7					
8			-----		
9					
10					

\_\_\_\_\_ : Common occurrence  
 ----- : Rare or scattered  
 No symbol : Species absent or casual

#### Species groups

1. *Melampyrum pratense*, *Rubus chamaemorus*, *Calliergon stramineum*, *Cephalozia* spp., *Cladopodiella fluitans*, *Dicranum affine*, *D. leioneuron*, *Drepanocladus fluitans*, *Gymnocolea inflata*, *Mylia* spp., *Sphagnum balticum*, *S. capillifolium*, *S. compactum*, *S. cuspidatum*, *S. girgensohnii*, *S. lindbergii*, *S. magellanicum*, *S. majus*, *S. rubellum*, *S. russowii*, *S. tenellum*.
2. *Carex pauciflora*, *Eriophorum vaginatum*, *Rhynchospora alba*, *Scheuchzeria palustris*, *Vaccinium* spp., *Aulacomnium palustre*, *Sphagnum flexuosum* s.lat., *S. imbricatum*, *S. papillosum*, *S. pulchrum*.
3. *Andromeda polifolia*, *Carex limosa*, *Drosera anglica*, *D. rotundifolia*, *Erica tetralix*, *Huperzia selago*, *Myrica gale*, *Narthecium ossifragum*, *Oxycoccus* spp., *Scirpus cespitosus*.
4. *Carex canescens*, *C. echinata*, *C. magellanica*, *C. rotundata*, *Cornus suecica*, *Juncus filiformis*, *Trientalis europea*, *Sphagnum angermanicum*, *S. annulatum* s.lat., *S. centrale*, *S. molle*, *S. riparium*.
5. *Carex lasiocarpa*, *C. nigra*, *C. panicea*, *C. rostrata*, *Equisetum fluviatile*, *Eriophorum angustifolium*, *Menyanthes trifoliata*, *Molinia caerulea*, *Potentilla erecta*, *Odontoschisma elongatum*.
6. *Carex livida*, *Viola palustris*, *Calliergon sarmentosum*, *Cinclidium subrotundum*, *Dicranum bonjeanii*, *Drepanocladus exannulatus*, *D. tundrae*, *Sphagnum platyphyllum*, *S. subfulvum*, *S. subnitens*, *S. subsecundum* s.lat., *S. teres*.
7. *Carex chordorrhiza*, *C. dioica*, *C. tumidicarpa*, *Equisetum palustre*, *Euphrasia frigida*, *Hammarbya paludosa*, *Juncus stygius*, *Pedicularis palustris*, *Pinguicula vulgaris*, *Rhynchospora fusca*, *Scirpus hudsonianus*, *Selaginella selaginoides*, *Succisa pratensis*, *Utricularia* spp., *Aneura pinguis*, *Drepanocladus badius*, *Paludella squarrosa*, *Sphagnum contortum*, *S. warnstorffii*.
8. *Parnassia palustris*, *Saussurea alpina*, *Tofieldia pusilla*, *Campylium stellatum*, *Drepanocladus revolvens*, *Homalothecium nitens*, *Lophozia borealis*, *Plagiomnium ellipticum*, *Scorpidium scorpioides*.
9. *Bartsia alpina*, *Carex appropinquata*, *C. buxbaumii*, *C. flava*, *C. heleonastes*, *C. pulicaris*, *C. saxatilis*, *Crepis paludosa*, *Dactylorhiza incarnata*, *Eleocharis quinqueflora*, *Eriophorum latifolium*, *Pedicularis oederi*, *Thalictrum alpinum*, *Triglochin palustris*, *Bryum pseudotriquetrum*, *Calliergon giganteum*, *C. richardsonii*, *C. trifarium*, *Calliergonella cuspidata*, *Cinclidium stygium*, *Meesia triquetra*, *M. uliginosa*, *Plagiomnium elatum*, *Rhizomnium magnifolium*, *R. pseudopunctatum*.
10. *Carex atrofusca*, *C. capillaris*, *C. capitata*, *C. hostiana*, *C. lepidocarpa*, *C. microglochin*, *Dactylorhiza cruenta*, *D. pseudocordigera*, *Juncus castaneus*, *J. triglumis*, *Gymnadenia conopsea*, *Kobresia simpliciuscula*, *Listera ovata*, *Salix myrsinites*, *Saxifraga aizoides*, *Schoenus ferrugineus*, *Catoscopium nigrum*, *Cratoneuron* spp., *Ctenidium molluscum*, *Fissidens adianthoides*, *F. osmundoides*, *Lophozia rutheana*.

Table 8.2.2 Schematic representation of the occurrences of the main plant species of the boreal mire vegetation of Central Norway, arranged according to the mire expanse-mire margin vegetational gradient. Only a few of the mire margin species are listed in species group 5.

Species group	Mire expanse	Mire margin	
1			_____ : Common occurrence
2		-----	----- : Rare or scattered
3			
4	-----		No symbol : Species absent or casual
5			

#### Species groups

1. *Carex limosa*, *C. livida*, *C. rariflora*, *Drosera anglica*, *D. intermedia*, *Hammarbya paludosa*, *Juncus stygius*, *Pinguicula villosa*, *Rhynchospora alba*, *R. fusca*, *Scheuchzeria palustris*, *Schoenus ferrugineus*, *Calliergon trifarium*, *Cladopodiella fluitans*, *Drepanocladus fluitans*, *Gymnocolea inflata*, *Sphagnum balticum*, *S. cuspidatum*, *S. lindbergii*, *S. majus*, *S. subfulvum*.
2. *Carex chordorrhiza*, *C. pauciflora*, *Dactylorhiza incarnata*, *Drosera rotundifolia*, *Calliergon stramineum*, *Cinclidium stygium*, *Dicranum affine*, *Drepanocladus badius*, *D. revolvens*, *Lophozia borealis*, *L. rutheana*, *Scorpidium scorpioides*, *Sphagnum annulatum* s.lat., *S. fuscum*, *S. magellanicum*, *S. pulchrum*, *S. rubellum*, *S. subnitens*.
3. *Andromeda polifolia*, *Bartsia alpina*, *Betula nana*, *Calluna vulgaris*, *Carex atrofusca*, *C. dioica*, *C. hostiana*, *C. lasiocarpa*, *C. lepidocarpa*, *C. panicea*, *C. rostrata*, *C. tumidicarpa*, *Dactylorhiza cruenta*, *D. pseudocordigera*, *Eleocharis quinqueflora*, *Empetrum* spp., *Equisetum fluviale*, *Erica tetralix*, *Eriophorum angustifolium*, *E. latifolium*, *E. vaginatum*, *Menyanthes trifoliata*, *Myrica gale*, *Molinia caerulea*, *Narthecium ossifragum*, *Oxycoccus* spp., *Parnassia palustris*, *Pedicularis palustris*, *Pinguicula vulgaris*, *Rubus chamaemorus*, *Scirpus cespitosus*, *S. hudsonianus*, *Selaginella selaginoides*, *Thalictrum alpinum*, *Tofieldia pusilla*, *Aneura pinguis*, *Campylium stellatum*, *Dicranum bonjeanii*, *Homalothecium nitens*, *Sphagnum compactum*, *S. contortum*, *S. papillosum*, *S. platyphyllum*, *S. subsecundum* s. lat., *S. tenellum*, *S. teres*, *S. warnstorffii*.
4. *Carex buxbaumii*, *C. canescens*, *C. echinata*, *C. flava*, *C. nigra*, *C. pulicaris*, *Dactylorhiza maculata*, *Equisetum palustre*, *Gymnadenia conopsea*, *Juniperus communis*, *Pedicularis oederi*, *Pinus sylvestris*, *Potentilla erecta*, *Succisa pratensis*, *Trientalis europaea*, *Viola epipsila*, *V. palustris*, *Vaccinium* spp., *Aulacomnium palustre*, *Calliergon giganteum*, *C. richardsonii*, *C. sarmentosum*, *Drepanocladus exannulatus*, *Sphagnum angermanicum*, *S. capillifolium*, *S. flexuosum* s.lat., *S. molle*, *S. riparium*, *S. russowii*.
5. *Agrostis canina*, *A. capillaris*, *Alnus* spp., *Betula pubescens*, *Calamagrostis purpurea*, *Carex capillaris*, *C. magellanica*, *C. stenolepis*, *C. vaginata*, *Cornus suecica*, *Crepis paludosa*, *Deschampsia cespitosa*, *Equisetum sylvaticum*, *Filipendula ulmaria*, *Galium boreale*, *G. palustre*, *Juncus filiformis*, *Melampyrum pratense*, *Picea abies*, *Polygonum viviparum*, *Ranunculus acris*, *Salix* spp., *Saussurea alpina*, *Calliergonella cuspidata*, *Cratoneuron* spp., *Philonotis* spp., *Plagiomnium* spp., *Sphagnum centrale*, *S. palustre*, *S. strictum*.

**Table 8.2.3** Schematic representation of the occurrences of the main plant species of the boreal mire vegetation of Central Norway, arranged according to the hummock-mud bottom vegetational gradient. Only a few of the mire margin species are listed in species group 4.

Species group	Hummock	Lawn	Carpet	Mud bottom
1				
2				
3				
4				
5				
6				
7				
8				

\_\_\_\_\_ : Common occurrence  
 - - - - - : Rare or scattered  
 No symbol : Species absent or casual

#### Species groups

1. *Calluna vulgaris*, *Empetrum* spp., *Pinguicula villosa*, *Pinus sylvestris*, *Vaccinium* spp., *Dicranum affine*, *Pleurozium schreberi*, *Racomitrium lanuginosum*, *Sphagnum capillifolium*, *S. fuscum*, *S. russowii*, *Cladina arbuscula* coll., *C. rangiferina*, *C. stellaris*.
2. *Betula nana*, *Melampyrum pratense*, *Rubus chamaemorus*, *Aulacomnium palustre*, *Dicranum bonjeanii*, *Homalothecium nitens*, *Mylia* spp., *Ptilidium ciliare*, *Sphagnum subfulvum*, *S. warnstorffii*.
3. *Andromeda polifolia*, *Drosera rotundifolia*, *Erica teralix*, *Eriophorum vaginatum*, *Oxycoccus* spp., *Dicranum leioneuron*, *Sphagnum magellanicum*, *S. papillosum*, *S. rubellum*.
4. *Bartsia alpina*, *Carex canescens*, *C. capillaris*, *C. echinata*, *C. flava*, *Dactylorhiza pseudocordigera*, *Kobresia simpliciuscula*, *Listera ovata*, *Molinia caerulea*, *Narthecium ossifragum*, *Schoenus ferrugineus*, *Saussurea alpina*, *Succisa pratensis*, *Thalictrum alpinum*, *Tofieldia pusilla*, *Drepanocladus badius*, *Fissidens adianthoides*, *F. osmundoides*.
5. *Carex atrofusca*, *C. dioica*, *C. hostiana*, *C. lepidocarpa*, *C. nigra*, *C. panicea*, *C. pauciflora*, *C. tumidicarpa*, *Dactylorhiza cruenta*, *D. incarnata*, *Eriophorum latifolium*, *Euphrasia frigida*, *Myrica gale*, *Parnassia palustris*, *Pinguicula vulgaris*, *Scirpus cespitosus*, *S. hudsonianus*, *Selaginella selaginoides*, *Campylium stellatum*, *Lophozia borealis*, *L. rutheana*, *Sphagnum contortum*, *S. papillosum*, *S. platyphyllum*, *S. subnitens*, *S. subsecundum* s.lat., *S. teres*.
6. *Carex lasiocarpa*, *C. rostrata*, *C. saxatilis*, *Drosera anglica*, *Eleocharis quinqueflora*, *Equisetum palustre*, *Eriophorum angustifolium*, *Menyanthes trifoliata*, *Pedicularis palustris*, *Phragmites australis*, *Triglochin palustre*, *Aneura pinguis*, *Cladopodiella fluitans*, *Drepanocladus revolvens*, *Sphagnum balticum*, *S. compactum*, *S. pulchrum*, *S. tenellum*.
7. *Carex chordorrhiza*, *C. limosa*, *C. heleonastes*, *Hammarbya paludosa*, *Rhynchospora alba*, *Scheuchzeria palustris*, *Utricularia* spp., *Calliergon giganteum*, *C. richardsonii*, *C. sarmentosum*, *C. trifarium*, *Cinclidium stygium*, *Cladopodiella fluitans*, *Drepanocladus exannulatus*, *D. fluitans*, *Gymnocolea inflata*, *Scorpidium scorpioides*, *Sphagnum annulatum* s.lat., *S. cuspidatum*, *S. lindbergii*, *S. majus*, *S. riparium*.
8. *Carex livida*, *Juncus stygius*, *J. triglumis*, *Lycopodiella inundata*, *Rhynchospora fusca*, *Utricularia intermedia*, *Fossombronina foveolata*, *Siphula ceratites*.

### 8.2.2 The Central European approach to the classification of mire vegetation: Dierssen's (1982) system

Tüxen (e.g. 1937, 1974) and Braun-Blanquet (e.g. 1964) have both described methods for investigating, and provided surveys of, the plant communities of Central Europe in a series of publications. A number of textbooks and surveys have subsequently been published that include descriptions of the hierarchical classification systems adopted; these include Oberdorfer (1977, 1983), Wilmanns (1978) and Runge (1980). All these systems are similar in their broad outlines and all the authors stress the point that the number of individual units recognised must not be too numerous (cf. the comments made by Kielland-Lund 1981: 70). This Central European classification system, primarily the German one, has also been used in Norway (cf. Kielland-Lund 1981, Vevle 1983, 1986). Further description of and comments on the classification systems for heathland and grassland vegetation will be given in section 11.

In accordance with the Tüxen tradition, Dierssen (1982) classified the plant communities of the mires of northwestern Europe into broad-based associations and alliances. Table 8.2.4 provides a survey of the "pure" mire communities (those omitted are communities belonging to the classes *Littorelletea* and *Phragmitetea*), together with short commentaries concerning the breadth of the association concepts.

The association is the basic unit used in this classification system. The majority of the 33 associations described (in addition there are 9 communities (Gesellschaften) which are described in the same way as the associations, but for which the sparsity of the material available did not justify the recognition of further units of association status) are defined in a traditional manner according to their characteristic and differential species.

Dierssen's associations are characterised by species that possess broad ecological amplitudes, and they often comprise communities covering the entire gradient from poor to rich. One and the same association may also show a wide range along the mud bottom - hummock gradient. The *Caricetum lasiocarpae* within the *Caricion lasiocarpae*, for example, ranges from poor fen communities (pH 4.2) to rich fen communities (pH of nearly 7.0), with *Carex lasiocarpa* representing the sole characteristic species!. An even wider range along the poor-rich gradient is exhibited by many others of his associations, e.g. the *Caricetum rostratae* and *Caricetum rariflorae* (both members of the *Caricion lasiocarpae*) range from the extremely poor fen community (pH 3.5) to the extremely rich fen (pH above 7.0)!. The associations *Caricetum limosae* and *Sphagno tenellii-Rhynchosporietum albae*, both within the *Rhynchosporion albae* alliance (cf. also Dierssen & Reichelt 1988) also range from the poorest types of mires (i.e. ombrotrophic communities with a pH below 3.5) to intermediate (and rich) types (the former association with a pH of up to and above 6.0).



Table 8.2.4 The mire classification system of Dierssen (1982), comprising two classes, five orders, eight alliances and (in Norway) 33 associations of open, "pure" mire communities.

- Cl.: *Oxycocco-Sphagnetea*  
 Ord.: *Sphagnetalia magellanici*  
 All.: *Oxycocco-Empetrion hermaphroditi*  
 3 associations, mainly the vegetation of hummocks, but also including some lawn communities (*Trichophoro-Sphagnetum compacti*).  
 Ord.: *Erico-Sphagnetalia*  
 All.: *Oxycocco-Ericion*  
 2 associations, mainly the hummock-lawn vegetation of ombrotrophic mires and poor fens in oceanic areas.  
 All.: *Ericion tetralicis*  
 1 association, oceanic mire communities, often transitional to heathland vegetation.
- Cl.: *Scheuchzerio-Caricetea nigrae*  
 Ord.: *Scheuchzerietalia palustris*  
 All.: *Rhynchosporion albae*  
 3 associations of the carpets and mud bottom vegetation of ombrotrophic-rich fens.  
 All.: *Caricion lasiocarpae*  
 7 associations of fen vegetation, mainly comprising tall sedge communities.  
 Ord.: *Caricetalia nigrae*  
 All.: *Caricion nigrae*  
 5 associations of fen vegetation.  
 Ord.: *Caricetalia davallianae*  
 All.: *Caricion davallianae*  
 5 associations of lowland, rich fen vegetation.  
 All.: *Caricion bicolori-atrofuscae*  
 7 associations of upland, rich fen vegetation.

Dierssen most often utilises the subassociation level to separate his mire communities along the poor - rich gradient, or along the other major gradients on mires.

The Central European classification system for mire vegetation is based to a high degree on the vascular plants. Bryophytes, however, are often the best indicator species and their mutual dominance relationships generally reflect the broad differences in the species compositions and habitat conditions of mire vegetation. Mosses and hepatics have been used too little in distinguishing between vegetational units of higher rank in all the classification systems mentioned (cf. also comments in Du Rietz 1949, Rybniček 1985). The presence

or absence of just a few (often only one or two) characteristic species has often been over-stressed in the above-mentioned systems. The entire species assemblage must be utilised for characterising the different units.

Some of the mire ecologists working in Central Europe have been well aware of these points of view, amongst others Rybniček (1974, 1985) and Moravec et al. (1983). For Czechoslovakian mires, Rybniček et al. (1984) have included, within their two broad classes of mires, 4 orders (the 4 first listed units of Dierssen; the *Caricetalia davallianae* has been discarded as a separate order), 13 alliances and 49 associations. The alliances and associations are defined on a basis of the entire species composition of the mire vegetation, as well as on the quantitative representation of the main diagnostic species (cf. Rybniček 1985).

### 8.2.3 A hierarchical classification system for Norway

It has been the tradition in the Nordic countries (e.g. Nordhagen, Du Rietz), when classifying vegetation, to ensure that the basic units (associations) are not too broadly delineated, that the entire species composition is used in defining the units, and that the units reflect clearly the ecological conditions. These principles ensure that the associations do not transgress the major ecological gradients in the vegetation (as has been the case for the associations described by Dierssen 1982). Furthermore, the attempt should be made as far as possible to subdivide the major units in keeping with the major differences noted in the vegetation types. These major principles formed the basis for the description of alpine vegetation given by Nordhagen (1936, 1943), Gjærevoll (1956) and Dahl (1957). Dahl (1987) has subsequently brought this system up-to-date (mainly with regard to the higher-ranking units) of the northern boreal and alpine vegetation of Norway. He has also, to some degree, adapted this system to accord with the Central European system referred to previously.

In an attempt to arrive at the best vegetational units to adopt in mapping the vegetation of Norway, this hierarchical, phytosociological, classification system was used as a basis, so far as possible, cf. Fremstad & Elven (1987). The vegetational units adopted for the mires, worked out in the main by me, are also related to well-defined, phytosociological, classification systems. Table 8.2.5 provides a review of this hierarchical system in regard to the various alliances of the mire and spring vegetation in Norway. An attempt has been made both to define the alliances with due regard to their positions along the main vegetational gradients and to try to keep the system compatible with the ones already accepted for Central Europe and for Norwegian mountain vegetation (Nordhagen 1936, 1943; Dahl 1957, 1987).

The classification system adopted comprises 2 classes, 4 orders and 12 alliances. The associations are not included here and, even though it will probably be found necessary to distinguish more than 40, as done by Dierssen (1982), the number of associations will not necessarily be much in excess of this total,

Table 8.2.5 A hierarchical classification system (Classes - Orders - Alliances) for the vegetation of mires and springs in Norway.

Cl. 1:	<i>Oxycocco-Sphagnetum</i> Br.-Bl. et Tx. 43
Ord. 1.1:	<i>Sphagnetalia magellanici</i> Pawl. 28 em. Moore 68
All. 1.1.1:	<i>Oxycocco-Empetrium hermaphroditum</i> Nordh. 36 Hummock vegetation of the boreal-alpine regions.
All. 1.1.2:	<i>Sphagnion magellanici</i> Kástn. et Flössn. 33 (Includes <i>Oxycocco-Pinetum</i> K.-Lund 81) Mainly a <i>Pinus</i> -dominated bog vegetation.
Ord. 1.2:	<i>Erico-Sphagnetalia</i> Schwick. 40 em. Br.-Bl. 49
All. 1.2.1:	<i>Oxycocco-Ericion tetralicis</i> (Nordh. 36) Tx. 37 em. Moore 68 Hummock vegetation in the coastal section.
All. 1.2.2:	<i>Ericion tetralicis</i> Schwick. 33 Mainly damp (oceanic) heathlands.
Cl. 2:	<i>Scheuchzerio-Caricetum nigrae</i> (Nordh. 36) Tx. 37
Ord. 2.1:	<i>Scheuchzerietalia palustris</i> Nordh. 36
All. 2.1.1:	<i>Leuko-Scheuchzerion palustris</i> Nordh. 43
2.1.1a:	<i>Scirpo-Eriophoremion vaginali</i> Nordh. 43
2.1.1b:	<i>Cuspidato-Scheuchzerion</i> Nordh. 43 Lawn communities (a) and carpets - mud bottoms (b) of ombrotrophic mires and poor fens.
All. 2.1.2:	<i>Stygio-Caricion limosae</i> Nordh. 36 Carpet and mud bottom communities of intermediate - rich fens.
All. 2.1.3:	<i>Caricion lasiocarpae</i> Van den Berghen 49 Tall-sedge, fen communities, including communities transitional to the <i>Magnocaricion</i> .
Ord. 2.2:	<i>Caricetalia nigrae</i> (Koch 26) Nordh. 36
All. 2.2.1:	<i>Caricion canescenti-nigrae</i> Nordh. 36 Mire margin communities of poor - intermediate fens.
All. 2.2.2:	<i>Sphagno-Tomenthypnion</i> Dahl 57 Mainly mire margin communities of intermediate - rich fens, most often forming a zone between the rich fen communities and the hummock vegetation.
All. 2.2.3:	<i>Caricion tumidicarpae</i> Rybníček 64 Lawn communities of intermediate - moderately rich fens.
All. 2.2.4:	<i>Caricion atrofuscae</i> Nordh. 35 Lawn communities of extremely rich fens in the northern boreal - low alpine regions, mainly mire margin vegetation.
All. 2.2.5:	<i>Schoenion ferruginei</i> Nordh. 36 Lawn communities of extremely rich fens in the boreonemoral - middle boreal regions.
Cl.	<i>Montio-Cardaminetum</i> Br.-Bl. et Tx. 43
Ord.:	<i>Montio-Cardaminetalia</i> Pawl. 28
All.:	<i>Cardamino-Montion</i> Br.-Bl. 26 Vegetation of poor - intermediate springs.
All.:	<i>Cratoneurion commutati</i> Koch 28. Vegetation of rich springs.

even if they are defined much more narrowly. This is partly because many of the associations recognised by Dierssen are in fact "parallel" associations (along the poor-rich gradient, as described above).

The two major classes of mire vegetation divide the mires in a similar manner to that found in most phytosociological papers. The class *Oxycocco-Sphagnetum* includes hummock vegetation and tree-covered bogs and poor fens. Dierssen (1982), in addition, included the lawn communities of bogs and poor fens (*Trichophoro-Sphagnetum compacti*) in this class. Traditionally, the class *Oxycocco-Sphagnetum* is split into 2 orders, each of which is in turn divided into 2 alliances.

The class *Scheuchzeria-Caricetum nigrae* includes a wide range of mire communities. Also this class is divided into only 2 orders, the extremely rich lawn communities not being distinguished as a separate order of their own (cf. for example the *Tofieldietalia* of Dahl 1987), which is in keeping with the classification presented by Moravec et al. (1983).

The *Scheuchzeriaetalia palustris* is split into 3 alliances: *Leuko-Scheuchzeria* (with two suballiances), *Stygio-Caricion limosae* and *Caricion lasiocarpae*. Nordhagen has defined the first two alliances, the third includes mainly taller-growing, fen communities, which often form a transition to *Magnocaricetum* (cf. further comments in section 8.4.5).

*Caricetalia nigrae* is here split into 5 alliances: *Caricion canescenti-nigrae*, *Sphagno-Tomenthypnion*, *Caricion tumidicarpae*, *Caricion atrofuscae* and *Schoenion ferruginei*. All these alliances, with the exception of the *Caricion tumidicarpae*, have been defined and discussed by Nordhagen (1935, 1936, 1943) or by Dahl (1957). The *Caricion atrofuscae* (and the *Schoenion ferruginei*) are restricted exclusively to extremely rich fens. Nordhagen (1935) distinguished between a *Caricion atrofuscae* and a *Caricion bicoloris*, as alliances belonging to mires and to mineral soil communities, respectively. Later, however, he amalgamated them (Nordhagen 1936, 1943) to form the *Caricion bicolori-atrofuscae* (= *Caricion atrofuscae-saxatilis*) alliance. This enlarged alliance comprises vegetation found on extremely rich fens, moderately rich fens, rich damp heath, rich grasslands along river and lake margins and streamsides etc. The original subdivision made in 1935 is much to be preferred, however, in order to obtain a more or less homogeneous alliance (with no mineral-soil communities). The *Schoenion ferruginei* is the Nordic equivalent to the *Caricion davallianae* further south (cf. further comments in section 8.4.3).

Dahl (1957) supplemented Nordhagen's classification system by introducing the *Sphagno-Tomenthypnion* alliance for the primarily moderately rich fen communities of mire margins. The mire system of Nordhagen-Dahl lacks a natural unit for the intermediate to moderately rich fen communities of the mire expanse vegetation (cf. also Sjörs 1948: 60; Persson 1961: 129). Nordhagen (1943) and Dahl (1957) have differing conceptions of the *Caricion canescenti-nigrae* alliance in so far as communities situated along the poor - rich gradient are

		Ombrotrophic vegetation	Minerotrophic vegetation (fen)				
		Bog	Poor fen	Intermediate fen	Moderately rich fen	Extremely rich fen	
Mire margin							
(Tree/shrub-covered mire)		Sphagnion magellanicum (Oxycocco Pinetum)	Caricion canescenti - nigrae		Sphagno-Tomenthypnion	Caricion atrofuscae	Mire margin
Mire expanse	Hummock	Oxycocco-Empetrium / Oxycocco-Ericion					
	Lawn			Caricion tumidicarpae		Schoenion ferruginei	Lawn
(Open mire)	Carpet	Leuko-Scheuchzerion		Stygio - Caricion limosae			Carpet
	Mud bottom						Mud bottom
Magnocaricetum fen		Caricion lasiocarpae					
Spring vegetation		Cardamino-Montion			Cratoneurion commutati		

Fig. 8.2.2 The main mire and spring alliances in Norway, schematically grouped along the three main vegetational gradients, found on mires.

concerned, cf. Dahl (1957: 213). He states: "To Nordhagen the absence of calcicolous indicators is the most important criterion separating the alliance from the *Caricion bicoloris-atrofuscae*. To me the presence of indicator species of oxygen-rich surface water such as *Calliergon stramineum* and *sarmentosum* and *Drepanocladus exannulatus*, are more important."

It is illogical, on Nordhagen's criteria, to place the *Carex goodenowii-Drepanocladus intermedius* sociation within the *Caricion canescenti-nigrae* alliance, when the *Scirpus cespitosus-Drepanocladus badius-Calliergon sarmentosum* sociation is placed in the *Caricion bicoloris-atrofuscae* alliance (Nordhagen 1943: 480). A whole series of plant communities have been described which it is difficult to know where to place, (e.g. the *Scirpus-Molinia* community from Sylane, Nordhagen 1928: 459), and the *Caricion tumidicarpae* fills the gap between the *Caricion canescenti-nigrae* alliance and the extremely rich fen alliances. It was for precisely this reason that Rybníček (1964) proposed the *Caricion tumidicarpae* alliance, which comprises the intermediate to moderately rich fen communities, primarily of the mire expanse, mentioned above and including such typical species as: *Carex tumidicarpa*, *Scirpus hudsonianus*, *Calliergon sarmentosum*, *Campylium stellatum*, *Dicranum bonjeanii*, *Drepanocladus badius*, *D. exannulatus*, *D. revolvens*, *Sphagnum subfulvum*, *S. subnitens*, *S. subsecunda* and *S. teres*. The *Caricion tumidicarpae* alliance includes, for example, the associations *Sarmentosetum* and *Subfulvetum* of Fransson (1972).

Table 8.2.5 and figure 8.2.2 also show the communities of springs arranged as a simple system of two alliances. A synsystematic survey of the spring vegetation has been dealt with in section 7.2.3.

Neither some plant communities of tree-covered mires and scrub (belonging to the *Vaccinio-Piceetea*, *Alnetea glutinosa* and *Betulo-Adenostyletea* classes), nor communities transitional between mires and heaths, meadows, lake and river



margins (such as those belonging to the *Molinio-Arrhenatheretea*, *Nardo-Callunetea* or *Phragmitetea* classes) are included in figure 8.2.2 and table 8.2.5.

### 8.3 COMMENTS ON THE FENNOSCANDIAN LITERATURE

Table 8.3.1 provides survey of the vegetational types at Sølendet in relation to the different classification systems.

#### 8.3.1 Norwegian publications

##### 8.3.1.1 Older literature, the Holmsen-Løddesøl classification system

Hanna Resvoll-Holmsen (1914, 1920) was the first to publish full phytosociological analyses of Norwegian upland mire vegetation. She used the quantitative methods of Raunkiaer. In her two publications, she provided 15 different analyses of rich fen and spring vegetation from upland areas south of Røros (only 8 of the analyses included bryophytes). Some of the analyses would seem to represent heterogeneous stands, (e.g. typical grassland species like *Festuca rubra* occur in typical fen communities!). In addition, the difference in the analysis methods used make close comparisons with the Sølendet types difficult. However, Resvoll-Holmsen's analyses well exemplify the extremely rich fen vegetation of the Cambro-Silurian areas. Most of the samples represent lawn communities of marginal type, i.e. they resemble that of cluster M6 from Sølendet. A *Scorpidium scorpioides*-dominated vegetation (resembling that of cluster M2 from Sølendet) is also listed in Resvoll-Holmsen (1920 Table 21 no. 1).

Hanna Resvoll-Holmsen's work on mire vegetation was important because it formed the phytosociological basis for Gunnar Holmsen's (1923) classification system for the mire vegetation of Norway. However, this system was essentially physiognomic. Holmsen (1923) separated out five main types and a number of subtypes. The main types were (Norw. and German names after Holmsen op.cit.: Mosemyr (Moosmoor), Grasmyr (Grasmoor), Lyngmyr (Zwergstrauchmoor), Krattmyr (Gebüschmoor), Skogmyr (Waldmoor). Holmsen's system was later further elaborated, first and foremost by Aasulv Løddesøl (cf. 1948, 1969). The Holmsen-Løddesøl system was the main classification system used for the mire inventory surveys carried out by the Norwegian Bog Association, including hundreds of publications and reports. Stress was placed on the use of the vegetation types and the mire species as indicators of the ecological conditions, cf. Løddesøl & Lid (1943, 1950). This Norwegian classification system had certain features in common with other European systems of that period, e.g. the Finnish system of Cajander (cf. section 8.3.3). However, the Norwegian system did not separate any mire units along the rich-poor vegetational gradient. The Finnish system used "Braunmoore" as a main unit. Holmsen (1923: 44), however, pointed out that in Norway there was no need for such a unit!. The "Grasmyr" unit thus included both the poorest and the richest types of vegetation, the only criteria

Table 8.3.1 Survey of the types of mire and spring vegetation at Seländet (clusters M1-18 described in section 5) compared with some of the classification systems and vegetational units/types described in the literature. Units shown in parenthesis are of questionable validity; some clusters (e.g. the transitional type M8) has been difficult to classify in most of the columns. Dotted lines between units indicate gradual changes. Key to vegetational units listed in column 3: A = Bog hummock; T = Wooded or scrub-covered moderately rich fen; V = Extremely rich lawn; W = Extr. rich carpet and mud bottom; X = Wooded or scrub-covered extr. rich fen; Å = Rich spring; Å = Rich Magnocariceta fen.

1. Main types (cf. content of sections 5.4, 8.4, 12.3)	2. Vegetat. types (clusters M1-18) of section 5. Clusters (a-o) of sect. 6 shown in parenthesis.	3. Veget. units of sect. 8.2.1	4. Alliances of the present phytosociolog. system (sect. 8.2.3)	5. Alliances and associ- ations of Nordhagen (1943)	6. Associations of Du Rietz (1949), Fransson (1963, 1972)	7. Vegetation/ Association of Persson (1961)	8. Units used in the Finnish mire site system, cf. Ruuhijärvi (1960), Euroala et al. (1984)	9. "Siedlungsgr." of Havas (1961)
Rich fen Scorp. comm.	M1 C rostrata- Scorp scorp (a) M2 Eleocho qui- Scorp-Drep rev (b)	W W	Stygio- Caricion limosae	Stygio- Caricion limosae	Scorpidietum Drepanocladetum	Scorpidium vegetation/ association	Scorpidium- Rimpbraunmoore, Drep. rev.- Rimpbraunmoore	(Siedlungen des Rimpiorizonts)
Rich fen Campyllum community	M3 C lasio-Camp ste-Drep rev (f) M4 C las-Pot ere- Camp ste (g) M5 Scirp ces-C host-Camp ste (h) M6 Molinia-Succ- Camp ste (i+j) M7 Molinia-Kobr- Camp ste (k+l)	V V V V(-X) V(-X)	Caricion atrofuscae	Caricion atrofuscae- saxatilis Scirpetum caespit- tosi-trichophori subarcticum Caricetum flavae subarcticum Caricetum atrofi- vaginatae (Salicetum myrs- cericetosum)	Campylietum Tomentypnetum	(Carex saxa- Drep.interm. ass.) Carex panicea ass. (Carex atro- fusca ass.) Carex dioica- Tomentypnum ass. (trans. to Sph. warnst.-parvif. veg./ass.) (Carex saxatilis- Drep. int. ass.)	Campyllum stellatum- Braunmoore Sphagnum warnstorffii- Braunmoore Braunmoor s.lat. (Sumpfbraunmoore/ Birkenbraun- moore)	Carex flava- Trichophorum- Campyllum stell- Siedlungsgruppe Carex flava- Filipendula ulm- Campyllum stell- Siedlungsgruppe
Rich fen Sph. warnst. community	M8 Bet nana- Molin-Camp ste (m) M9 Sauss-C vagr- Sph warnst (n) M10 C rostrata- Sph warnst (o)	X X(-T) X(-T)	Sphagno- Tomenthypnion	Saliceto-Caric. inflatae- canescentis	Drepanocladetum	Filipendula- Mnium veg./ass.	Braunmoorbrücker Hainbrücker/ Weidenbrücker	Carex magell- Filip. ulm.- Sph. warnst.- Siedlungsgruppe
Rich fen Cinclidium- Meesia comm.	M11 Menyanth- C heleon-Cincl (c) M12 C heleon-Drep rev-Meesia (d) M13 Salix-Equi- pal-Drep rev	W(-Å) W(-Å) W-X	Caricion lasiocarpae	(Drepanoclado- Caricetum infl- canescentis/ associations of Caricion atrofi- saxatilis all.)	(Tomentypnetum)			
Rich fen Salix comm.	M14 Salix-Filip- Plag ellipt M15 Salix-Caltha- Pellia	X(-T) X(-T)	(Sphagno- Tomenthypnion) (Lactucion alpinae)	(Saliceto-Caric. inflatae- canescentis)				
Rich spring Cratoneuron comm.	M16 Saxifr aiz- Cratoneuron M17 Epilob als- Cratoneuron	Å Å	Cratoneuron commutati	Cratoneureto- Saxifragion aizoidis		Cratoneuron veg./ ass.	Eutrophe Quellvegetation	
Bog hummock	M18 Bet nana - Sph fuscum	Å	Oxycocco- Empetrium	Oxycocco-Empetrium	Fuscetum	Rubus chamaem.- Sph. fusc. veg./ ass.	Sphagnum fuscum Reisemoore	

being the dominant occurrence of graminoids. The classification system of Holmsen-Løddesøl was never ecologically updated, e.g. to separate ombrotrophic and minerotrophic types, or to separate units along the main vegetational gradients (e.g. Sjörs 1948). It therefore proved unusable in subsequent phytosociological, ecological or regional studies of mire vegetation in Norway.

The mire vegetation of Sølendet belongs to the following types: "Grasmyr" covers most of the area, and the subtypes "Starrmyr" (i.e. *Carex* fen) and "Ren grasmyr" (i.e. Grass fen s.str.) occur. In addition, some fen areas could be classified as the "Krattmyr" main type, including both the subtypes of "Dverg-bjørkkattmyr" (i.e. *Betula nana* type) and "Vierkrattmyr" (i.e. *Salix* type). The *Sphagnum fuscum*-vegetation (i.e. that of cluster M18) could be classified as the "Lyngrik kvitmosemyr" (i.e. dwarf-shrub *Sphagnum*) subtype of the "Mosemyr" main type.

Mork & Heiberg (1937), in their study of the vegetation of Hirkjølen in Opland county, included analyses of four fen types, though only in the form of synoptic tables, including species frequency and main degree of cover. The "sociations" of Mork & Heiberg (1937) are again heterogeneous units (as compared to my mire clusters), which makes direct comparison with the vegetation at Sølendet difficult. However, their *Geranium-Geum-Carex vaginata-Picea-Betula* sociation represents a transitional community between rich fen margin and damp grassland vegetation, i.e. with some resemblance to my clusters M14-15. The *Cyperaceae-Amblystegiaceae* sociations (nos. 15 and 18) represent rich fen margin communities dominated by *Campylium stellatum*, that resemble clusters M6-7.

Nordhagen's (1928, 1935, 1936, 1943) and Dahl's (1957, 1987) studies and proposed systems for the classification of mire vegetation have been described in the previous section; table 8.3.1 provides a comparison of Nordhagen's (1943) units with the Sølendet clusters (cf. also section 2.2.1).

Lid (1959) published some phytosociological analyses of extremely rich fen vegetation from Hardangervidda, but without a complete list of the bryophytes present.

#### 8.3.1.2 Recent studies of upland mires

More recent studies made of the rich fen vegetation of Central Norway, together with studies of the hay fens of Fennoscandia, have been summarized in section 2.3. Phytosociological analyses of mire vegetation of the upper boreal region of Central Norway can be found in a number of (unpublished) cand. real. theses, e.g. those of Gaare (1963), Moen (1970), Flatberg (1970, mainly southern boreal vegetation), Klock (1974), Singsaas (1981) and Selnes (1982). Some phytosociological analyses from these theses have been published. Moen (1969, 1976b, 1985b) and Frisvoll & Moen (1980) which included quadrat analyses (frequency values and characteristic degrees of cover) for some of the communities of Nordmarka, an area in the upper part of the middle boreal and the lower

part of northern boreal regions. Moen (1976b) gave the most complete account, including full species lists for 11 fen communities (representing 42 stands and 183 small quadrats), together with pH values for the fen water and details of the field layer production (made both by scything and by cutting with scissors) for each of the 11 communities. Klokke (1982) included analyses of 36 mire communities at Klæbu, representing 85 mire stands (altogether 367 small quadrats). The vegetation ranges from ombrotrophic to extremely rich, and the area covers both the southern and middle boreal regions. Both Moen and Klokke arranged/classified the communities according to the three main vegetational gradients. Selnes (1981) included phytosociological analyses of more than 200 quadrats, which, by using the TABORD program, separated into 14 clusters, mainly of ombrotrophic and poor fen vegetation, with one moderately rich fen cluster. Singaas (1989) recently published phytosociological analyses from Stormyra, Tynset; a middle boreal, flat fen, dominated by rich vegetation. Singaas used the TABORD classification and the DCA-ordination (the same methods as those described in the present monograph). Most of the seven clusters described represent communities rather different from the Sølendet vegetation, the closest relationships are with the *Scorpidium* types.

Vorren (1979a) described the ombrotrophic-poor fen vegetation of a northern boreal palsa mire in Finnmark; the vegetation was classified according to Nordhagen's (1936, 1943) system; Vorren (1979b) also described the types of mire vegetation found in Namdalen. These included some analyses from the upper boreal region, classified according to the Finnish system.

Galten (1987) carried out a numerical analysis of the mire vegetation of Åsenmyra, in Hedmark county, an ombro-minerotrophic mire situated on the border between the middle and northern boreal regions. A regularly-spaced sampling technique was used, with 4 vegetational blocks; 9 sub-blocks and 20 groups were defined. Galten related these units to the different classification systems in use in Fennoscandia. 4 sub-blocks (including 6 groups) represent rich fen vegetation, but none of the units included extremely rich fen vegetation. The closest relationships with the Sølendet types are with the *Scorpidium* and the *Sphagnum warnstorffii* types.

### 8.3.2 Swedish publications

There are three classical Swedish works which describe the upland northern mires: Melin (1917) who mainly studied the upland mires in Ångermanland; Malmström (1923), who studied the mire vegetation and habitat conditions of Degerö Stormyr in Västerbotten (dominated by ombrotrophic and poor fen vegetation); and Booberg (1930), who published a monograph on the mire vegetation of Gisselåsmýren, an extremely rich fen in Jämtland and situated ca. 200 km ENE of Sølendet (further comments below).

The analysis methods and terminology used in all three monographs were those of the Uppsala School, dating from the first half of the present century (described by e.g. Trass & Malmer 1973).



A new mire classification terminology was developed by Sjörs (1948, 1950) and Du Rietz (1949, 1954), in which the vegetational units were defined and arranged according to the variation present in the vegetation, i.e. the vegetational units (usually defined separately for each study area) were related to the environmental gradients. This system was developed further by several workers, e.g. Persson (1961) and Malmer (1962, 1973). Fransson (1963, 1972) further evaluated the classification system proposed by Du Rietz (1949, 1954), based on the differentiation of distinct units along the vegetational gradients. The relationships of Du Rietz's-Fransson's associations to the Sølendet mire vegetation are set out in table 8.3.1. Malmer (1968) has also suggested a hierarchical phytosociological system based on the three main vegetational gradients. However, his system was based on a study of the mire vegetation in South Sweden, wherefore no further comparisons will be made here.

The studies of hay fens by Jan Elveland and Carin Tyler have been summarized in section 2.3.

A large number of other studies of upland mire vegetation in Sweden have been published; here only the most important ones, those related to the vegetation types at Sølendet, will be mentioned; Sjörs (1983) provides a review of the literature.

Booberg (1930) gave a thorough description of the Gisselåsmýren, and included a large-scale, very detailed, vegetation map and a description of 79 "sociations", the majority of which are of the extremely rich vegetation type. Some of these communities bear resemblance to some of the vegetational types found at Sølendet. However, even though both these extremely rich fen complexes are situated in Cambro-Silurian bedrock areas, there are great differences between them. Gisselåsmýren (ca. 320 m above s.l.) is situated in the lower part of the middle boreal region, and its vegetation includes lowland species/communities, e.g. *Schoenus ferrugineus* lawns, and lacks a number of the upland/alpine species characteristic of the vegetation at Sølendet. Gisselåsmýren is dominated by flat fen synsites. No areas of sloping fen exist. These geographical facts explain the relatively large differences between the vegetation of these two study sites. This is most easily seen when the vegetation maps and the composition of the most common plant communities are compared.

Sjörs (1946) has described the mire and spring vegetation of an upper boreal area of Jämtland, with a rather humid climate, situated close to the border with Norway. The main emphasis was laid on the sloping fens (general inclination of 6-12°, in extreme cases up to 20°) dominated by a poor type of vegetation (including *Narthecium ossifragum*). Seven of the quadrats from his *Carex flava*-*Drepanocladus intermedius*-association represent rich fen vegetation, which bears some resemblance to the vegetation of clusters M3-6 from Sølendet. However, Sjörs's (1946) samples mainly represent moderately rich fen vegetation, as also do the analyses of the rich fen vegetation in the same part of Jämtland published by Fransson (1963). An extremely rich fen vegetation, resembling



that found at Sølendet, does however, cover quite large areas in other parts of Jämtland (e.g. Sjörs et al. 1965, Sjörs 1985), but few phytosociological analyses, other than that of Booberg (1930), have so far been published.

Persson (1961, 1962) described the mire and spring vegetation, and the habitat conditions, of the Torneträsk area, in North Sweden. Stress was laid on the extremely rich, sloping fen vegetation, which resembles the equivalent vegetation at Sølendet (cf. the comparison in Table 8.3.1).

Sonesson (1970a & b) has also studied the mire vegetation of the Torneträsk area, although he concentrated his attention on the poor fen vegetation. He included some analyses of a *Scorpidium* vegetation that resembles that found at Sølendet.

Tyler (e.g. 1979a & b, 1981a) has used multivariate analysis methods, viz. TABORD classification and RA-ordination, in her studies of the *Schoenus*-dominated extremely rich fens from Sweden and all over Fennoscandia.

### 8.3.3 Finnish publications; the mire site types

The main groups of the Finnish mire site types; first proposed by Cajander (1913) and further elaborated by e.g. Kalela (1939) in his monograph on the vegetation of the Rybachi Peninsula, Murmansk, are characterized by the dominant occurrence of certain tree species and by the presence/absence of rich fen species (in Finland called "eutrophic" species). The Finnish mires have been classified as oligotrophic, mesotrophic or eutrophic on a basis of their base status, pH, etc., e.g. Ruuhijärvi (1983). Four main mire site types have been distinguished: the pine mires (German: Reisermoore), the spruce (and birch) mires (Bruchmoore), the treeless oligotrophic and mesotrophic mires (Weissmoore) and the treeless eutrophic mires (Braunmoore).

The initial system was developed for forestry purposes, but it was based on a detailed knowledge of the ecology of mire plants dating from Cajander's time. Over the years, a number of ecological corrections have been made, e.g. by Ruuhijärvi (1960) and by Eurola (1962), who drew attention to the three main vegetational gradients (described by Sjörs 1948). Ruuhijärvi (1960), working in North Finland, subdivided the above-mentioned four main types, into 62 different mire site types. Eurola et al. (1984) listed 68 mire site types in the forest zone of Finland (including four spring types); and even some additional alpine types.

Kalliola (1939), in his monograph on the vegetation of the alpine region in Finnish Lapland, used a hierarchical classification system that resembled that used by Nordhagen (1936, 1943). Kotilainen (e.g. 1927, 1951) has described the occurrences of fen species and communities in relation to data for the pH and nutrient status of the peat and mire water. Lounamaa (1961) has described the rich fen vegetation of E. Karelia (east of present-day Finland).

Tuomikoski (1942) emphasized the multidimensional nature of mire vegetation (= Variationsrichtungen), and thereby initiated the study of vegetational gradients on mires, which was then developed further by Sjörs (1948). The use of multivariate analysis methods in phytosociology, with the aid of computers, has proved a great help in the study of vegetational gradients and in the classification of data from the Finnish mire site types. The analyses of the types present in North Finland (Pakarinen & Ruuhijärvi 1978, Pakarinen 1985) were based on frequency data from 56 site types. A number of ordination and classification techniques were used (e.g. DECORANA and TWINSpan) and the analyses classified the phytosociological structure and species groupings derived from the earlier Finnish mire site system. Some new relationships between the mire site types were discovered, e.g. Pakarinen & Ruuhijärvi (1978) stated that "the dominant tree species has sometimes played too great a role in the Finnish mire type system".

The Finnish mire site type system has been used successfully in vegetational research in Finland, as also in the typification of vegetation for practical purposes, e.g. in forestry, cf. Heikurainen & Pakarinen (1982). Vorren (1979b) has applied the Finnish system to Norway in his classification of the mire vegetation of Namdalen in Central Norway.

Those Finnish mire site types that are most closely related to the types of vegetation found at Sølendet are listed in table 8.3.1. The units (Siedlungsgruppen) recognised by Havas (1961) are tabulated in another column. He used correlation analysis methods to form species groups, which defined the vegetational units of the sloping fens of eastern Finland. Havas related his vegetation units to certain ecological gradients, e.g. in pH and in the mineral content of the groundwater and the peat, the degree of slope, the groundwater level, the O<sub>2</sub> content of the groundwater, etc.

#### 8.4 THE VEGETATIONAL TYPES OF SØLENDET COMPARED WITH THOSE IN THE LITERATURE

##### 8.4.1 Introduction

The hierarchical phytosociological system proposed for Norway in section 8.2 is mainly based on Nordhagen (1935, 1936, 1943). At Sølendet the rich fen vegetation is included in the *Stygio-Caricion limosae* and *Caricion atrofuscae* alliances of Nordhagen, the hummock vegetation belongs to the *Oxycocco-Empeirion*. In addition to these "Nordhagen alliances", some of the fen communities at Sølendet have been assigned to the *Sphagno-Tomenthypnion* alliance of Dahl (1957) and to the *Caricion lasiocarpae* alliance (cf. section 8.4.5). Nordhagen split up each of his alliances into a number of associations; however, these associations are, in the main, quite narrowly defined (viz. on the "conformity system", which resulted in the existence of parallel associations for the open and for the scrub-covered types, cf. Nordhagen 1943: 49).

In the Rondane area, described by Dahl (1957), the most important mire vegetation types found at Sølendet are absent, wherefore Dahl's association scheme is inapplicable to Sølendet.

Dierssen (1982), in general, defined his associations in a wholly different manner (cf. section 8.2.2). The types of mire vegetation found at Sølendet have therefore not been classified into formal associations. Instead, certain parallelisms are shown in table 8.3.1 and comments given in the text for units described by other authors and which bear resemblance to the Sølendet vegetation types.

## 8.4.2 Rich fen, *Scorpidium* communities

### 8.4.2.1 Comments on the clusters

The Sølendet vegetational types dealt with here are described in the account of clusters M1-2 in section 5 (= clusters a-b of section 6). Cluster M1 is a mud bottom community of the *Stygio-Caricion limosae* alliance. Cluster M2 represents a carpet community (one sample is transitional to a lawn) at the "dry" extremity of the alliance. The bottom layer dominant is *Scorpidium scorpioides*; two samples of cluster M2 have *Drepanocladus revolvens* and *Campylium stellatum* as codominants.

Survey of the clusters:

M1 (= a)	<i>C. rostrata</i> - <i>Scorp. scorp.</i> type	2 samples
M2 (= b)	<i>Eleocharis acicularis</i> - <i>Scorp.</i> - <i>Drep. rev.</i> type	3 samples

### 8.4.2.2 *Stygio-Caricion limosae*

The intermediate to extremely rich fen expanse communities of mud bottom and carpet vegetation are included in the *Stygio-Caricion limosae* alliance, described by Nordhagen (1936, 1943). The field layer is either poorly developed or is dominated by low-growing sedge species (Parvocariceta). A list of differential species is shown in table 8.2.1 (species groups 6-10) which serve to differentiate these communities from the poorer types of fen vegetation (= *Leuko-Scheuchzerion*, which is not represented at Sølendet). The species groups 7 & 8 in table 8.2.3 provide a list of the differential species which separate the above from drier plant communities (e.g. *Caricion atrofuscae*). The alliance also includes types that are transitional to fen margin vegetation and to some other tall-sedge communities (*Caricion lasiocarpae*), viz. the species groups no. 1 and, in part, no. 2 in table 8.2.2 list the differential species. The delimitation of the alliance is fully in accord with that made by Nordhagen (1943).

The differentiation of associations within the alliance, however, is rather unsatisfactory at present. The four associations recognised by Nordhagen (1943) are narrowly defined units, based mainly on the field layer dominants. Dahl (1957: 232) included only one association (*Scorpideteo-Caricetum limosae*) in this alliance. In addition some of the samples within his heterogeneous *Drepanocladeetum revolutis* association in the *Caricion bicolori-atrofuscae* alliance, bear many similarities with the *Stygio-Caricion limosae*, and the samples of cluster M2.

Kielland-Lund (1986b), in his preliminary synoptic table of the Northwest-European boreal communities within the *Scheuchzerietalia* order, distinguished three associations within the *Stygio-Caricion limosae* alliance. The greatest similarity of the Sølendet samples is with his *Utricularia intermedia-Carex livida* association, although certain similarities also exist with his *Carex chordorrhiza-Scorpidium*-association.

Several of the associations included by Dierssen (1982) in his *Rhynchosporion albae* and *Caricion lasiocarpae* alliances include both poor fen and rich fen types of vegetation; *Scorpidium* communities that are clearly related to the above-mentioned Sølendet samples can be recognised in a number of his associations, e.g. in his *Caricetum limosae* (subass. of *Scorpidium scorpioides*) and *Caricetum rostratae* (subass. of *Scorpidium scorpioides*).

#### 8.4.2.3 Further comments on the literature

The *Scorpidium*-dominated vegetation of the upland areas in Norway has been described in a number of publications, the first being that of Hanna Resvoll-Holmsen (cf. section 8.3.1.1). Some additional descriptions, including phytosociological analyses for samples resembling those in clusters M1-2 exist for the following areas:

Sylane - the *Scorpidium*-reiche *Carex chordorrhiza*-Ass. (Nordhagen 1928: 399-401).

Nordmarka in Nordmøre - the three *Scorpidium* samf. IV-VI of Moen (1976b: 4-7).

Klæbu, in Sør-Trøndelag - the *Scorpidium scorpioides* community Klokke (1982: 38).

Engerdal, in Hedmark - the *Scorpidium scorpioides* block (Galten 1987).

Stormyra, in Tynset - the *Scorpidium scorpioides* community (Singsaas 1989).

At Gisselåsmyren in Jämtland, Booberg (1930: 74) differentiated between more than ten *Scorpidium* sociations, some of which include some lowland species (e.g. *Carex lepidocarpa*, *Phragmites australis* and *Schoenus ferrugineus*). A number of these flark sociations (flarkarnas sociationer) show a great similarity with the clusters M1 and M2 at Sølendet (e.g. Booberg 1930: Table 61).

The *Scorpidium*-dominated communities were placed by both Du Rietz (1949) and Fransson (1963, 1972) in the *Scorpidietum* association. Cluster M1 certainly belongs to this association, though cluster M2 is transitional to their *Drepanocladetum* association.

Persson (1961) distinguished several variants of his *Scorpidium* association. The two relevant ones are the richest, his *Eleocharis-Triglochin* var. and the poorer *Carex rostrata-limosa* var., both of which bear a resemblance to the Sølendet cluster M1. A number of references to a *Scorpidium*-dominated vegetation in Sweden that appear in older publications are cited in Persson (1961), Sonesson (1970a: 91) and Fransson (1972: 46-47).

The *Scorpidium* communities are also quite common in Finland, e.g. Ruuhijärvi (1960: 116). In the Finnish system these are communities that belong to the rich flark fens (Rimpibraunmoore). The samples forming cluster M1 would be included in the *Scorpidium*-Rimpibraunmoore, those forming cluster M2 are best characterized as falling within the *Drepanocladus revolvens*-Rimpibraunmoore type.

Kalela (1939: 439) has described a number of different types of *Drepanocladus intermedius*-*Scorpidium scorpioides* Braunmoore from the Rybachi Peninsula; some of these communities closely parallel the Sølendet types (e.g. the *Scirpus pauciflorus*-*Scorpidium scorpioides*-*Drepanocladus intermedius* Braunmoore, Kalela 1939: 478). Similar *Scorpidium*-dominated vegetation is quite common in boreal areas all over the world (e.g. Sjörs 1963, who described such communities from the Hudson Bay area in Canada).

#### 8.4.2.4 Synecology

The Sølendet clusters M1-2 comprise mud bottom to carpet types of the (extremely) rich fen vegetation. The groundwater-level lies close to the surface throughout the summer; water samples showed pH values in excess of 7.0 and specific conductivity values of ca. 150; the peat has a pH of ca. 6.5. The communities occur on flat fens, with a peat layer depth of 20-50 cm.

Similar ecological conditions for *Scorpidium* communities elsewhere are reported in the literature. Witting (1949) found pH values above 7.0 for the *Scorpidium* communities of the extremely rich fens in Jämtland and the specific conductivity values were even higher than those found for Sølendet. Persson (1962: Tables 6 & 7) found pH and specific conductivity values higher than the Sølendet ones for his *Eleocharis-Triglochin* var. at Torneträsk (water pH: 7.6;  $K_{20}$ : 236), but the values for his other *Scorpidium* communities were lower.

The pH values for fen water samples from the *Scorpidium* communities at both Nordmarka (e.g. Moen 1976b) and Klæbu (Klokk 1982) were somewhat lower (pH ca. 6.0-6.6) than those recorded from Sølendet.



The general conclusion is that the *Scorpidium* communities belonging to the *Stygio-Caricion limosae* alliance occur on flat fens with a thick peat layer, and with a water pH value close to neutral (ca. 7.0).

### 8.4.3 Rich fen, *Campylium* communities

#### 8.4.3.1 Comments on the clusters

The Sølendet vegetational types dealt with here are those that comprise clusters M3-7 (cf. description in section 5). These communities account for more than a half of all my own mire samples from Sølendet. The great majority of Gaare's samples also belong to the *Campylium* communities, they are included in the clusters f-l (described in section 6; cluster e of that section includes the 10 of Gaare's samples which I regard as representing a mixture of the communities described under sections 8.4.2, 8.4.3 and 8.4.5. No further comments or comparisons will be made here with regard to cluster e).

The samples forming clusters M3-7 (as well as those of clusters f-l) represent a gradual transition, with no sharp boundaries, from fen expanse communities resembling those described in the previous section (= *Scorpidium* communities), to typical lawn communities, and finally to fen margin communities which, in turn, are transitional to damp grassland vegetation (cf. the descriptions in section 5, e.g. Figs 5.2.4-6). However, I have characterized clusters M3-5 (f-h) as representing fen expanse communities, and clusters M6-7 (i-l) as fen margin communities. Cluster M8 (= m) may be regarded as occupying the far end of the wet-dry gradient, next to the cluster that represents damp grassland vegetation, which is dealt with in section 9.7.

The fen margin communities with which we are concerned here are documented and described in greatest detail in section 6; clusters i and j provide additional information for the vegetation types comprising cluster M6, and clusters k & l additional information for cluster M7. In addition to references to clusters M6-7, reference will also be made to clusters i-l in some cases.

Survey of the clusters M3-7 of section 5 and clusters f-l of section 6:

M3 (= f)	<i>C. las.-Camp. ste.-Drep. rev. type</i>	5 samples
M4	<i>C. las.-Pote. ere.-Camp. ste. type</i>	14 samples
g	<i>C. las.-Thalictr.-Camp. ste. type</i>	17 samples
M5 (= h)	<i>Scirp. ces.-C. host.-Camp. ste. type</i>	4 samples
M6	<i>Molinia-Succisa-Camp. ste. type</i>	12 samples
i	<i>Sauss.-Sph. warnst.-Homal. type</i>	3 samples
j	<i>C. flava-Thalictr.-Camp. ste. type</i>	16 samples

M7	<i>Molinia-Kobresia-Camp. ste. type</i>	4 samples
k	<i>Kobresia-Thalictr.-Camp. ste. type</i>	11 samples
l	<i>Succisa-Camp. ste.-Tort. to. type</i>	10 samples

#### 8.4.3.2 Comments on frequent species; *Lophozia borealis* and *Carex dioica*

The dominants in the vegetation of clusters M3-7 (altogether 41 samples) are *Scirpus cespitosus* and *Campyllum stellatum*. Additional dominants/common species are as follows: *Equisetum palustre*, *E. variegatum*, *Polygonum viviparum*, *Potentilla erecta*, *Saussurea alpina*, *Selaginella selaginoides*, *Thalictrum alpinum*, *Carex dioica*, *C. flava*, *C. panicea*, *Eriophorum angustifolium*, *Molinia caerulea*, *Bryum pseudotriquetrum*, *Drepanocladus revolvens*, *Fissidens adianthoides* and *Lophozia borealis*. All these species are very frequent in the extremely rich vegetation of the sloping fens at Sølendet (cf. Appendix C, Tables 5, 6, 7, 9 & 10, including the 186 small quadrats from the stands of clusters M2-7 in all of which, almost without exception, these species occur).

All of the graminoid and bryophyte species mentioned above, together with *Potentilla erecta*, *Selaginella selaginoides* and *Thalictrum alpinum*, also occur in almost all of the samples of rich vegetation from the sloping fens of Nordmarka (cf. Moen 1976b: Table 3). However, at least two of the above-mentioned species are either absent, or occur only sparsely, in similar communities described in other publications.

I was the first to recognize *Lophozia borealis*, which is a newly described species (Frisvoll & Moen 1980) that occurs in the rich fens of the boreal region in Fennoscandia. It thus seems inevitable that, in earlier phytosociological investigations, this species will have been confused with other hepatics, most likely with *Gymnocolea inflata* (e.g. Sjörs 1946: 50; Havas 1961: 43), *Cladopodiella fluitans* (Nordhagen 1928: 401) or *Lophozia collaris* (Dierssen 1982: Table 37B). However, all these "erroneous" taxa do occur, although only very rarely, in the phytosociological analyses of rich fen vegetation in Fennoscandia.

*Carex dioica* is the other species which, whilst it occurs in nearly all of my rich fen lawn quadrats, is only mentioned rarely in most phytosociological tables from studies made elsewhere in Fennoscandia. The growth of both of these two species is furthered by regular scything (cf. section 13.4.2). This explains, to some extent at least, the differences noted in the phytosociological tables. Nevertheless, both *Lophozia borealis* and *Carex dioica* (the latter usually sterile in most fen communities) have almost certainly also been overlooked by some investigators; Dierssen (1982) for example, lists a number of quadrats from which they are absent and yet where they certainly would have been expected to occur, e.g. in a majority of the samples of the *Caricetum atrofuscae-vaginatae* and the *Drepanoclado-Trichophoretum cespitosi* associations.

8.4.3.3 *Caricion atrofuscae*

The alliance *Caricion atrofuscae* Nordh. 35 is not synonymous with the more widely defined *Caricion atrofuscae-saxatilis* Nordh. 43 (= *Caricion bicolori-atrofuscae* Nordh. 36) (cf. section 8.2.3). The *Caricion atrofuscae* includes the extremely rich fen vegetation of open mires, mainly lawn communities, and of mire margin (cf. the species groups listed in Tables 8.2.1-3). The *Caricion atrofuscae* is mainly a low alpine and northern boreal alliance. The *Schoenion ferruginei* is the parallel alliance found in the lowlands. In upland, boreal areas, communities transitional between these two alliances exist, and, even at Sølendet, some features of the *Schoenion ferruginei* are discernible (e.g. the common occurrence of both *Carex hostiana* and *C. flava* x *C. hostiana* in cluster M5, and the absence or scarcity of the typical "alpine" species in a number of samples from the mire expanse communities).

At Sølendet, however, I regard all the rich lawn communities as belonging to the *Caricion atrofuscae* alliance. A future publication, which will include samples from a number of upland localities in Central Norway, e.g. the sloping fen communities at Nordmarka (cf. Moen 1976b), will deal further with the limits between the two alliances.

Nordhagen (1943) distinguished 6 associations within his *Caricion atrofuscae-saxatilis*, five of which fall within the scope of *Caricion atrofuscae* (the sixth, his *Caricetum microglochinis*, includes the *Carex bicolor*-communities of the *Caricion bicoloris* Nordh. 35 alliance). The lawn communities of the fen expanse at Sølendet (clusters M3-5) resemble the *Scirpetum caespitosi-trichophori subarcticum* association of Nordhagen (1943: 473). The fen margin communities at Sølendet (clusters M6-7) resemble a number of the associations distinguished by Nordhagen (1943), but first and foremost his *Caricetum flavae subarcticum* and *Caricetum atrofuscae-vaginatae*.

Dahl (1957) recognised only a single association (*Drepanocladeetum revolvantis*) from Rondane. He characterized this association as "the least calcicolous one within the alliance" (op.cit.: 223). Table 45 in Dahl (1957) shows a very heterogeneous "association", including samples that I would prefer to classify as belonging to the alliances *Caricion lasiocarpae* (samples nos. 355 and 576) and *Stygio-Caricion limosae* (e.g. samples nos. 577 and 610).

Dierssen (1982) subdivided the *Caricion bicolori-atrofuscae* alliance into 7 associations and two "Gesellschaften". He included the *Carex bicolor*-communities within this alliance (in part as a specific *Caricetum bicoloris* association), but in other respects defined the alliance somewhat differently from Nordhagen; e.g. Nordhagen's *Scirpetum caespitosi-trichophori subarcticum* and *Caricetum flavae subarcticum* associations are included in Dierssen's *Drepanoclado revolvantis-Trichophoretum caespitosi* association of the *Caricion davallianae* alliance; the *Carex saxatilis*-dominated communities being included in the *Calliergono sarmentosi-Caricetum saxatilis* association of the *Caricion nigrae* alliance. Compared to Nordhagen's attitude, Dierssen (1982) defined the *Caricion*

*bicolori-atrofuscae* much more narrowly, as an alliance of mainly alpine, extremely rich, fens and flushes.

According to the Dierssen system, the Sølendet samples comprising cluster M6 (and cluster j) would be included in the *Caricetum atrofusco-vaginatae* association, and the samples of cluster M7 (and clusters k & l) in the *Kobresietum simpliciusculae* association, both of which associations belong to his *Caricion bicolori-atrofuscae* alliance. Dierssen himself (1982: Table 37B) included 6 of his Sølendet samples in the latter association. The classification of the samples of clusters M3-5 as belonging to the *Caricion bicolori-atrofuscae* alliance is more questionable, because alpine, extremely rich fen, indicator species occur more sparingly, and some lowland species also occur (cf. the comments made at the start of this subsection). It would seem quite reasonable to assign the above-mentioned samples mainly to the *Drepanoclado revolutis-Trichophoretum cespitosi* association of the *Caricion davallianae* alliance in Dierssen's system. Some samples could even be included in his *Campylia-Caricetum dioicae* (cf. Dierssen 1982: Table 30C, which includes one sample from Sølendet, placed in the above-mentioned association).

#### 8.4.3.4 Further comments on the literature

In addition to the publications of Nordhagen (1935, 1936, 1943), Dahl (1957) and Dierssen (1982), all of whom utilize the formal hierarchical classification system referred to in the foregoing subsection, rich lawn communities, resembling the types found at Sølendet are dealt with in numerous other Fennoscandian publications (cf. also the references given in section 8.3). Here, comparisons will be limited to a few of the more seminal publications.

Sernander (1902) was the first who described *Scirpus cespitosus*-dominated rich fens, from Fjällnäs, ca. 20 km E of Sølendet. Melin (1917) already pointed out that *Scirpus cespitosus* rich fens are very rare in Sweden (further comments on the Swedish and Finnish literature made below).

Nordhagen (1928: 408) described three stands of the *Drepanocladus intermedius*-reiche *Scirpus austriacus*-Ass. from Sylane, that bear a resemblance to the samples comprising my clusters M2 (stand II of Nordhagen), M3 (stand I) and M4 (stand III), respectively. *Drepanocladus revolvens* shows greater cover values in the Sylane types than at Sølendet, where *Campylium* is the predominant bryophyte species in most of the samples. *Campylium* is rarely the predominant species even in the fen margin types of vegetation from Sylane, and is very often co-dominant with *Drepanocladus revolvens*. The explanation of this difference may be that the Sølendet samples belong to typical sloping fens, and/or because of the effects of scything at Sølendet (cf. section 13.4). The Braunmoosreiche *Carex panicea*-Ass. and the Braunmoosreiche *Carex flava*-Ass. of Sylane (in Nordhagen 1928: 410; combined to form a single sociation, belonging to the *Caricetum flavae subarcticum* association in Nordhagen 1943: 469) bear a great resemblance to the samples of clusters M4-7, (a majority of the Sylane samples are most closely related to cluster M6).



Nordhagen (1928: 415-426) also described a number of stands from Sylane that were transitional between the vegetation of rich fen and damp grassland (in part also transitional to heathlands). Some of these stands, e.g. nos. IV & V of his Braunmoosreiche *Carex sparsiflora*-*Thalictrum alpinum*-Ass., resemble the Sølendet clusters M7-8 (and clusters l-m). Species common to both are e.g. *Betula nana*, *Carex capillaris*, *Deschampsia cespitosa*, *Kobresia simpliciuscula* and *Saussurea alpina*. However, compared to the stands in clusters M7 (and l), the Sylane stands include a large number of species growing on mineral soils (e.g. *Anthoxanthum odoratum*, *Campanula rotundifolia*, *Carex bigelowii* and *Silene acaulis*) and I do not regard these communities of Nordhagen as representing genuine mire vegetation (cf. also the comments in Nordhagen 1928: 415). His Braunmoos-*Carex ustulata*-*Thalictrum alpinum*-reiches *Salix myrsinites*-Zwerg-gebüsch (op. cit.: 191) comprising only a single stand, is an extremely rich marginal, fen community bearing some resemblance to cluster M7 from Sølendet.

Klokk (1982: Table XV) has published an analysis of five stands of extremely rich, sloping fen vegetation at Klæbu, and Moen (1976b: Table 3) one for five similar stands from Nordmarka. Both these communities are dominated by *Scirpus cespitosus* and *Campylium stellatum* and bear great similarities with the stands composing clusters M3-5 at Sølendet, even the absence of some alpine species (e.g. *Equisetum variegatum*). The marginal, extremely rich, fen margin vegetation at Klæbu and Nordmarka, however, differs more widely from that at Sølendet.

Wilmann (1981) included analyses (not complete species lists) of some extremely rich fen communities in her *Pedicularis oederi* synedrium from Rindal. These quadrats included types that resemble the Sølendet clusters M5-7, where also *Pedicularis* occurs as a constant species (complete phytosociological analyses, including analyses of *Kobresia simpliciuscula* and *Carex atrofusca*-communities as well, can be found in her unpublished, cand. real. thesis, Wilmann 1983).

In Sweden, Booberg (1930) described some communities from Gisselåsmýren that resemble the Sølendet samples within clusters M3-7. However, only a few of the Gisselåsmýren samples (except the *Schoenus ferrugineus* lawns) are dominated by *Campylium stellatum* (there are no sloping fen areas at Gisselåsmýren, cf. subsection 8.3.2). The *Scirpus austriacus*-*Trichophorum*-*Amblystegium intermedium-stellatum*-sociation (Booberg op.cit.: 76) represents a lawn community of the fen expanse that resembles the Sølendet samples in clusters M2-5. His *Molinia coerulea* sociationen (p. 66) represent fen margin communities that are similar to those found at Sølendet, viz. cluster M6-7.

In the classification system used by Du Rietz & Fransson (cf. Table 8.3.1), the Sølendet clusters M2 to M4 would represent a gradual transition from the *Scorpidietum* association to the *Drepanocladetum* and further to the *Campylietum* association (also including clusters M5-7).



Persson (1961), subdivided his *Salix myrsinites*-*Campylium* vegetation into two types: communities dominated by *Drepanocladus intermedius* and/or *Campylium stellatum* (including 4 associations); and communities dominated by "*Tomentypnum nitens* and *Sphagnum warnstorffianum*" (2 associations). This bipartition is the same as that done for Sølendet. The clusters M3-7 belong to his former type, the clusters M9-10 to the latter. In addition, one of the samples in cluster M6 (no. 87) and the whole of cluster i belong to the latter type (cf. further comments in the next subsection). Persson's *Carex panicea* association is the one that most resembles the one represented by the clusters M2-7 from Sølendet. Persson split this association into four variants, three of which are documented by phytosociological analyses. In a majority of these samples *Drepanocladus intermedius* is dominant in the bottom layer (e.g. the *Carex dioica*-*Drepanocladus intermedius* var.). *Campylium stellatum* is dominant in one of the stands of the *Trichophorum caespitosum*-*Carex capitata* var. and in all the stands of the *Trichophorum caespitosum*-*alpinum* var. (at times with *Drepanocladus* as co-dominant). *Campylium* occurs much more scattered in the other communities. Persson (1961: 103) also points out that the typical *Campylium* stage (*Campylietum* of Du Rietz 1949) is rarely developed at Torneträsk. This is one of the main differences between the extremely rich, sloping fens of that area and those at Sølendet. However, the two last-mentioned vars. of Persson bear a great resemblance to the samples of clusters M3-7 from Sølendet.

In the Finnish system, the Sølendet clusters M3-8 would be classified as *Campylium stellatum*-Braunmoore; cf. Ruuhijärvi (1960: 99) who also gives references to the older Finnish literature. Ruuhijärvi's (1960: Table 21) 59 samples include a wide variety of plant communities. Only a few of the samples are *Scirpus cespitosus*-lawns that resemble the main types found at Sølendet (cf. also Launamaa 1961).

Kaliola (1939) has described a number of sociations from North Finland, in his *Salicion myrsinitis* alliance, that resemble some of the Sølendet types. However, *Campylium stellatum* was not a dominant species in his rich fen communities. Kalela (1939) described the plant communities of extremely rich fens on the Rybachi Peninsula. His *Drepanocladus intermedius*-*Scorpidium scorpioides*-Braunmoore included a large number of mire expanse communities that resemble those forming the clusters M1-M5 from Sølendet, e.g. the *Scirpus austriacus*-*Drepanocladus intermedius*-Braunmoor (op. cit.: 450). However, these "Rimpiaktige Moore" did not include *Campylium stellatum* as a dominant in the bottom layer. The Buntmoosbraunmoore of Kalela (1939) represent communities of rich fen margins (transitional to damp grasslands) and include a number of *Campylium stellatum*-dominated communities, e.g. the *Scirpus austriacus*-Buntmoosbraunmoor, which is similar to clusters M6-7 from Sølendet.

Havas (1961) described a *Carex flava*-*Trichophorum*-*Campylium stellatum*-Siedlungsgruppe, that include 18 samples from a type which greatly resembles the Sølendet types forming clusters M3-5(-7). In conclusion, in Finland, as in Sweden, *Scirpus*-*Campylium* lawns of the types found at Sølendet, only cover

small areas; they mainly occur scattered about on the sloping fens found in the northern and eastern parts of Finland, e.g. in Kuusamo (cf. Havas 1961: 46-47). Havas's *Carex flava-Filipendula ulmaria-Campylium stellatum*-Siedlungsgruppe greatly resembles the vegetation represented by clusters M6-7 (and clusters j-l) from Sølendet.

#### 8.4.3.5 Synecology

The habitat of the *Campylium* fen expanse communities (clusters M3-5) usually shows a slope inclination of ca. 3-5° and a peat depth of ca. 40 cm (range 15-60 cm). The habitat of the *Campylium* fen margin communities (clusters M6-7) in contrast, have a slope of ca. 5° and a peat depth of ca. 20 cm (range 10-35 cm).

Havas (1961), too, found as a general rule that the greater the slope of the fen, the thinner peat depth. His *Carex flava-Trichophorum-Campylium stellatum*-Siedlungsgruppe (resembling clusters M3-5) had an average inclination of ca. 3-4°, and a peat depth mostly exceeding 1 m. His *Carex flava-Filipendula ulmaria-Campylium stellatum*-Siedlungsgruppe (resembling clusters M6-7) was usually found on 5-6° slopes and with a thinner peat layer (ca. 0.4 m).

The groundwater-level in these communities at Sølendet fluctuates widely during the summer-time. In dry periods the recorded level was ca. 30-40 cm below the fen surface, the values increasing for the stands from clusters M1 to M7. The mean values for these clusters for the "sum of groundwater-levels", represented by the 4 values recorded during summer 1982, show an increasing trend, well illustrated in figure 8.4.1 (for further details cf. section 5.4).

The ecological effects of groundwater-fluctuations on sloping fens have been discussed by e.g. Havas (1961) and Persson (1962). The aeration of the peat and the oxygenation degree is of fundamental importance for the plant communities (cf. also Heikurainen 1953: 147). As a general rule, the greater the slope, the further below the surface is the groundwater-level in dry periods and the better the aeration of the peat. Good aeration leads to a lesser accumulation of peat, which explains the fact that, in general, the greater the fen surface slope, the thinner the peat layer. As shown in section 5 (e.g. Tables 5.3.1-2) these "rules of thumb" also apply in the main at Sølendet. However, the influence of a water supply from springs changes the ecological conditions, producing both a constant and high groundwater-level and, at the same time, a good supply of oxygen (cf. the comments made in section 5.4.3.2).

The pH values for the peats from the samples of clusters M3-7 were 6.2-6.6, corresponding water analysis values were ca. 7.0, and the  $K_{20}$  values ca. 90-150. All the above-mentioned values are high ones for mire ecosystems. Similar values were recorded for the extremely rich fen communities, resembling those at Sølendet, by e.g. Havas (1961), Persson (1962) and Moen (1970, 1976b).

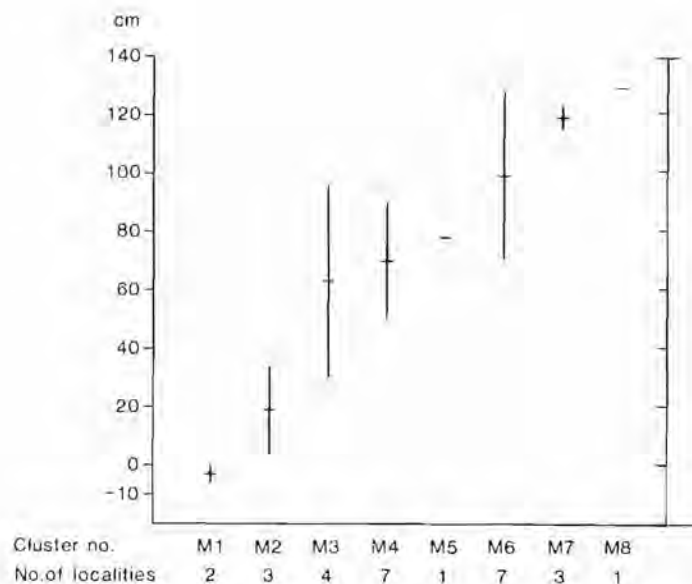


Fig. 8.4.1 Groundwater-levels for the samples of clusters M1-8 at Sølendet. Mean values in cm (with s.d.) for the sum of the four groundwater-levels recorded in 1982 (cf. Table 5.3.1).

Scything of the sloping fen communities (clusters M3-7) in former times has also been an important ecological factor (cf. the review in section 2.3.3, including a reference to Booberg (1930); cf. also section 13.4). Havas (1961: 41) mentioned that scything of the vegetation representing the samples of his *Carex flava-Trichophorum-Campylium stellatum*-Siedlungsgruppe had occurred in the past.

The *Scirpus cespitosus-Campylium stellatum*-dominated communities, that cover large areas at Sølendet, are not a type commonly found in the boreal region in other parts of Fennoscandia. They occur on the sloping fens and seem to be most common in regions with a suboceanic climate, i.e. they are more common in Norway than in Sweden or Finland. As extremely rich fen communities, they only occur in areas where the subsoil is calcium-rich. Former scything for hay is another important ecological factor that has influenced the typical composition of these plant communities.

#### 8.4.4 Rich fen, *Sphagnum warnstorffii* communities

##### 8.4.4.1 Comments on the clusters

These vegetational types at Sølendet are the ones included in clusters M8-10 described in section 5 (clusters i and m-o in section 6).

Cluster M8 represents a vegetational type transitional between fen margin and damp grassland. One of the samples (no. 74) is more fen-like, with some similarity to clusters M6 & 7 (belonging to the *Caricion atrofuscae* alliance), the other sample is closer to the communities in the *Lactucion alpinae* alliance. The greatest similarity of cluster M8, however, is with the communities placed in the *Sphagno-Tomenthypnion* alliance. No further comments on the phytosociological status or references to the literature will be made for this cluster.

Survey of the clusters:

i	<i>Sauss.-Sph.warnst.-Homalot.</i> type	3 samples
[M8 (= m)	<i>Bet. nana-Molinia-Camp.ste.</i> type	2 samples]
M9 (= n)	<i>Sauss.-C. vag.-Sph.warnst.</i> type	4 samples
M10 (= o)	<i>C. rostrata-Sph. warnst.</i> type	2 samples

#### 8.4.4.2 *Sphagno-Tomenthypnion*

This alliance was described from Rondane by Dahl (1957: 228) as encompassing the rich fen communities of marginal type. In agreement with Dahl (1957), I regard the *Sphagno-Tomenthypnion* as an important unit apropos the marginal communities of rich fens. The *Sphagno-Tomenthypnion* alliance is separated from the *Caricion canescenti-nigrae* alliance by the occurrence of rich fen species and the absence of poor fen species (cf. Table 8.2.1, species groups 8-10 and 1, 2 & 4, respectively). Compared to the other rich fen margin communities (e.g. the *Caricion atrofuscae*) the *Sphagno-Tomenthypnion* alliance characteristically includes some (low) hummock species that prefer dry habitats, e.g. the dwarf-shrubs, *Empetrum* spp., *Vaccinium* spp. etc., and a number of bryophytes. *Homalothecium nitens* and *Sphagnum warnstorffii* are dominant species and, in addition, the following species also occur: *Aulacomnium palustre*, *Dicranum* spp. (e.g. *D. bonjeanii*, *D. scoparium*), *Drepanocladus badius*, *Helodium blandowii*, *Hylocomium pyrenaicum*, *Hypnum lindbergii*, *H. pratense*, *Paludella squarrosa*, *Philonotis* spp., *Plagiomnium elatum*, *P. ellipticum*, *Pleurozium schreberi*, *Pohlia* spp., *Polytrichum* spp., *Sphagnum subnitens*, *S. teres*, *Thuidium recognitum*, *Barbilophozia* spp. and *Cephalozia* spp. *Campylium stellatum* and *Drepanocladus revolvens* are the predominant species in the other rich lawn communities, but are not the predominant species in the communities of the *Sphagno-Tomenthypnion* alliance.

Dahl (1957) included one specific association, the *Aulacomnieta-Sphagnetum warnstorffiani*, that occurs in upland areas. He listed a number of earlier publications which had described communities of this alliance/association. However, he suggested that further vegetational analyses were needed before making any more detailed subdivision of the alliance. In Czechoslovakia, the alliance has been split into four associations (cf. Rybniček et al. 1984). The marginal communities of Fennoscandian lowland rich fens will also probably prove to belong to this alliance, but first much more research remains to be done; I

fully agree with Dahl's view, expressed above, in regard to the situation in Norway. In Finland and Sweden, however, much more phytosociological data have been published (summarized below).

The phytosociological data for Sølendet are too sparse for a detailed description to be attempted. The samples forming clusters M9-10 and i, have similarities to, and they should thus perhaps be included in, the association described by Dahl (1957).

Certain communities bridge the gap between the *Caricion atrofuscae* and the *Sphagno-Tomenthypnion*, e.g. the *Carex dioica-Tomentypnum* association of Persson (1961). Cluster i at Sølendet is such a transitional one. However, the effect of former scything has certainly led to the difference between the composition of these two alliances being more clearcut at Sølendet than in some other areas (cf. comments in the following subsections).

According to Nordhagen's (1943) classification, the communities in the *Sphagno-Tomenthypnion* alliance should mostly belong to his *Caricion canescentis-goode-nowii* alliance. Some of the stands placed in the *Saliceto-Caricetum inflatae-canescens* association by Nordhagen (1943: 504) bear a great similarity to the Sølendet samples forming clusters M9-10. From Sylane, however, Nordhagen (1928) described no communities that possess any great similarity with those of the Sølendet clusters. Some samples of a vegetation that resembles that in clusters M9-10 at Sølendet are included by Dierssen (1982) in his *Menyantho-Sphagnetum teretis* association of the *Caricion nigrae* alliance (cf. his Table 21D, which even includes one Sølendet quadrat).

#### 8.4.4.3 Further comments on the literature

Resvoll-Holmsen (1920) included one stand of a northern boreal *Sphagnum warnstorffii* community (Table 21 no. 7) on Dovrefjell. Dahl (1957: 229) regarded an alpine stand described by Resvoll-Holmsen (1920: Table 24 no. 4) as belonging to the *Sphagno-Tomenthypnion* alliance. That stand included a number of typical mineral-soil species, however, and I do not regard it as representing a true mire plant community. In alpine areas, in particular, gradual changes can be found from communities typical of the *Sphagno-Tomenthypnion* alliance to damp heathlands and to grasslands. *Homalothecium nitens* also occurs commonly in these communities, as described from Sylane (Nordhagen 1928: 420).

Phytosociological analyses of *Sphagno-Tomenthypnion* communities from the middle boreal areas of East Norway have recently been published by Galten (1987) and by Singaas (1989: cluster V). In general, the typical communities of the *Sphagno-Tomenthypnion* alliance (i.e. those included in the association described by Dahl 1957) mainly occur in the more continental parts of Fennoscandia. In the upper boreal region in Sweden and Finland, they seem to be quite common on areas of calcareous bedrock.



In the classification system proposed by Du Rietz & Fransson (cf. Table 8.3.1), the *Tomentypnetum* association is distinguished as one of the main types. Boberg (1930: 53) described 5 sociations of the "svällande mattornas sociationer", that covered more than 5% of the Gisselåsmýren. Some of these sociations are very similar to the clusters for Sølendet. Rich fen *Homalothecium* communities are also common at Torneträsk, where Persson (1961) made a distinction between two associations, one of which, the *Carex dioica*-*Tomentypnum* association, is very like that into which the samples forming clusters i, M9 and M10 fall. Persson made a prime separation between the vegetation types of rich fens and of intermediate fens. Many of the dominant species of his *Sphagnum warnstorffianum*-*parvifolium* vegetation/association are in common with those in the Sølendet samples, but the typical rich fen indicator species (e.g. *Thalictrum alpinum*) are absent.

In the Finnish classification, the *Sphagnum warnstorffii*-Braunmoore includes both the rich fen and the intermediate fen types; cf. Ruuhijärvi (1960: 94) who lists a number of samples from Kuusamo that resemble the Sølendet types (species in common are e.g.: *Gymnadenia conopsea*, *Saussurea alpina*, *Thalictrum alpinum*). Havas (1961), too, included rich and intermediate fen types in his *Carex magellanica*-*Filipendula ulmaria*-*Sphagnum warnstorffianum*-Siedlungsgruppe; his two rich fen samples from Kuusamo (nos. 13 and 25 in his Table 7) resemble the Sølendet types. Both Ruuhijärvi (1960) and Havas (1961) provide references to the large number of Finnish publications that deal with similar kinds of vegetation.

#### 8.4.4.4 Synecology

The stands comprising clusters M9-10 and i, include communities of rather different types, and represent analyses from only a few localities. The ecological parameters also differ rather widely (cf. Table 5.3.1).

Clusters M9 and 10 represent the *Sphagnum warnstorffii*-dominated, fen margin communities that occur on the borderline between flat fens, with a rich carpet or lawn vegetation, and drier grassland/heathland vegetation. The position of three of the M9 stands are shown in the Vassdalen transect (Fig. 7.3.1). The samples of cluster i represent *Sphagnum warnstorffii*-*Homalothecium nitens*-dominated cushions, of low elevation, in lawns on sloping fens. At the sites of the samples in clusters M9-10 the groundwater-level never reaches the surface. Nevertheless, nor do they dry up completely in the summertime. The depth of the peat layer is thin to moderate; the pH and specific conductivity values of the groundwater are somewhat lower at the surface than those recorded in the adjacent extremely rich, carpet and lawn communities. However, the values are still high, indicating typical rich fen conditions. These ecological parameters correspond with those found by Dahl (1957), Havas (1961) and Persson (1962) for rich fens of similar type. An autogenic succession (cf. Tansley 1929) takes place in most mire communities, i.e. the composition of the plant communities change as litter accumulates and the peat depth increases.

However, regular scything of the Sølendet fens in the past stopped any further peat accumulation. After this activity ceased, the normal succession has recommenced, and the changes can be seen all over Sølendet in those areas which have been left unscythed. The cushions of *Sphagnum warnstorffii* and *Homalothecium nitens* are expanding.

Different stages or levels of this typical succession on rich fens are described in the literature. The changes in the bottom layer are especially prominent and the following "stages" can be separated, characterized by the dominant species, (or associations, as in Table 8.3.1 column no. 6) which are: *Scorpidium-Drepanocladus-Campylium-Homalothecium/Sphagnum warnstorffii-Sphagnum fuscum* (cf. also Booberg (1930), Sjörs (1950), Dahl (1957), Persson (1961)).

In the future, in the absence of regular scything, I think that some of the areas of *Campylium* communities of the fen margin, which are not flooded, will develop towards the *Homalothecium* stage, as stand 87 has already done. On their margins, mainly, the vegetation of some of the flatter areas (of cluster types M2-3, M11-13) will develop towards *Sphagnum warnstorffii*-communities of the types represented by clusters M9-10.

#### 8.4.5 Rich fen, *Drepanocladus-Meesia* communities

##### 8.4.5.1 Comments on the clusters

This section deals with the samples comprising clusters M11-13, as described in section 5.4.5 (cf. also the Vassdalen transect, Fig. 7.3.1, which includes samples typical of clusters M12 and 13).

Survey of the clusters:

M11	<i>Menyanth.-C. heleon.-Cincl.</i> type	2 samples
M12	<i>C. heleon.-Drep. rev.-Meesia</i> type	4 samples
M13	<i>Salix-Equi. pal.-Drep. rev.</i> type	3 samples

##### 8.4.5.2 *Caricion lasiocarpae*

The *Caricion lasiocarpae* alliance, has been characterised quite differently by different authors and its syntaxonomy is virtually in a state of chaos (Rybniček 1985). Oberdorfer (1977, 1983), Dierssen (1982, cf. Table 8.2.4), and Vevle (1983, 1986) conceived the alliance in a wide sense, as one of two alliances in the order *Scheuchzerietalia*. The *Stygio-Caricion limosae* alliance was then included as a part of the alliance *Caricion lasiocarpae* (cf. also Runge 1980, Ellenberg 1988). In the Czechoslovakian system (cf. Rybniček et al. 1984, Rybniček 1985) the *Caricion lasiocarpae* alliance represents a more restricted unit of the rich fens (included in the order *Caricetalia fuscae*). Wheeler (1980: 368) described the *Caricion lasiocarpae* in England as "vegetation of wet areas in calcareous

mires", and included it in the order *Tofieldietalia* (synonymous with the *Caricetalia davallianae*).

In the system proposed for Norway (Table 8.2.5), I have classified the alliance as belonging to the order *Scheuchzerietalia* (together with the *Leuko-Scheuchzerion* and *Stygio-Caricion limosae*). The suggestions made on figure 8.2.2 is that the alliance includes the vegetation of *Magnocariceta* fens, from poor to extremely rich types. There are certainly great differences between the poorest types (often *Carex rostrata*-dominated in the upper boreal region) and the types delineated by clusters M11-13, and a further separation, at alliance level, will need to be carried out sometime in the future. However, only the rich types will be dealt with here.

I have been somewhat in doubt about the propriety of assigning the vegetation of the samples in clusters M11-13 to the *Caricion lasiocarpae* alliance. These clusters do not represent true *Magnocariceta* communities (rather *Mediocariceta* sensu Nordquist, in Sjörs et al. 1965). They can be characterized as (extremely) rich carpet communities, bearing a certain relationship to the *Stygio-Caricion limosae* alliance. The results of the multivariate analyses (of section 5), however, indicated that the samples forming clusters M11-13 are quite distinct from the typical samples of the *Stygio-Caricion limosae*. The samples in clusters M11-13 include a number of fen margin species (cf. species groups 4-5 in Table 8.2.2) which represent differential species in regard to the mire expanse communities of that alliance, e.g. *Salix* spp. and *Calliergon giganteum* (cf. also Nordhagen 1943: 521, and subsection 8.4.2.2).

The results of the multivariate analyses further showed that the vegetation of clusters M11-13 is quite distinct from that in the clusters of the *Caricion atrofuscae* alliance, which represent the lawn communities (Table 8.2.3 lists the species groups that characterize carpets and lawns, respectively). According to the classifications of Nordhagen (1936, 1943) and Dahl (1957), the communities of the *Caricion lasiocarpae* ought to be mostly placed in the alliance *Caricion canescenti-nigrae*. However, that alliance does not include typical rich fen communities as defined here.

In conclusion, the clusters M11-13 represent extremely rich fen communities of the *Caricion lasiocarpae* alliance. Sample 60 (the *Carex appropinquata* community described in section 5.4.9) should also be included in this alliance.

#### 8.4.5.3 Further comments on the literature about *Carex heleonastes* communities

From Sylane, Nordhagen (1928) described a *Drepanocladus intermedius*-reiche *Carex Goodenoughii*-Ass., a rich fen community classified within the *Caricion canescenti-nigrae* alliance by Nordhagen (1943), with a composition resembling that of the samples composing clusters M11-12 from Sølendet; however, *Carex heleonastes* was not present in the Sylane community, Nordhagen (1943)

published analyses from Sikilsdalen of two stands that did include *Carex heleonastes*, viz. in the *Drepanoclado-Caricetum inflatae-canescens* association within the same alliance. As mentioned earlier (section 8.2.3), Nordhagen included some rich (even extremely rich) fen communities in his *Caricion canescens-nigrae* alliance; he even regarded *C. heleonastes* as a regionally characteristic species for that alliance (Nordhagen 1943: 483); he did not consider this species as a calcicole (op. cit.: 448). As in the case of *Eleocharis quinqueflora* as well, this contrasts with my classification of them as rich fen species (cf. Table 8.2.1).

Dahl (1957) reported *Carex heleonastes* from one of the stands of his *Drepanocladeetum revolvens* association within the *Caricion bicolori-atrofuscae* alliance. This sample (op. cit.: Table 45) greatly resembles those from Sølendet in the clusters M11-13 (as also some of the other samples listed in Dahl's table).

Dierssen (1982) classified three quadrats from Fokstumyra, Dovre, that included *Carex heleonastes*, in his association *Caricetum heleonastae* Waren 26. The Fokstumyra samples (which even include some additional alpine species, e.g. *Scorpidium turgescens*), as well as the other Fennoscandian and German communities placed in this association (Dierssen 1982: Table 16) show certain similarities with the Sølendet samples. In addition to *Carex heleonastes*, *Meesia triquetra* is also a characteristic species, and, in the Dierssen system, clusters M11-13 would be included in the above-mentioned association (which is a part of the alliance *Caricion lasiocarpae*).

At Gisselåsmyren (Booberg 1930), *Carex heleonastes* occurred in some of the sociations dominated by *Drepanocladus revolvens*, e.g. in the *Carex heleonastes-Amblystegium intermedium*-soc. (op.cit.: Table 52). In Persson's (1961) analyses, however, *Carex heleonastes* is absent from his *Carex saxatilis-Drepanocladus intermedius*-ass. (op. cit.: Table 7), which resembles vegetation exemplified by clusters M11-12 at Sølendet, as does his *Calliergon giganteum* community as well (op. cit.: 67).

In Finland, a large number of phytosociological analyses of a vegetation that resembles that of the samples forming clusters M11-13 and (which often includes *Carex heleonastes*) have been published, e.g. Ruuhijärvi (1960: Table 23; Birkenbraunmoore; Tables 26 & 27; Rimpibraunmoore) and Lounamaa (1961: Table 4; Birkenbraunmoore).

In conclusion: *Carex heleonastes* is a rich fen species with a limited ecological amplitude, i.e. it represents a good characteristic species of a rather minor hierarchical unit; it seems reasonable therefore that the samples composing the clusters M11-13 from Sølendet should be assigned to the *Caricetum heleonastae* association. The association has an eastern (continental) distribution in Fennoscandia.



#### 8.4.5.4 Synecology

The Sølendet communities represent an extremely rich fen vegetation, situated on flat, regularly inundated fens, with a relatively deep peat layer and with a high groundwater-level during most of the year. The pH of the peat is ca. 6.5, that of the groundwater exceeds 7.0 and has a specific conductivity value of 90–150. The stands are situated in areas influenced by well-oxygenated, calcium-rich, seepage water. Many of the publications referred to previously (e.g. Nordhagen 1943, Dahl 1957, Ruuhijärvi 1960, Dierssen 1982) described habitat conditions for the *Carex heleonastes*-communities similar to those found at Sølendet. However, most of these are moderately rich fen communities, with lower pH values for both groundwater and peat than the values cited for Sølendet. Dahl (1957) even found that the pH could fall as low as 5.0 in the peat.

#### 8.4.6 Rich fen, *Salix* communities

##### 8.4.6.1 Comments on the clusters

The vegetational types dealt with here are those included in the clusters M14–15, described in section 5.4.6.

M14: *Salix* spp.–*Filipendula ulmaria*–*Plagiomnium ellipticum* type with 3 samples (nos. 82, 83, 103), including altogether 7 quadrats, each of 4 m<sup>2</sup>.

M15: *Salix glauca*–*Caltha palustris*–*Pellia neesiana* type with 2 samples (nos. 84, 85, each of one 4 m<sup>2</sup> quadrat). This cluster is assigned to the *Filipendulo-Salicetum phylicifoliae* association within the alliance *Lactucion alpinae* described in section 11.3.6.6, wherefore only a few further comments will be made here.

##### 8.4.6.2 Phytosociological classification and comments on the literature

Cluster M14 represents a mire community. Samples nos. 82 and 83 (6 quadrats) are dominated by *Salix pentandra*. They represent a distinctive community that occurs on the margin of fens that are liable to seepage outflow in springtime. Phytosociologically it is a difficult community to classify; in table 8.3.1 a placement in the *Sphagno-Tomenthypnion* alliance is suggested. However, it differs appreciably in composition from that of the typical communities in that alliance (e.g. clusters M9–10; the coefficient of similarity between the clusters M9 and M14 is only 0.42; cf. Fig. 5.2.1), and a differentiation, at least at suballiance level, needs to be made.

Nordhagen (1928, 1943) did not describe any community that shows any marked similarity with the Sølendet samples comprising cluster M14. The nearest comparison is with the samples of his *Saliceto-Caricetum inflatae-canescens* association in the *Caricion canescenti-nigrae* alliance. On my criteria, however,



that alliance can not come into the question, because the samples in cluster M14 all represent rich fen communities.

The samples of cluster M14 also show some similarity with the communities placed in the *Lactucion alpinae* alliance (e.g. a similarity value of 0.48 with the cluster M15). However, I regard the M14 samples as representing genuine fen communities, which eliminates any consideration of the "alliances of mineral soils".

Kielland-Lund (1981) described an *Alno incanae-Salicion pentandrae* alliance (with one association *Calamagrostio purpurea-Salicetum pentandrae*) from the boreal region in eastern Norway, as part of the class *Alnetea glutinosae*. That alliance includes communities which are transitional between fen margin vegetation and that of damp, wooded grassland, and includes as characteristic and differential species, a number of those typical of cluster M14 (cf. Kielland-Lund 1981: Table 12) e.g. *Salix pentandra*, *Calamagrostis purpurea*, *Sphagnum warnstorffii* and *Chiloscyphus pallescens*. However, a number of lowland species are also present in Kielland-Lund's community, and a number of alpine/upland species are absent. The M14 samples could be regarded as a northern boreal "parallel" (vicarious) to the above-mentioned association, although I prefer at present to stress the regional differences and to consider the communities of the class *Alnetea glutinosae* as lowland types. I also prefer to differentiate, at a major level in the phytosociological hierarchy, between fen communities and those of grasslands/heathlands. Kielland-Lund's (1981) *Alno-Salicion* samples can mostly be characterized as belonging to the grassland type.

From Troms, Fremstad & Øvstedal (1979) have described an *Alnus incana-Sphagnum warnstorffii* community and a "swamp with *Salix* spp." community, both of which have certain features in common with the communities within clusters M14-15 from Sølendet.

A large number of publications exist from Sweden and Finland on fen margin communities that are transitional to damp grasslands of the types included in the Sølendet clusters M14-15. Booberg (1930: 106) described some sociations of "Lövkärret" that show a resemblance. Persson's (1961) *Filipendula-Mnium* vegetation also includes a number of quadrats of similar type. Both Ruuhijärvi (1960: 194, describing Braunmoorbrücker and Hainbrücker) and Havas (1961: 56, the *Carex magellanica-Filipendula ulmaria-Sphagnum warnstorffianum*-Siedlungsgruppe) have likewise described such communities from Finland.

#### 8.4.6.3 Synecology

The stands comprising cluster M14 represent a rich fen community influenced by groundwater seepage in springtime. The peat layer depth of the *Salix pentandra*-dominated samples is ca. 1 m and the pH value 6.2, compared with a groundwater pH of 6.7. The stands of damp grassland in cluster M15 have a thinner peat/humus layer and a lower pH value. Similar ecological parameters have been reported by e.g. Havas (1961: Tables 6 & 7) for such communities.

#### 8.4.7 Bog hummock, *Sphagnum fuscum* communities

Cluster M18 *Betula nana*-*Sphagnum fuscum* type, described in section 5, represents the two stands of bog hummock vegetation from Sølendet.

This cluster has to be placed in the association *Oxycocco-Empetretum hermaphroditi sphagnosum*, within the alliance *Oxycocco-Empetrion* (cf. Nordhagen 1928: 277, 1936: 82, 1943: 534). Dahl (1957) changed the name of this association to the *Betuleto-Sphagnetum fusci* (valid name: *Betulo-Sphagnetum fusci*). He also gave (p. 245) a complete list of references to the large number of Fennoscandian publications that deal with this typical community of the northern boreal and low alpine regions; cf. also Ruuhijärvi (1960: 144), Persson (1961: 88), Sonesson (1970a: 38), Dierssen (1982: 187).

Some species regarded as minerotrophic species in other parts of Fennoscandia occur in "ombrotrophic" hummock communities of the Sølendet area, e.g. *Arctostaphylos alpina* (mainly an alpine heathland species), *Carex pauciflora* and *Dicranum angustum*, all three of which occur in sample 71. However, the peat layer is thin and minerogenic peat is always just below the surface, so that deep-rooting species can certainly obtain their nutrient supplies from deeper levels. That this is very often the case, is shown by the occurrence, of species such as *Carex rostrata* and *Eriophorum angustifolium* in these hummock communities, cf. also Sonesson (1970a: 27).

The rather rare hepatic species, *Lophozia laxa* (cf. Flatberg 1972) occurs in sample 89 (also found in a few additional localities). *Pinguicula villosa* which is a good characteristic species of the association (e.g. Dahl 1987) occurs in hummock vegetation a few hundred metres N of the reserve. Further comments on species occurring in this type of vegetation outside the analysed quadrats will be given in section 12.4.

The pH values for both peat and groundwater at locality 71 were ca. 4.0. Persson (1962: 72) reported somewhat lower values from the Torneträsk area, cf. also Dierssen (1982: 193).

## 9 HEATHLAND AND GRASSLAND VEGETATION AT SØLENDET, VEGETATIONAL TYPES AND HABITAT CONDITIONS

### 9.1 INTRODUCTION

Phytosociological analyses of the heathland and grassland vegetation at Sølendet were made in ca. 60 localities. In some localities more than one quadrat was analysed; in addition a few of the permanent quadrats of the wooded grasslands was reanalysed after clearance and scything. Table 1 of Appendix A provides a survey of all the sample stands.

The phytosociological analyses of grasslands at Sølendet are dealt with in two different data sets. The first one (section 9.2) deals with the 55 samples of woodland (including all the heathland analyses). The second (section 9.3) deals with the 34 samples of open grassland, including some analyses of the willow scrub and mire margin communities. Some of the samples are common to both data sets, and some samples were even included in the treatment of the mire types (section 5).

The vegetational types of the woodlands (clusters W1-11) and the open grasslands (clusters O1-5) have been defined from the results of the multivariate analyses of the Sølendet samples. The clusters and cluster groups have been established in a fashion parallel to that described for the mire vegetation (section 5.1). The names of the heathland cluster groups (in section 9.5) are used as the headings for the same types of vegetation in sections 11.2 and 12.5.

The wooded grassland samples of Sølendet are also included in the multivariate analyses described in section 10, together with samples from three other areas in Central Norway.

A synsystematic survey of the heathland and grassland vegetation, including comparisons with descriptions of similar vegetation given in the literature, is given in section 11. The relationship between the mapped units and the heathland and grassland types of Sølendet is evaluated in sections 12.5 and 12.6, respectively.

### 9.2 MULTIVARIATE ANALYSES OF HEATHLAND AND WOODED GRASSLAND VEGETATION

#### 9.2.1 The full data set

All the typical woodland samples are dealt with in this section, together with some types of scrub and open *Nardus*-vegetation. The data set comprises 55 samples (cf. Table 9.2.1 for details).

Table 9.2.1 Details of the 55 stands used for the woodland analyses. Cluster no. (W1-11) refers to that shown in Appendix D-table 1 and table 9.2.2, and within each cluster the stand samples are grouped in numerical order. C. = cover; Cl. = cluster; H. = height in m; Oliv. limit = *Parmelia olivacea* limit; Circumfer. = circumference of birch trunks ca 1.5 m above ground level; q = quadrat. Further details in table 1 of Appendix A.

Cl. no.	Stand sample no.	Locality & stand quadrat	No. & size in m <sup>2</sup> of quadrats	Tree layer		Shrub layer		Field layer		Bot- tom layer	Lit- ter	Trees		
				C.	H. m	C.	H. cm	C.	H. cm			Oliv. limit in m	Nos.	Circumfer. in cm
W1	049	49A+B	1x25	-	-	-	-	6	10	6	6	-	-	-
	055	55A+B	1x25	-	-	-	-	6	10	5	6	-	-	-
W2	044	44A+B	1x25	1	5	-	-	5	15	6	1	1.3	1	31
	045	45	1x25	4	7	1	100	5	10	6	1	1.3	4	45
	046	46A+B	1x25	3	8	-	-	4	10	6	1	1.1	4	40
	047	47	1x25	1	5	4	110	5	10	6	1	0.9	1	32
W3	057	57	1x25	1	5	3	120	6	15	6	3	0.9	2	22
	080	80	1x25	4	8	5	120	6	15	5	4	1.6	11	-
	270	prf1 q1-2+	1x4	3	3	2	55	5	-	5	3	0.9	5	-
	271	prf1 q3+	1x4	3	4	4	55	4	-	5	3	1.0	2	-
W4	028	28A+B	1x25	2	7	2	75	6	15	6	2	1.8	2	41
	041	41A+B	1x25	5	5	1	90	6	15	6	2	1.3	15	15
	042	42A+B	1x25	5	5	1	90	6	15	5	5	1.5	25	15
	043	43A+B	1x25	5	5	1	115	6	15	3	6	1.4	13	17
W5	023	23A+B	1x25	4	8	4	100	6	15	4	5	2.0	3	33
	024	24	1x25	3	8	5	120	6	20	3	6	2.0	2	38
	025	25A+B	1x25	3	12	4	75	6	12	5	5	2.0	2	57
	030	30A+B	1x25	3	10	1	30	6	10	6	3	2.0	3	43
	032	32A+B	1x25	2	10	1	70	6	10	6	4	1.5	1	58
	039	39A+B	1x25	3	12	2	140	6	25	2	6	1.9	1	56
	048	48	1x25	4	5	6	100	6	10	6	3	1.7	1	44
W6	031	31A+B	1x25	3	12	1	90	6	20	6	4	1.5	1	51
	033	33A+B	1x25	4	15	1	100	6	25	3	6	1.8	3	56
W7	022	22A+B	1x25	5	9	2	100	6	40	3	6	0.8	2	60
	034	34A+B	1x25	4	15	1	30	6	25	1	6	1.8	1	87
	035	35A+B	1x25	3	3	4	180	6	35	4	5	1.5	ca. 50	15
	036	36A+B	1x25	2	2	5	180	6	35	5	3	1.4	ca. 20	7
	037	37A+B	1x25	4	8	-	-	6	35	6	2	2.0	3	32
	038	38A+B	1x25	3	8	1	40	6	25	6	1	2.0	1	47
	250	35A	1x12.5	3	8	5	80	5	30	5	5	1.5	1	27
	251	35B	1x12.5	-	-	-	-	6	20	5	5	1.5	0	-
	272	prf1 q21-22+	1x4	3	6	4	100	6	-	5	5	0.9	1	-
W8	020	20A+B	1x25	4	10	1	110	6	30	4	5	2.5	2	58
	021	21A+B	1x25	3	12	1	70	6	20	5	4	2.3	1	62
	026	26	1x25	1	5	2	60	6	15	6	1	1.5	2	18
	056	56A+B	1x25	2	8	2	50	6	20	6	1	1.2	1	42
W9	027	27A+B	1x25	2	10	-	-	6	35	5	4	1.3	1	60
	029	29A+B	1x25	3	9	1	75	6	30	5	4	2.0	4	38
	255	5A	1x12.5	1	10	-	-	6	20	6	2	1.0	0	-
	256	5B	1x12.5	1	8	-	-	6	30	5	4	1.0	0	-
	257	5D	1x12.5	4	8	1	80	6	60	3	6	1.0	0	-
	258	5A+B	1x25	1	9	1	50	6	50	4	5	1.0	0	-
W10	008	8A+B	1x25	3	12	1	100	6	60	4	6	1.0	3	41
	040	40A+B	1x25	3	12	1	110	6	50	4	5	1.3	1	88
	050	50A+B	1x25	-	-	5	150	6	60	4	5	-	-	-
	252	40A	1x12.5	5	12	5	80	5	20	4	5	1.3	1	-
	253	40B	1x12.5	2	12	-	-	6	30	4	5	1.3	0	-
	254	40C	1x12.5	2	10	1	60	6	60	5	6	1.3	0	-
	259	8C	1x12.5	4	12	2	120	6	70	4	6	1.0	0	-
	260	8A	1x12.5	3	12	-	-	6	35	6	1	1.0	3	41
	261	8B	1x12.5	2	8	1	100	6	50	6	3	1.0	0	-
W11	082	82	4x4	1	3	5	150	5	40	6	3	0.9	-	-
	083	83	2x4	4	5	4	55	5	30	6	2	1.5	-	-
	084	84	1x4	-	-	6	150	6	50	3	5	1.2	-	-
	085	85	1x4	2	5	6	150	5	50	6	5	1.2	-	-

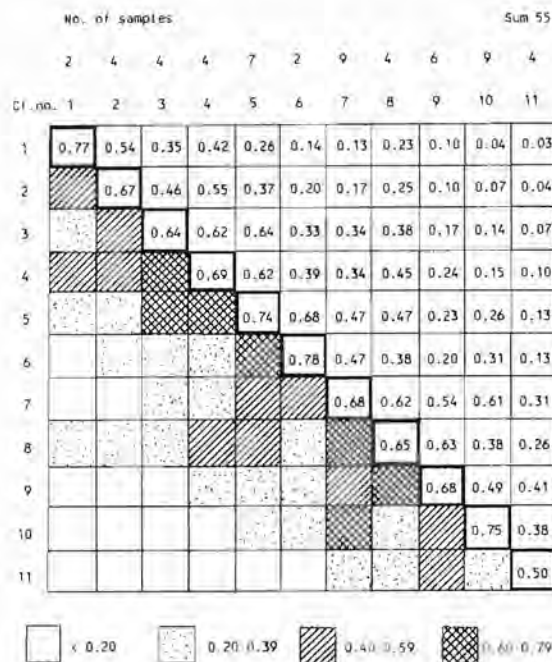


Fig. 9.2.1

Resemblance between the 11 clusters (W1-11) of woodland vegetation at Sø-lendet, calculated from the "similarity ratio" values. The diagonal shows the within-cluster similarity.

Most of the samples represent data for 25 m<sup>2</sup> quadrats, but 11 were 12.5 m<sup>2</sup>, all of which were second-time analyses made after reclamation and scything; 5 samples were from 1 x 4 m<sup>2</sup> quadrats; and 2 samples are synthesis samples from respectively 2 and 4 quadrats of 4 m<sup>2</sup>. The data set of the 55 samples included 237 taxa (species occurring in more than one layer are counted as separate "taxa").

The cover scale of all the samples was transformed to the following scale, used for all samples before making the multivariate analysis (the cover values u & l were merged, the respective values on the 9-degree scale are shown in brackets): +(1), s(2), l(4), 2(5), 3(6), 4(7), 5(8), 6(9).

### 9.2.2 Classification

The description of the 11 types of woodland vegetation (clusters W1-11) is based on the results shown in the phytosociological table (Appendix D-Table 1), showing the 55 samples classified into 11 clusters. The basis used for the groupings has been the result of the TABORD classification, with threshold level of 0.44 and a fusion level of 0.7. At a threshold value of 0.5 two of the samples of cluster 11 became split off, to fall into the residual group, all the



		Heathland communities					Grassland communities					
Cluster no.		W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11
No. of samples		2	4	4	4	7	2	9	4	6	9	4
I	<i>Betula pubescens</i> - A	.	75-3	100-3	100-4	100-3	100-4	100-3	100-3	100-3	100-3	25-2
	<i>Betula pubescens</i> - B	.	50-1	100-2	75-1	29-1	.	67-3	50-1	17-1	.	25-1
	<i>Betula pubescens</i>	.	25-1	75-1	.	.	.	.	.	.	.	.
	<i>Solidago virgaurea</i>	100-1	50-1	100-1	100-3	100-2	100-3	100-3	100-2	100-1	89-2	100-1
	<i>Trientalis europaea</i>	50-1	100-1	100-1	100-1	100-1	100-1	78-1	75-1	50-2	78-1	75-1
	<i>Deschampsia flexuosa</i>	100-4	100-3	100-3	100-4	100-5	100-5	100-3	100-3	67-1	78-u	.
	<i>Barbilophozia lycopodioides</i>	50-1	75-2	100-3	100-2	100-3	100-1	100-2	100-2	50-1	78-u	.
II	<i>Carex brunescens</i>	100-1	.	.	.	.	.	.	.	.	.	.
	<i>Aulacomnium palustre</i>	100-1	.	25-1	50-1	.	.	.	50-1	33-s	.	50-2
	<i>Dicranum majus</i>	100-1	50-1	.	.	.	.	.	25-1	.	11-1	.
	<i>Lophozia ventricosa</i>	100-1	50-1	.	25-1	.	.	.	.	.	.	.
	<i>Cladonia arbuscula</i> coll.	100-1	.	50-1	.	.	.	.	.	.	.	.
	<i>Cladonia carneola</i>	100-1	.	.	.	.	.	.	.	.	.	.
	<i>Nephroma arcticum</i>	100-1	.	50-1	.	.	.	.	.	.	.	.
	<i>Barbilophozia kunzeana</i>	100-1	75-1	50-u	.	.	.	11-s	50-1	.	.	.
	<i>Rubus chamaemorus</i>	.	100-1	.	.	.	.	.	.	.	.	.
	<i>Polia nutans</i>	50-1	25-1	75-1	50-1	.	.	11-1	.	17-1	.	.
	<i>Hieracium</i> sect. <i>Piloselloidea</i>	.	50-1	.	100-1	.	.	.	25-1	.	.	.
	<i>Tritomaria quinqueidentata</i>	.	.	50-s	75-1	.	.	11-1	50-2	67-1	.	.
	<i>Gymnocarpium dryopteris</i>	.	.	.	.	88-4	100-5	11-1	50-2	17-s	.	.
	<i>Listera cordata</i>	.	.	25-1	50-s	86-1	100-u	.	25-s	33-s	.	50-1
	<i>Cicerbita alpina</i>	.	.	.	25-0	57-s	100-1	.	25-s	17-s	67-2	50-1
	<i>Convallaria majalis</i>	.	.	.	.	.	100-2	11-s	.	.	.	.
	<i>Maianthemum bifolium</i>	.	.	.	25-3	57-3	100-2	11-1	25-1	.	.	.
	<i>Ranunculus platanifolius</i>	.	.	.	.	43-1	100-3	33-u	.	.	.	.
	<i>Silene dioica</i>	.	.	.	.	.	100-u	67-u	.	.	11-1	.
	<i>Milium effusum</i>	.	.	.	.	29-s	100-2	33-1	.	.	56-1	.
	<i>Pyrola rotundifolia</i>	.	.	.	.	14-1	50-1	100-1	50-1	33-1	11-1	50-2
	<i>Rubus saxatilis</i>	.	.	.	.	14-s	.	78-1	.	17-s	22-u	.
	<i>Rhinanthus minor</i>	.	.	25-s	.	.	50-1	89-u	100-1	.	.	.
	<i>Selaginella selaginoides</i>	.	.	25-1	.	.	.	89-2	100-1	50-2	11-1	.
	<i>Luzula multiflora</i>	.	.	.	50-1	29-1	50-1	78-1	75-1	33-1	.	.
	<i>Phleum alpinum</i>	.	.	.	.	14-1	50-1	78-1	100-1	50-u	44-s	.
	<i>Pedicularis oederi</i>	.	.	.	.	.	.	11-s	75-1	17-2	.	.
	<i>Molinia caerulea</i>	.	.	.	25-1	14-1	.	.	75-2	50-1	.	25-0
	<i>Bartsia alpina</i>	.	.	.	.	.	.	67-1	100-1	83-u	.	50-u
	<i>Leontodon autumnalis</i>	.	.	.	.	.	.	75-1	83-1	.	.	.
	<i>Succisa pratensis</i>	.	.	25-1	.	14-1	.	.	100-2	100-2	.	25-2
	<i>Luzula sudetica</i>	.	.	.	.	.	.	11-1	100-1	83-1	33-s	25-1
	<i>Drepanocladus uncinatus</i>	.	.	25-1	25-1	.	.	11-1	100-1	83-1	44-u	50-1
	<i>Lophocolea bidentata</i>	.	.	.	.	.	.	11-1	75-2	83-1	22-u	.
	<i>Carex nigra</i>	.	25-s	.	.	.	.	.	.	83-u	11-s	50-1
	<i>Campylopus stellatus</i>	.	.	.	.	.	.	11-1	25-2	100-3	44-u	25-1
	<i>Climacium dendroides</i>	.	.	.	.	.	.	22-2	50-1	83-2	67-u	.
	<i>Fissidens adianthoides</i>	.	.	.	.	.	.	11-1	25-1	83-u	.	.
	<i>Galium boreale</i>	.	.	.	.	.	.	33-3	50-2	100-1	78-u	50-1
	<i>Aconitum septentrionale</i>	.	.	.	.	.	.	67-u	.	.	100-4	.
	<i>Angelica archangelica</i>	.	.	.	.	.	.	11-0	.	.	100-2	25-0
	<i>Paris quadrifolia</i>	.	.	.	.	.	.	56-u	.	67-u	100-1	25-1
	<i>Poa nemoralis</i>	.	.	.	.	.	.	44-1	.	67-2	100-2	.
	<i>Mnium stellare</i>	.	.	.	.	.	.	.	.	17-s	89-1	.
	<i>Salix glauca</i>	.	.	.	.	.	.	33-u	.	50-u	22-s	75-1
	<i>Caltha palustris</i>	.	.	.	.	.	.	.	.	17-s	.	75-3
	<i>Epilobium palustre</i>	.	.	.	.	.	.	.	.	.	.	100-1
	<i>Equisetum sylvaticum</i>	.	.	.	.	.	.	.	.	67-u	44-1	75-1
	<i>Calamagrostis purpurea</i>	.	.	.	.	.	.	.	.	.	44-3	100-1

Table 9.2.2 continued

Cluster no. No. of samples	Heathland communities						Grassland communities				
	W1 2	W2 4	W3 4	W4 4	W5 7	W6 2	W7 9	W8 4	W9 6	W10 9	W11 4
<i>Bryum weigelii</i>	.	.	.	.	.	.	22-u	.	33-1	22-u	75-1
<i>Plagiommium ellipticum</i>	.	.	.	.	.	.	.	.	33-u	.	75-3
<i>Sphagnum warnstorffii</i>	.	.	.	.	.	.	.	.	67-u	11-1	100-4
<i>Aneura pinguis</i>	.	.	.	.	.	.	.	.	.	11-1	75-1
<i>Marchantia alpestris</i>	.	.	.	.	.	.	.	.	.	11-1	75-2
III											
<i>Potentilla erecta</i>	100-1	.	50-1	100-2	71-1	.	78-1	75-3	100-2	.	25-1
<i>Festuca ovina</i>	100-1	.	50-1	.	43-1	.	11-s	75-1	50-1	.	25-1
<i>Nardus stricta</i>	100-5	100-4	100-1	100-4	71-2	50-1	44-1	100-2	100-2	.	.
<i>Dicranum scoparium</i>	100-1	100-1	100-1	100-2	86-2	100-1	56-2	100-1	67-u	.	.
<i>Pleurozium schreberi</i>	100-3	100-1	100-4	100-2	100-2	50-1	44-2	100-1	.	.	.
<i>Polytrichum commune</i>	100-2	100-5	75-2	100-3	100-3	100-2	11-1	100-2	.	.	.
<i>Polytrichum juniperinum</i>	100-5	100-3	75-1	25-1	57-1	.	56-1	25-1	.	11-1	.
<i>Sphagnum russowii</i>	100-1	100-3	.	25-4	.	.	.	75-2	.	.	.
<i>Barbilophozia floerkei</i>	100-2	100-2	25-4	100-4	.	.	.	50-2	50-1	.	.
<i>Vaccinium myrtillus</i>	.	75-1	100-3	100-3	100-1	100-1	89-1	100-1	33-u	44-s	.
<i>Vaccinium vitis-idaea</i>	.	100-1	100-2	25-1	86-2	.	56-2	.	.	.	25-1
<i>Juniperus communis</i> - B	.	.	100-4	100-1	86-4	100-1	56-1	50-2	17-1	22-u	.
<i>Empetrum hermaphroditum</i>	.	.	100-4	25-1	71-1	.	22-u	50-u	.	.	.
<i>Melampyrum pratense</i>	.	.	100-1	25-1	100-2	100-2	56-1	100-1	17-1	.	.
<i>Brachythecium reflexum</i>	.	.	75-u	.	100-1	100-1	89-2	25-1	17-1	100-2	75-1
<i>Hylocomium splendens</i>	.	25-1	100-3	75-1	86-1	.	89-2	100-3	100-1	67-1	25-1
<i>Anthoxanthum odoratum</i>	.	.	50-u	100-1	100-2	100-2	89-2	100-2	100-2	89-1	50-2
<i>Luzula pilosa</i>	.	.	50-1	75-1	100-2	100-1	67-1	50-1	33-1	.	.
<i>Lophozia obtusa</i>	.	.	.	75-2	100-1	100-1	89-1	50-1	.	67-u	75-2
<i>Dactylorhiza fuchsii</i>	.	.	.	.	71-u	100-1	56-u	75-1	100-u	67-u	.
<i>Geranium sylvaticum</i>	.	.	25-1	.	86-1	50-1	100-5	100-3	100-4	100-4	100-3
<i>Gnaphalium norvegicum</i>	.	.	.	25-1	71-1	50-1	89-1	100-1	.	89-1	.
<i>Melampyrum sylvaticum</i>	.	.	25-1	.	71-u	100-2	89-1	100-1	33-1	67-1	50-1
<i>Oxalis acetosella</i>	.	.	.	.	71-1	100-1	44-u	.	.	78-2	.
<i>Brachythecium salebrosum</i>	.	.	25-1	.	86-1	100-4	100-2	25-1	.	100-3	.
<i>Rhodobryum roseum</i>	.	.	.	.	100-1	100-2	100-2	100-2	100-2	100-1	25-4
<i>Euphrasia frigida</i>	.	.	.	25-1	29-1	100-u	56-1	75-u	67-u	.	50-u
<i>Hieracium</i> spp.	.	.	25-1	.	43-1	100-1	78-1	100-1	50-1	44-1	.
<i>Polygonum viviparum</i>	.	.	.	25-1	29-u	100-1	89-1	100-1	100-1	78-u	25-2
<i>Pyrola minor</i>	.	.	.	.	.	100-1	89-1	75-1	83-1	56-1	25-1
<i>Rumex acetosa</i>	.	.	.	25-s	57-1	100-1	78-1	75-1	67-u	100-1	100-1
<i>Viola biflora</i>	.	.	25-s	.	.	100-u	89-3	25-1	.	100-2	.
<i>Mnium spinosum</i>	.	.	25-2	.	14-1	100-1	100-2	.	17-1	100-3	.
<i>Salix glauca</i> - B	.	.	.	.	.	.	78-1	75-2	.	67-1	100-4
<i>Alchemilla</i> spp.	.	.	.	.	.	.	100-3	100-2	100-4	100-3	100-3
<i>Filipendula ulmaria</i>	.	.	.	.	.	.	78-1	.	83-1	100-2	100-3
<i>Geum rivale</i>	.	.	.	.	.	.	78-1	25-1	100-2	100-2	100-3
<i>Myosotis decumbens</i>	.	.	.	.	.	.	78-u	.	33-s	89-1	.
<i>Parnassia palustris</i>	.	.	.	.	.	.	78-1	25-1	100-1	56-s	50-2
<i>Ranunculus acris</i>	.	.	.	.	.	.	100-1	50-1	100-2	100-1	50-u
<i>Saussurea alpina</i>	.	.	.	.	.	.	89-2	75-1	83-3	89-1	100-2
<i>Thalictrum alpinum</i>	.	.	.	.	.	.	78-1	25-3	100-3	.	.
<i>Agrostis capillaris</i>	.	.	25-1	50-1	43-1	.	89-2	100-3	100-2	89-2	.
<i>Carex vaginata</i>	.	.	25-1	50-s	14-s	50-1	78-1	100-1	100-2	.	50-2
<i>Deschampsia cespitosa</i>	.	.	.	50-1	14-1	.	89-3	100-3	100-4	100-3	100-2
<i>Festuca rubra</i>	.	.	.	.	.	.	89-1	25-1	83-1	44-u	.
<i>Crepis paludosa</i>	.	.	.	.	.	.	22-1	100-1	100-3	100-3	100-2
<i>Rhytidiadelphus</i> sq./subpinnatus	.	.	.	25-1	.	.	22-1	75-1	83-3	100-2	.
<i>Plagiochila porelloides</i>	.	.	.	.	14-1	.	56-u	75-1	100-2	100-2	25-1
<i>Angelica sylvestris</i>	.	.	.	.	.	.	44-u	50-1	83-1	22-u	100-1
<i>Rhizomnium magnifolium</i>	.	.	.	.	.	.	.	.	83-1	44-1	75-3
<i>Chiloscyphus pallescens</i>	.	.	.	.	.	.	.	.	100-2	44-2	100-1
<i>Pellia neesiana</i>	.	.	.	.	.	.	.	.	83-1	44-2	100-3

other clusters remained unchanged. One exception has been made to the TABORD groupings, sample no. 22 has been assigned to cluster 7, not to cluster 10 (cf. the comments made in the description of type 7). The table order is that given by the FLEXCLUS program, with subjective ordering of the clusters (chosen after studying the DCA diagrams, TWINSpan dendrograms etc.), and polar ordination within the clusters (shown in Table 1 of Appendix D). The order of the species shown in the table is that given by the FLEXCLUS program (with minor rearrangement by hand), showing two diagonal structures with a level of 70% for constant species; table 9.2.2 shows the 114 taxa occurring as constants in at least one cluster.

Figure 9.2.1 shows the degrees of similarity within and between the clusters of the woodland types. Figure 9.2.2 shows the TABORD dendrogram for the 11 clusters (really 12), progressively agglomerating. Figure 9.2.3 shows the TWINSpan dendrogram obtained using the divisive technique.

The dendrograms derived by both the agglomerative classification technique and the divisive technique indicate the major split between the samples belonging to the heathland and the grassland series. Both dendrograms also classify the samples and clusters more or less in the same manner.

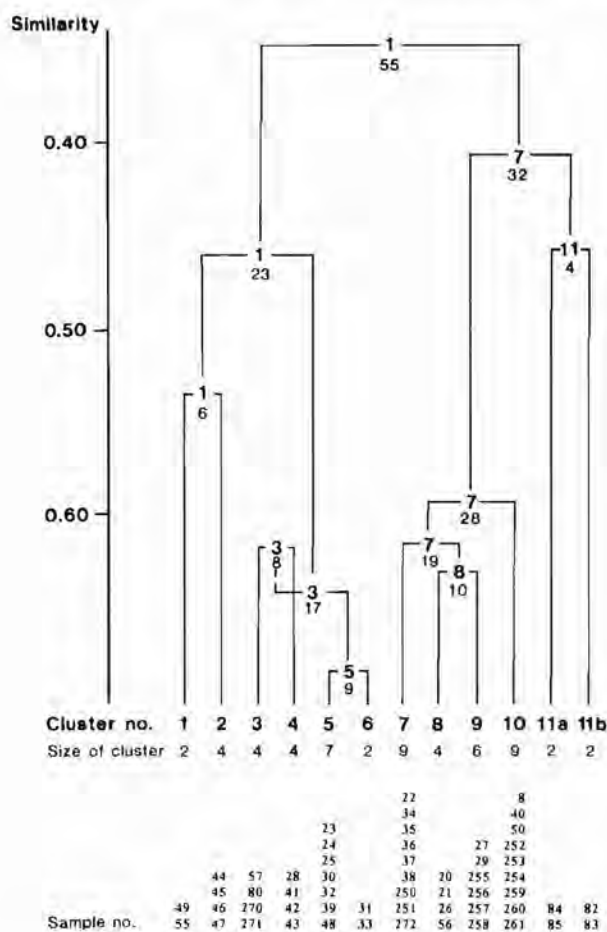


Fig. 9.2.2

TABORD dendrogram of the clusters of the 55 samples of woodland vegetation at Sølendet. The starting clusters (W1-11b) are identical with the clusters shown in tables 9.2.1-2, i.e. the TABORD clusters for threshold and fusion levels of 0.44 and 0.70, respectively, with one exception: sample 22 is grouped with cluster 7. The dendrogram shows how the starting clusters agglomerate, using threshold and fusion levels of 0. Sample 22 was the only one that changed cluster during the relocation process. Index: similarity ratio.

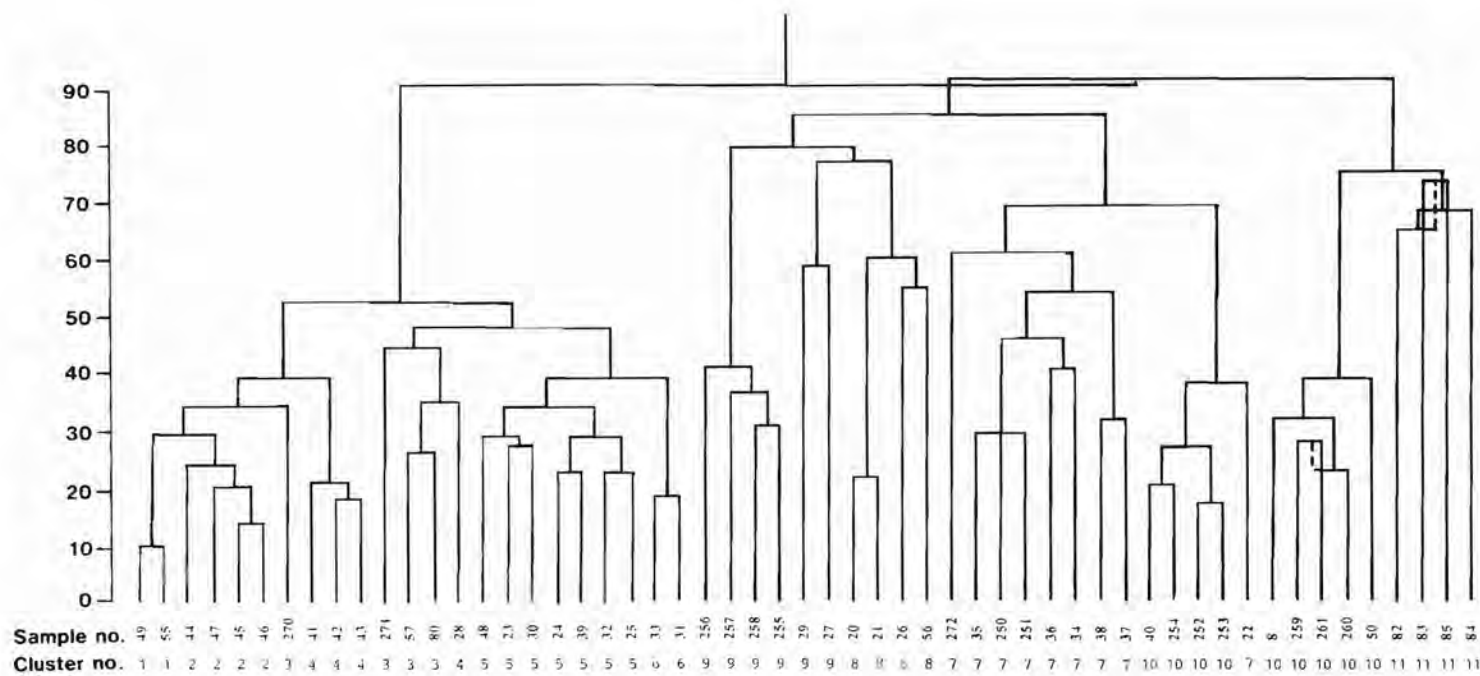


Fig. 9.2.3 TWINSpan dendrogram of the 55 samples of woodland vegetation at Sølendet. Seven levels of division were used, after which all except one cluster (viz. samples 35, 250 and 251) split into single or double members. The ordinate shows the heterogeneity within the clusters. Cluster no. refers to the TABORD clusters W1-11 (Table 9.2.2).

### 9.2.3 Ordination

Figure 9.2.4 shows the results of the DCA ordination, for axes 1 & 2 and 1 & 3. The clusters have been delimited by hand and assigned cluster numbers. The species ordination diagrams are shown in figure 9.2.5, only the occurrence near the ends of the axes of a few typical and common species will be mentioned.

**The first axis** (eigenvalue 0.51, length 4.5 s.d.) represents a gradient from rich willow grasslands to wooded grasslands, further to wooded small-fern communities; poor heathlands are to be found furthest right. Species ordination of this axis shows low values for *Salix* spp. (e.g. *S. pentandra*), *Carex dioica* and *Sphagnum warnstorffii*; high values for *Vaccinium* spp., *Rubus chamaemorus*, *Carex brunnescens*, *Cladina arbuscula* coll. and *Nephroma arcticum*. This first axis mainly represents a rich to poor gradient for communities on mineral soil.

**The second axis** (eigenvalue 0.22, length 2.1 s.d.; when sample 27 is excluded, however, the length is only 1.7) distinguishes between xerophilous-mesophilous communities with low values, and more hygrophilous communities with high values. Species characterizing dry habitats occur with low values, e.g. the following (with values less than -1.0 s.d.): *Achillea millefolium*, *Convallaria majalis* and *Mnium spinosum*. Fen species and species of damp soil and peat are most common among the high-value species, e.g. the following (with values over 3.0 s.d.): *Pedicularis oederi*, *Succisa pratensis*, *Molinia caerulea* and *Fissidens adianthoides*. The axis mainly represent a dry-wet gradient.

**The third axis** (eigenvalue 0.18, length 2.4 s.d.; when sample 270 is excluded the length is 2.0) is not so easy to characterize in terms of a single vegetational gradient, but it is nevertheless important because, for example, it separates the samples of cluster 2 (with low values) from those of clusters 1, 3 and 4. *Rubus chamaemorus* has the lowest value (-2.2 s.d.) of the common species in the data set, and another large number of damp-site indicators (e.g. *Sphagnum russowii*) have low values; but also some dry habitat species (e.g. *Convallaria majalis*) have minus-values. In contrast, a number of more xerophilous species occur with high values on this axis (most of the lichen species, e.g. *Cladina arbuscula* coll., *Nephroma arcticum*; *Festuca ovina* etc.); but also species indicating damp habitats (e.g. *Succisa pratensis* and *Aulacomnium palustre*) are among the species with high values. Axis 3 has elements of a wet-dry gradient, but it is certainly complex.

**Axis no. 4** (eigenvalue 0.12, length 2.0 s.d.; when excluding the three most peripheral samples, the length is only 1.0 s.d) has not been presented in any figure. Different samples of cluster 11 make up the samples with the lowest values (i.e. no. 83) and the highest values (i.e. samples 84 and 85) along this gradient, and it is not possible to find any main habitat gradient correlated with sample/species distribution along this axis.

In the DCA diagrams the grassland types fall on the left and the heathlands on the right-hand sides of the diagrams, completing the main picture of separating the grassland and heathland communities in the classification.



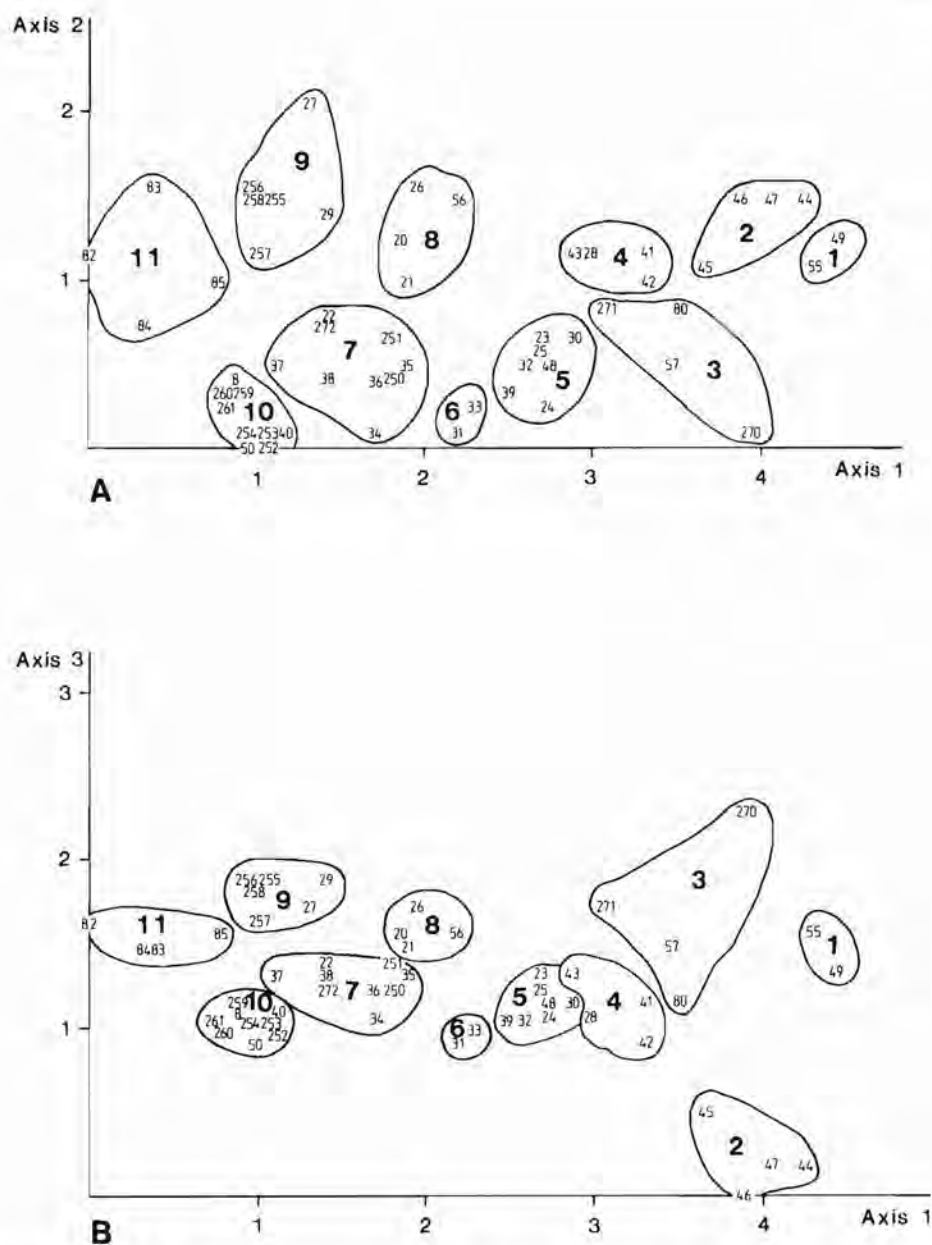
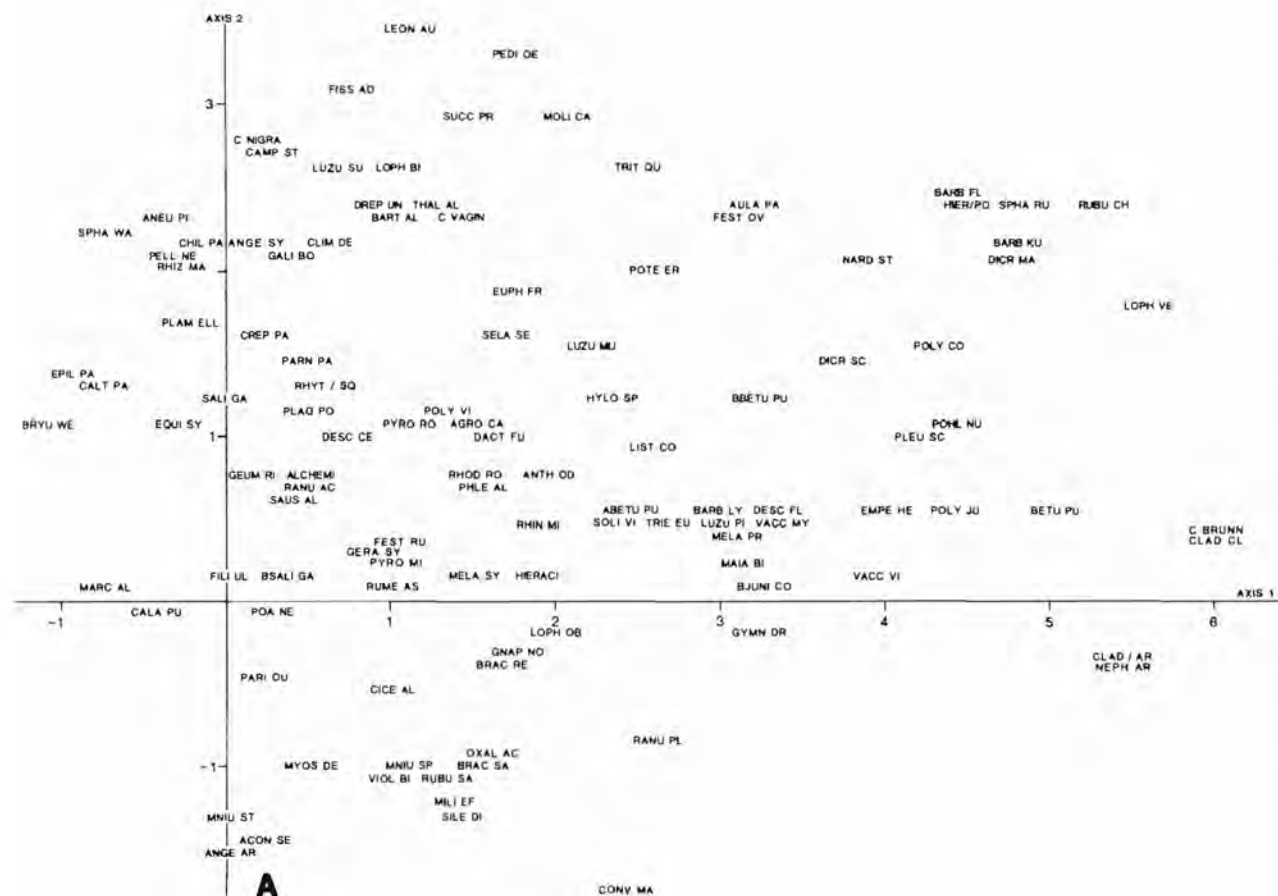


Fig. 9.2.4

DCA-ordination diagrams of the 55 woodland samples at Sølend-  
et. A: axes 1 & 2; B: axes 1 & 3. Eigenvalues of the axes: 1:  
0.508; 2: 0.216; 3: 0.175. Sample and cluster numbers (nos. 1-  
11, delimited by hand) as in tables 9.2.1-2.



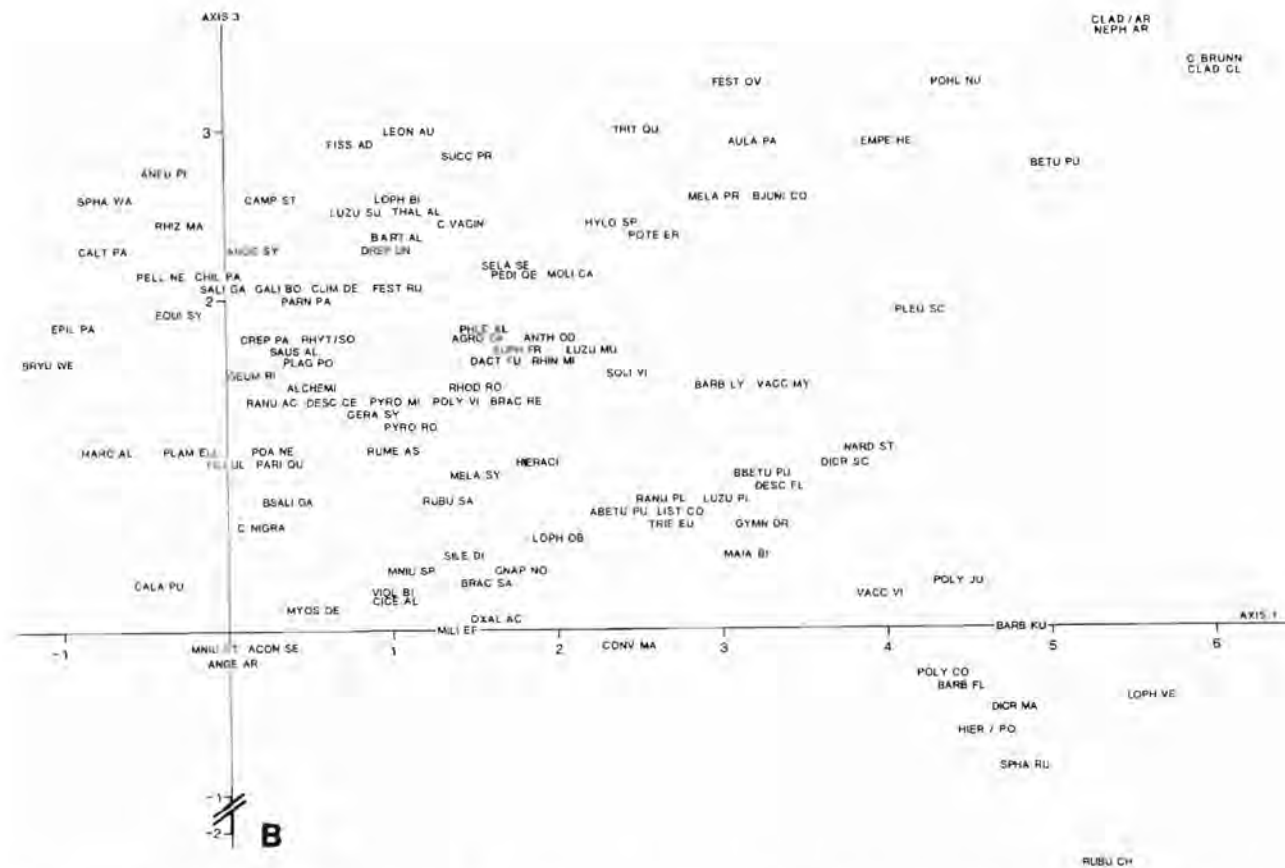


Fig. 9.2.5

DCA-ordination diagrams of the species (all constant species in any cluster) for the woodland samples (shown in Fig. 9.2.4). A: axes 1 & 2; B: axes 1 & 3. Species in the shrub and tree layers are entered separately (B and A prefixes, respectively); 114 entries altogether. Species s.lat. marked /. Abbreviations: Appendix F.

## 9.3 MULTIVARIATE ANALYSES OF THE OPEN GRASSLAND VEGETATION

## 9.3.1 The full data set

34 samples are dealt with in this section. They include areas of open dry grassland, transitional types between grassland and rich heathland, scrub-covered damp grassland and transitional communities between grassland and fen vegetation.

All the samples represent analyses of small quadrats of 0.25-4 m<sup>2</sup> (cf. details shown in Table 9.3.1.). As many as 22 of the 34 samples have also been included

Tab. 9.3.1 Details of the 34 stands/small quadrats used for the analyses of open grassland vegetation. Cluster no. (01-5) refers to that shown in Appendix D-table 2 and table 9.3.2. C = cover; Cl. = cluster; H. = height in.; R = residual sample.

Cl. no.	Stand sample no.	Locality & stand quadrat	No. x size in m <sup>2</sup> of quadrats	Tree layer		Shrub layer		Field layer		Bottom layer cover	Litter cover
				C.	H. m	C.	H. cm	C.	H. cm		
01	075	75	1x1	-	-	-	-	6	15	5	6
	076	76	1x0.25	-	-	-	-	6	15	5	-
	077	77	1x1	-	-	s	40	6	5	5	-
	078	78	1x1	-	-	-	-	6	5	4	-
	079	79	1x1	-	-	-	-	6	15	5	-
	287	81 q1	1x1	-	-	3	40	6	15	5	3
	288	81 q2	1x1	-	-	+	-	5	15	6	2
	289	81 q3	1x1	-	-	4	40	6	15	5	3
02	054	54	2x1	-	-	-	-	66	15	34	66
	088	88	1x1	-	-	2	100	6	15	6	3
	273	prf1 q5-6	2x0.9	-	-	-	-	65	-	45	33
	290	prf1 q18	1x1.8	-	-	3	50	6	-	4	5
	291	prf1 q19	1x0.7	-	-	+	-	6	-	4	6
	292	prf1 q20	1x0.7	-	-	+	-	6	-	5	5
	293	prf1 q7	1x1.9	-	-	-	-	6	-	5	4
	294	prf1 q8	1x1	-	-	-	-	5	-	5	4
03	074	74A+B	5x0.25	-	-	55525	65	34555	40	32242	66666
	101	101	3x0.25	-	-	++3	60	655	20	566	543
	102	102+101	3x0.25	-	-	+2+	55	555	20	666	454
	191	74a	2x0.25	-	-	-	-	54	15	12	66
	192	74c	2x0.25	-	-	45	75	55	40	2u	66
04	072	72	2x0.25	4	12	-	-	66	40	45	32
	086	86	2x0.25	+	-	-	-	56	30	55	42
05	005	5A+B	4x0.25	1	10	+1++	50	6666	50	5443	2232
	084	84	1x4	-	-	6	150	6	50	3	5
	085	85	1x4	2	5	6	150	5	50	6	5
	103	103	1x4	-	-	3	160	3	40	6	3
	281	82 q1	1x4	2	4	5	150	5	40	6	2
	282	82 q2	1x4	1	3	4	150	5	40	6	3
	283	82 q3	1x4	1	3	5	150	5	40	6	3
	284	82 q4	1x4	1	3	5	150	5	40	6	2
	285	83 q1	1x4	4	5	3	50	5	30	6	2
	286	83 q2	1x4	4	5	4	60	5	30	6	2
R	277	prf1 q15	1x4	3	4	5	200	5	-	6	5

as samples, or small quadrats of synthesis samples, in the treatments of woodland and/or mire types (i.e. sample nos. 74, 84, 85, 101-103, 192, 277, 281-294). Ten of the samples are synthesis samples from 2-5 small quadrats. The other 24 are single quadrat samples, usually of 1-4 m<sup>2</sup>, but with three from quadrats of less than 1 m<sup>2</sup>, (nos. 76: 0.25 m<sup>2</sup>; 291: 0.7 m<sup>2</sup>; 292: 0.7 m<sup>2</sup>). The data for the three localities (nos. 81, 82, 83) represented by more than one quadrat of 1-4 m<sup>2</sup> have been split up in the analytical treatments, each of the quadrats being considered as a separate sample (i.e. nos. 281-289).

Sample no. 5 is a synthesis sample of four small-sized quadrats analysed within a 25 m<sup>2</sup> quadrat, the entire data for which represent the large quadrat no. 258 (this sample is included in cluster W9 of the woodland types).

Seven of the samples (nos. 273, 277, 290-294) are quadrat analyses taken from the main profile in Vassdalen. A further group of samples are from the south-eastern part of Sølendet, in areas established to study the ecology of interesting species, viz. nos. 54, 75, 77, 81 and 88 (*Nigritella nigra*), 76 and 79 (*Botrychium lanceolatum*), and 78 (*Botrychium multifidum*).

As described above, the samples dealt with in this section are a heterogeneous set. Some of the quadrats analysed are too small to cover the minimal area of the community they represent. This is obvious in the case of e.g. samples 76, 78 and 79, because these were mainly intended to include the occurrences of the particular species being studied. Nevertheless, all these samples represent homogeneous areas of vegetation.

The full data set (34 samples) included 246 taxa (species occurring in more than one layer are counted as separate taxa).

In the multivariate treatment of the data set of the 34 samples, the cover values of all samples have been transformed to the same scale (transformed values of the original 9-degree scale shown in brackets): + (1), 1 (4), 2 (5), 3 (6), 4 (7), 5 (8), 6 (9).

### 9.3.2 Classification

A number of TABORD trials, using different sets of samples, different threshold and fusion levels, different sizes of cluster, etc. were made. The final classification adopted has also been influenced by the results of the TWINSpan and DCA analyses.

The phytosociological tables (Appendix D-Table 2 and Table 9.3.2) show the 33 samples grouped into 5 separate clusters. The limit for constant species is 60%, and 112 taxa occur as constants in at least one cluster. The residual sample (no. 277) of the TABORD trial (threshold and fusion levels 0.30 and 0.45 respectively), was omitted from the FLEXCLUS trial when the table was made.



Table 9.3.2 Synoptic table of the open grassland vegetation at Sølendet, showing species frequency and characteristic degree of cover. Only species occurring as constants (limit 60%) in at least one cluster are listed. Table 2 of Appendix D has a complete list of species, with cover values for the 33 samples classified into 5 clusters. I. Indifferent species. II. Constant species of one or two neighbouring clusters. III. Constant species of other clusters. A: tree layer; B: shrub layer.

Cluster no.	01	02	03	04	05
No. of samples	8	8	5	2	10
I <i>Geranium sylvaticum</i>	88-2	75-1	100-1	100-5	100-3
<i>Saussurea alpina</i>	88-2	100-3	100-2	100-2	100-2
II <i>Salix phylicifolia</i>	63-1	50-2	.	.	20-u
<i>Vaccinium vitis-idaea</i>	75-1	25-1	.	.	10-1
<i>Achillea millefolium</i>	88-3	.	.	50-0	.
<i>Antennaria dioica</i>	100-2	25-1	40-1	.	.
<i>Botrychium lunaria</i>	88-u	.	.	.	.
<i>Campanula rotundifolia</i>	75-1	.	.	50-0	.
<i>Erigeron boreale</i>	63-u	.	40-0	.	.
<i>Gentiana nivalis</i>	88-u	.	.	.	.
<i>Nigritella nigra</i>	63-1	38-1	.	.	.
<i>Potentilla crantzii</i>	63-u	.	.	.	.
<i>Viola montana</i>	63-1	.	.	.	.
<i>Luzula multiflora</i>	63-u	38-1	.	50-0	.
<i>Bryum</i> sp.	88-1	38-1	.	.	10-1
<i>Dicranum muehlenbeckii</i>	63-1	.	.	.	.
<i>Dicranum scoparium</i>	63-1	.	.	.	.
<i>Drepanocladus uncinatus</i>	63-1	50-1	.	50-3	50-u
<i>Hylocomium pyrenaicum</i>	88-1	38-2	60-1	.	10-1
<i>Pleurozium schreberi</i>	88-2	50-2	60-2	.	.
<i>Polytrichum juniperinum</i>	75-1	.	.	.	.
<i>Tortula ruralis</i>	88-3	.	.	.	.
<i>Barbilophozia barbata</i>	63-1	.	.	50-1	.
<i>Ptilidium ciliare</i>	88-1	13-1	.	.	.
<i>Cladonia furcata</i>	88-1	.	.	.	.
<i>Peltigera canina</i>	63-1	.	.	.	.
<i>Peltigera leucophlebia</i>	63-2	.	.	.	.
<i>Leontodon autumnalis</i>	75-1	63-1	40-1	.	10-1
<i>Rhinanthus minor</i>	88-1	75-1	.	50-0	.
<i>Nardus stricta</i>	63-2	100-3	40-1	50-0	20-1
<i>Pedicularis oederi</i>	13-2	75-1	40-1	.	.
<i>Viola palustris/epipsila</i>	.	63-1	.	.	30-1
<i>Scirpus cespitosus</i>	.	63-2	60-3	.	.
<i>Aulacomnium palustre</i>	50-1	100-3	.	.	30-2
<i>Dicranum bonjeanii</i>	.	88-1	20-1	.	.
<i>Homalothecium nitens</i>	.	88-3	60-1	.	20-u
<i>Rhizomnium pseudopunctatum</i>	.	100-2	.	.	10-1
<i>Tritomaria quinqueidentata</i>	13-1	100-2	60-1	.	10-1
<i>Betula nana</i>	.	75-1	100-3	.	20-1
<i>Gymnadenia conopsea</i>	.	63-u	100-1	.	40-0
<i>Succisa pratensis</i>	50-2	63-3	100-3	50-0	40-2
<i>Carex dioica</i>	.	63-1	80-1	.	20-u
<i>Carex panicea</i>	.	63-2	80-2	.	.
<i>Betula nana</i> - B	.	13-1	80-4	.	20-u
<i>Equisetum variegatum</i>	.	.	80-1	.	10-1
<i>Listera ovata</i>	.	.	80-u	.	10-1
<i>Potentilla erecta</i>	38-u	25-2	100-1	.	30-2
<i>Carex capillaris</i>	50-1	50-1	100-1	.	.
<i>Molinia caerulea</i>	13-1	13-1	100-3	.	30-u
<i>Campylium stellatum</i>	.	50-1	100-4	50-1	60-1
<i>Fissidens adianthoides</i>	.	13-2	80-1	.	20-1
<i>Betula pubescens</i> - A	.	.	.	100-0	20-1
<i>Angelica archangelica</i>	.	.	.	100-0	40-0
<i>Cicerbita alpina</i>	.	.	.	100-1	20-1

Table 9.3.2 continued

Cluster no.	01	02	03	04	05
No. of samples	8	8	5	2	10
<i>Dactylorhiza fuchsii</i>	.	.	.	100-0	10-1
<i>Gnaphalium norvegicum</i>	.	.	.	100-1	.
<i>Hieracium sect. Vulgata</i>	.	.	.	100-2	.
<i>Myosotis decumbens</i>	.	.	.	100-1	.
<i>Pyrola minor</i>	13-1	25-1	.	100-u	20-1
<i>Pyrola rotundifolia</i>	13-1	.	.	100-1	60-2
<i>Viola biflora</i>	13-1	.	.	100-3	.
<i>Carex atrata</i>	13-1	.	.	100-0	.
<i>Festuca rubra</i>	.	38-1	.	100-u	20-1
<i>Luzula sudetica</i>	.	50-1	20-0	100-u	40-1
<i>Phleum alpinum</i>	.	25-u	.	100-2	10-0
<i>Mnium stellare</i>	.	.	.	100-2	.
<i>Rhodobryum roseum</i>	38-1	.	.	100-2	20-3
<i>Plagiochila porelloides</i>	.	.	20-1	100-2	50-1
<i>Bartsia alpina</i>	.	38-1	40-0	100-u	70-u
<i>Coeloglossum viride</i>	.	13-0	.	100-u	70-u
<i>Filipendula ulmaria</i>	.	38-3	20-0	100-0	100-3
<i>Geum rivale</i>	.	38-2	20-0	100-2	100-3
<i>Rumex acetosa</i>	.	.	.	100-2	100-1
<i>Salix glauca</i> - B	.	13-2	.	.	90-3
<i>Salix glauca</i>	.	38-2	20-0	50-1	90-1
<i>Caltha palustris</i>	.	.	.	.	70-2
<i>Epilobium palustre</i>	.	.	.	.	90-1
<i>Equisetum sylvaticum</i>	.	.	.	.	70-1
<i>Calamagrostis purpurea</i>	.	.	.	.	90-1
<i>Carex nigra</i>	.	50-1	.	.	80-2
<i>Hierochloa odorata</i>	.	13-1	.	.	70-u
<i>Bryum pseudotriquetrum</i>	.	13-1	60-1	.	70-1
<i>Bryum weigelii</i>	.	.	.	.	70-1
<i>Rhizomnium magnifolium</i>	.	.	.	.	80-3
<i>Aneura pinguis</i>	.	38-1	20-1	.	80-1
<i>Chiloscyphus pallescens</i>	.	.	.	.	100-2
<i>Marchantia alpestris</i>	.	.	.	50-1	70-1
<i>Pellia neesiana</i>	.	.	.	.	100-3
III <i>Alchemilla</i> sp.	63-1	38-2	.	100-4	100-3
<i>Euphrasia frigida</i>	75-1	.	.	100-u	80-u
<i>Galium boreale</i>	63-1	38-1	60-2	100-1	80-1
<i>Polygonum viviparum</i>	100-2	100-2	100-1	100-1	40-1
<i>Ranunculus acris</i>	100-1	25-1	20-1	100-1	80-u
<i>Selaginella selaginoides</i>	100-2	75-1	80-1	50-1	10-1
<i>Solidago virgaurea</i>	88-2	38-1	.	100-2	90-u
<i>Thalictrum alpinum</i>	75-3	88-3	100-3	50-1	20-2
<i>Agrostis capillaris</i>	88-1	75-1	.	100-3	10-3
<i>Anthoxanthum odoratum</i>	75-1	75-2	20-0	100-1	50-1
<i>Carex vaginata</i>	100-1	88-2	80-1	.	50-2
<i>Deschampsia flexuosa</i>	88-2	25-1	.	100-1	20-1
<i>Festuca ovina</i>	100-1	38-2	100-1	.	20-1
<i>Brachythecium salebrosum</i>	75-1	.	.	100-2	.
<i>Hylocomium splendens</i>	88-3	38-2	40-u	100-1	20-1
<i>Mnium spinosum</i>	75-2	.	.	100-3	.
<i>Barbilophozia lycopodioides</i>	75-2	75-2	60-1	100-1	.
<i>Equisetum palustre</i>	.	75-1	20-1	.	70-2
<i>Parnassia palustris</i>	13-1	75-1	20-0	100-u	80-2
<i>Deschampsia cespitosa</i>	38-2	63-3	100-2	100-2	100-2
<i>Plagiomnium ellipticum</i>	.	88-2	.	.	90-3
<i>Sphagnum warnstorffii</i>	.	100-4	.	.	100-4
<i>Angelica sylvestris</i>	.	13-1	100-u	50-1	100-1
<i>Crepis paludosa</i>	50-u	.	100-u	100-3	100-3

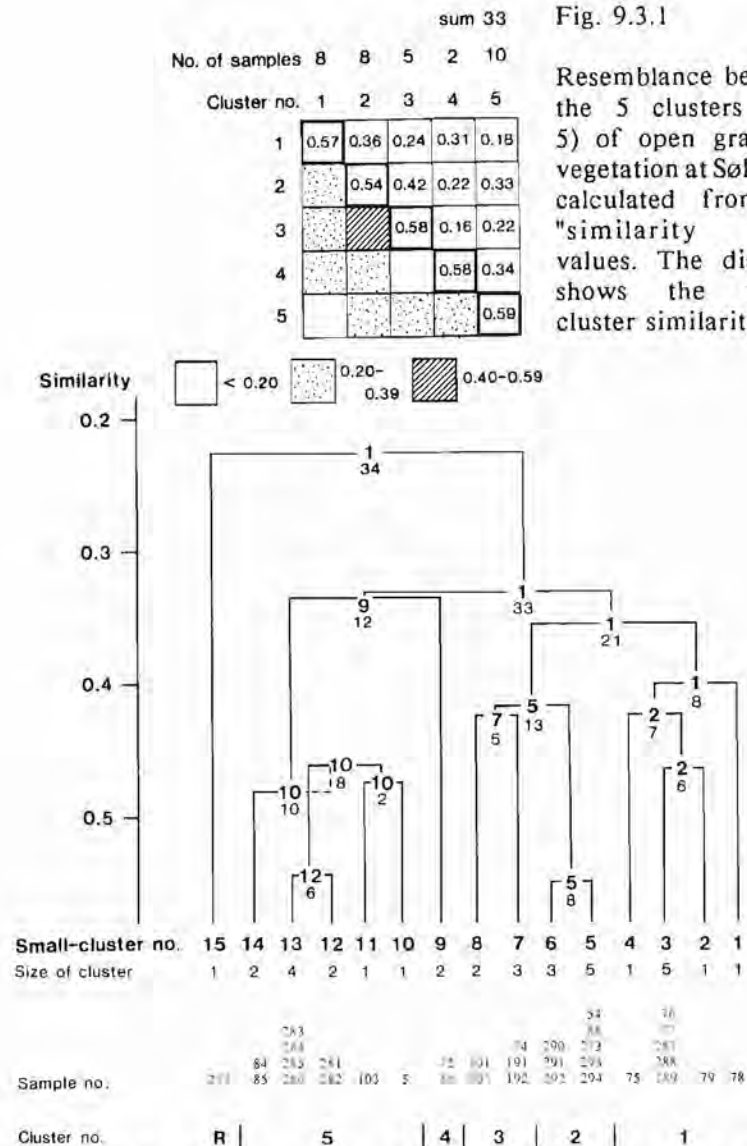


Fig. 9.3.2

TABORD dendrogram of the clusters of the 34 samples of open grassland vegetation at Sølendet. The initial 15 "small-clusters" are separated at a fusion level of 0.55 (threshold level 0.3), and the diagram shows how they agglomerate using threshold and fusion levels of 0. No sample changed cluster during the relocation process. Cluster no. refers to the clusters (01-5) of table 9.3.2. Index: similarity ratio. R = residual sample.

Figure 9.3.1 shows the degrees of similarity within and between the five clusters. Figure 9.3.2, the TABORD dendrogram, shows the structure of clusters for different values of similarity (= fusion levels). The dendrogram shows how the 15 "small-clusters" (four of the five described clusters were split up into more homogeneous parts) agglomerate, using threshold and fusion levels of 0. The 15 "small-clusters" were separated at a similarity value of ca. 0.55; the 5 clusters separated at a similarity value of ca. 0.42; and at a similarity value of ca. 0.32 all the clusters became united into one large cluster (sample 277 not included, it became united at a similarity of 0.22). The TWINSpan dendrogram (Fig. 9.3.3) also shows the inter-relationships of the samples and clusters. Both dendrograms yielded a similar structure.

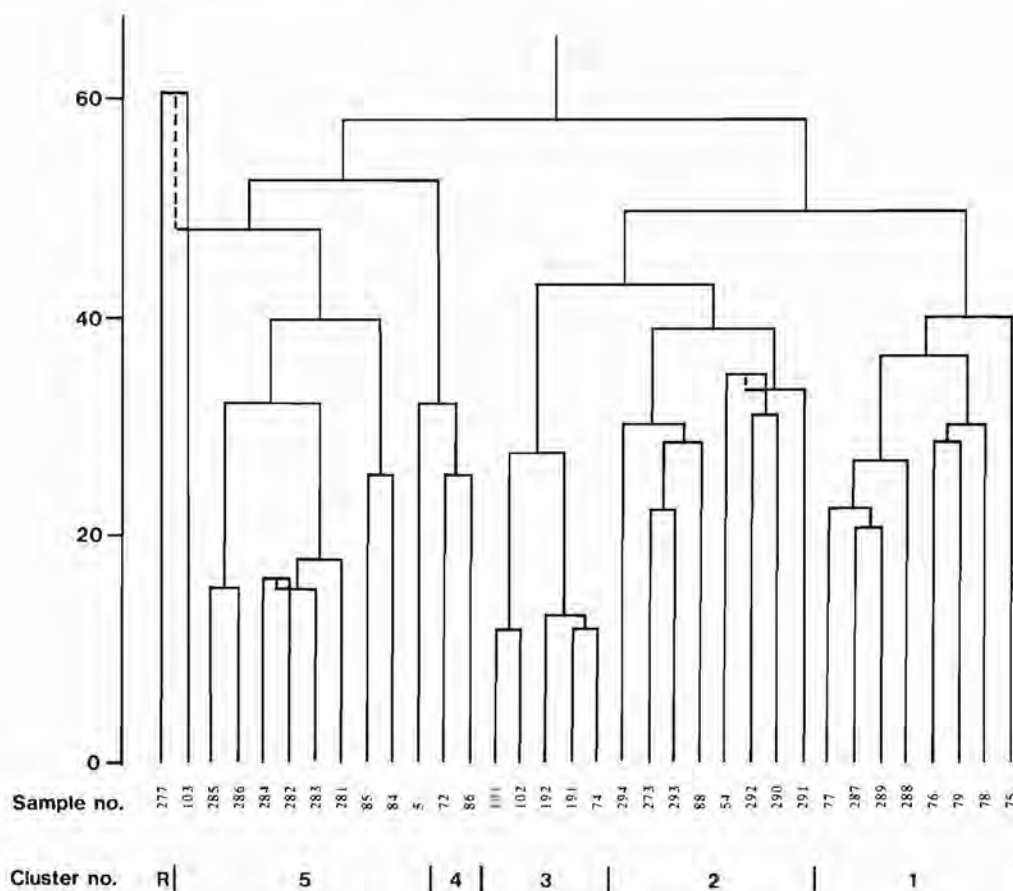


Fig. 9.3.3 TWINSpan dendrogram of the 34 samples of open grassland vegetation at Sølendet. The ordinate shows the heterogeneity within the clusters. Cluster no. refers to the TABORD clusters 01-5 (Table 9.3.2). R = residual sample.

### 9.3.3 Ordination

In the DCA diagrams, axes 1 & 2 and 1 & 3 (cf. Fig. 9.3.4) order the samples into rather dense clusters which, in the main, are identical with the results of the TABORD and TWINSpan classifications. The species ordinations are not presented here, and the occurrence of only a few species will be mentioned.

The first axis (eigenvalue 0.54, length 3.6 s.d.) represents a gradient from tall-herb and moisture-demanding communities/species (with low values) to low-herb and more xerophilous communities/species. E.g. the following species record low values (minus): *Salix pentandra*, *Caltha palustris*, *Pellia neesiana*. Species with high values (exceeding 4.0 s.d.) along the 1st axis are e.g.: *Botrychium* spp., *Campanula rotundifolia*, *Gentianella* spp. and *Tortula ruralis*. *Nigritella nigra* (value 3.6 s.d.) also belongs to the species with high values along the first axis.

The second axis (eigenvalue 0.29, length 3.1 s.d.) represents a gradient from typical grassland communities/species, with low values (e.g. the following species with minus scores: *Gentianella* spp., *Myosotis decumbens*), to damp grassland or more heathland-like types, and further to fenlike communities/species with high values (e.g. the following species, all exceeding 3.0 s.d.: *Carex panicea*, *Molinia caerulea* and *Fissidens adianthoides*).

Axes 1 and 2 both represent elements of a damp-dry gradient. Seen together in the diagram (Fig. 9.3.4.A), however, this gradient runs from upper left to bottom right. Along this gradient the samples of clusters 3-2-1 represent a "chain" of low-herb communities, from fen margin vegetation to types transitional between fen, grassland and heathland, and further to dry heath/grassland types. The samples of clusters 5 and 4 represent another "chain", of tall-herb communities. The wet-dry gradient is followed by a differentiation in soil profile from peat to brown earth.

The third axis (eigenvalue 0.14, length 1.7 s.d.) is not easily correlated with any of the main ecological gradients. Species with low values (less than -0.5 s.d.) include: *Salix lapponum*, *Melampyrum sylvaticum*, *Aulacomnium palustre* and *Sphagnum warnstorffii*. Species with high values (exceeding 2.5 s.d.) are e.g. *Equisetum variegatum*, *Potentilla erecta*, *Molinia caerulea* and *Fissidens adianthoides*. The samples from Vassdalen (i.e. samples of cluster 2) have low values, and along axis 3 this cluster is well separated from the samples of cluster 3.

Axis no. 4 (eigenvalue 0.1, length 1.8 s.d.) has not been included in any figure, and it is not easily correlated with any main ecological gradient. Sample 192 has the lowest and no. 293 the highest value.



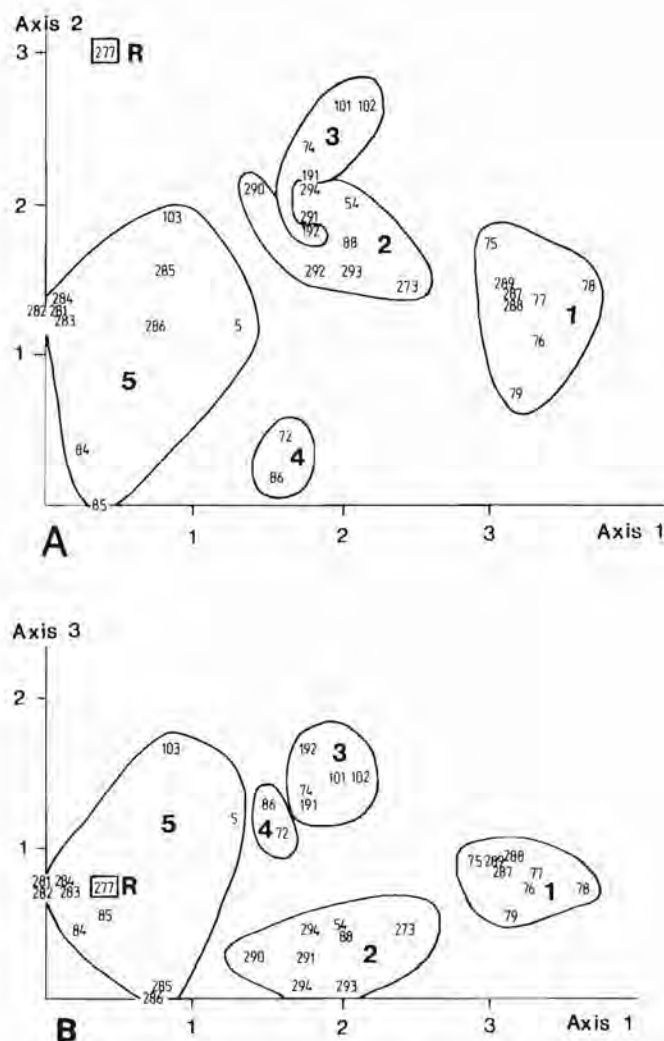


Fig. 9.3.4

DCA-ordination diagrams of the 34 samples of open grassland vegetation at Sølendet. A: axes 1 & 2, B: axes 1 & 3. Eigenvalues of the axes: 1: 0.537; 2: 0.290; 3: 0.142. Sample and cluster numbers (nos. 1-5 delimited by hand, R = residual) as in tables 9.3.1-2.

#### 9.4 ECOLOGICAL DATA AND FIELD LAYER PRODUCTION

The methods used for making the ecological observations and in the production studies are described in section 4.5. The tables in Appendices A and E list the details.

Table 9.4.1 Ecological data (mean value and standard deviation) for the 6 types of heathland vegetation at Sølendet. Details of the clusters, stand localities etc. in table 9.2.1 and Appendix A.

Cluster number and name	No. of stand local.	Tree layer height in m	Oliv. limit in m	Soil profile			pH in humus	
				No. of local.	Humus cm	Bleached layer cm	No. of soil samp.	Values
W1 Open Nardus-Polytr jun	2	-	-	2	2-3	10	5	3.8±0
W2 Bet p-Nard-Rub ch-Pol com	4	6±1	1.2±0.2	4	9±2	7±4	8	3.8±0.1
W3 Bet pub-Empetr-Pleurozium	4	5±2	1.1±0.3	2	4±1	9±4	4	4.8±0.2
W4 Bet pub-Vacc myr-wiry gr	4	6±1	1.5±0.2	4	5±1	11±3	8	4.1±0.1
W5 Bet pub-Gymnoc-Desc flex	7	9±2	1.9±0.2	5	5±1	7±3	14	4.5±0.5
W6 Bet pub-Gymnoc-Convall	2	12±2	1.7±0.2	1	5	7	4	4.8±0.3

Tab. 9.4.2 Ecological data (mean value and standard deviation) for the different types of grassland vegetation described in sections 9.6-7. Details of the clusters, stand localities etc. in tables 9.2.1, 9.3.1 and Appendix A.

Cluster number and name	No. of stand local.	Tree layer height in m	Oliv. limit in m	Soil		pH in humus/mull	
				No. of local.	Humus/mull cm	No. of soil samp.	Values
W7 Bet pub-Ger syl-Rub sax	7	7±4	1.5±0.4	7	ca.10	14	5.9±0.3
W8 Bet pub-Agr cap-Succisa	4	9±3	1.9±0.6	4	ca.10	8	5.4±0.3
W9 Bet pub-Crepis-Camp stel	3	9±1	1.4±0.5	3	ca.15	6	6.0±0.3
W10 Bet pub-Aconit-Ang arc	3	11±1	1.2±0.2	3	ca.15	6	5.7±0.2
W11A Salix-Filip-Sph warnst	2	4±1	1.2±0.4	2	85±21	4	6.2±0.2
W11B Salix-Filip-Sph warnst	2	3±4	1.2±0	2	4±1	2	5.3±0.1
O1 Achillea mill-Tort rur	6	-	-	8	4±1	10	5.4±0.5
O2 Nardus-Thal alp-Sph warn	8	-	-	7	11±2	6	5.6±0.6
O3 Bet nan-Molinia-Camp st	2	-	-	5	13±5	4	6.3±0.4
O5 Salix-Alchem-Sph warnst	6	3±3	1.2±0	3	61±43	10	5.9±0.5

Summaries of the ecological data for the heathland and grassland clusters are shown in tables 9.4.1-2, respectively. Mean values of the field layer production from scything are shown for nine of these clusters in table 9.4.3.

"The first scything" refers to that first done after an interval of ca. 25 years. The estimated production values do not include the standing crop of shrubs, but some of the dwarf-shrubs are included, in addition to a large proportion of dead, small twigs, branches and leaves etc. from the birches in the tree layer. Large-sized twigs etc. were removed before scything started. The litter proportions were sometimes as high as ca. 50% for the heathland types, ca. 25% for the grassland types.

Table 9.4.3 Survey of the field layer production of the heathland and the grassland types of Sølandet. Further explanation given in table 5.3.2.

Cl. no.	The first scything			Scything every second year			Scything every year		
	No. of loc.- samples	Mean $\frac{g}{m^2}$ $\pm$ s.d.	Litter in %	No. of loc.- samples	Mean $\frac{g}{m^2}$ $\pm$ s.d.	Litter in %	No. of loc.- samples	Mean $\frac{g}{m^2}$ $\pm$ s.d.	Litter in %
W1	2-3	147 $\pm$ 11	50	1-3	63( $\pm$ 9)	ca.30	-	-	-
W2	2-2	72 $\pm$ 83	ca.50	-	-	-	-	-	-
W4	4-4	135 $\pm$ 21	ca.50	-	-	-	-	-	-
W5	5-5	99 $\pm$ 24	ca.50	5-11	55 $\pm$ 12	ca.30	-	-	-
W6	2-2	136 $\pm$ 18	ca.40	2-12	70 $\pm$ 23	20	-	-	-
W7	6-6	166 $\pm$ 44	ca.25	7-39	127 $\pm$ 30	18	1-4	96( $\pm$ 12)	9
W8	3-3	183 $\pm$ 37	ca.25	2-14	122 $\pm$ 1	ca.20	-	-	-
W9	3-5	215 $\pm$ 88	19	3-18	141 $\pm$ 36	ca.20	1-9	85( $\pm$ 19)	13
W10	3-6	241 $\pm$ 2	20	3-30	156 $\pm$ 11	14	1-8	79( $\pm$ 10)	ca.15

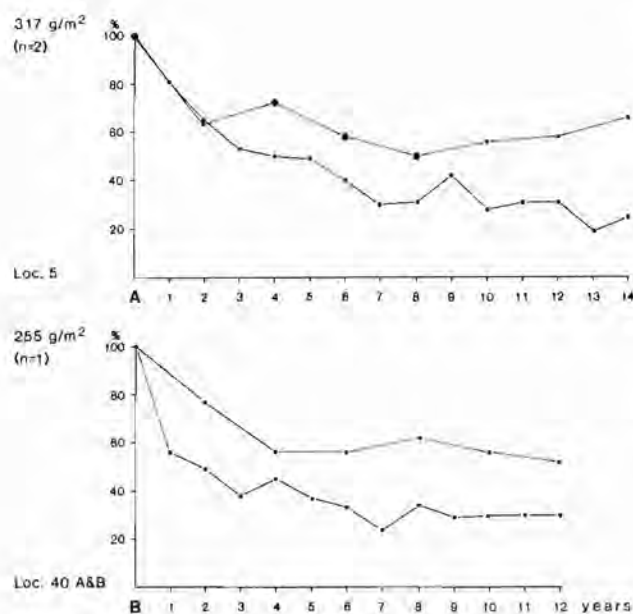


Fig. 9.4.1

A-B. The field layer production of the permanent quadrats of two wooded grassland localities (nos. 5 & 40), scythed every other year (upper curve) or every year (lower curve). The value for the first year of scything is shown and the other values are expressed as a percentage of this value. Further explanation given in figure 5.3.1.

The litter proportions for the woodland types that were scythed every second year were usually ca. 30% for the heathland types, and most often less than 20% for the grassland types.

The field layer production for the permanent quadrats in two wooded grassland localities scythed every year and every second year, respectively, are shown in figure 9.4.1. Further comments on the ecological data are given under the heading for each cluster group.

## 9.5 THE 6 TYPES OF HEATHLAND VEGETATION (W1-6) AND THEIR ECOLOGY

The description of the 11 types of woodland vegetation (W1-11) is based on the results of the multivariate analyses, described in section 9.2, including tables 9.2.1-2, Appendix D-table 1 and figures 9.2.1-5. Ecological data and records of field layer production are summarized in section 9.4 (cf. Tables 9.4.1-3). The above mentioned tables and figures will only in exceptional cases be referred to further in the text.

Types W1-6 represent heathland communities, only no. 1 is open vegetation without a tree layer. Types W7-11 will be described in section 9.6.

### 9.5.1 Wiry grass heaths

#### 9.5.1.1 The clusters W1-2

W1. Open *Nardus stricta*-*Polytrichum juniperinum* type  
2 samples (49 & 55) in cluster 1.

A distinct type of open grass heath found in shallow depressions surrounded by birch forest vegetation of types W2 and 4. This vegetation is quite common in the upper parts of Sølendet.

*Nardus stricta* predominates and characterizes the type. *Deschampsia flexuosa* is also a dominant species. The field layer is compact, with a heavy litter layer. *Polytrichum juniperinum* and *Pleurozium schreberi* are dominants in the bottom layer. Seven species are exclusive constants for this particular cluster, e.g. *Carex brunnescens*, *Aulacomnium palustre* and *Lophozia ventricosa*.

The two quadrats analysed belong to the same area, and may even be regarded as one large stand s.lat. The cluster has a high within-cluster similarity (0.77), and its resemblance to the other clusters is low, the greatest being to cluster no. 2 (0.54). The TABORD and TWINSpan dendrograms and the ordination diagrams also show that this cluster is rather distinct, with closest resemblance to samples 44 and 47 of cluster 2.

- W2. *Betula pubescens*-*Nardus stricta*-*Rubus chamaemorus*-*Polytrichum commune* type  
4 samples (44-47) in cluster 2.

Rather open birch woodland, with a tree layer 5-7 m high, the shrub layer sparse or absent, a field layer dominated by wiry grass species, and a dense moss layer. It is a damp grass heath woodland, occurring mainly in the upper part of the reserve together with other poor heathland communities.

*Polytrichum commune* predominates, and it characterizes the type with its dense, voluminous mats. The analysed quadrats can be grouped into two subtypes, one with dominant *Nardus stricta* and *Polytrichum strictum* (samples 44 & 47) and the other with a predominance of *Deschampsia flexuosa* (samples 45 & 46). *Rubus chamaemorus* and other species of damp communities are characteristic and constant species, e.g. *Barbilophozia kunzeana* and *Sphagnum russowii* (even a dominant), and *Eriophorum vaginatum* and *Juncus filiformis* with more scattered occurrences.

All the analyses are derived from the same part of Sølendet, but from different stands. The within-cluster similarity is 0.67, and the closest resemblance is to cluster 4 (0.55) and cluster 1 (0.54).

The TWINSpan classification also groups these four samples together, and in the TWINSpan and TABORD dendrograms the samples of cluster 2 are grouped closest to the samples of cluster 1. The DCA diagrams, too, show the samples grouped together, with the greatest resemblance being to cluster 1, to samples 41 and 42 of cluster 4, and to sample 80 of cluster 3.

#### 9.5.1.2 Habitat conditions, field layer production

The stands of type W1 are situated in a flat area in a shallow depression with a rather heavy snow cover. During springtime the surface is covered by stagnant water (see Fig. 9.5.1). The stands of type W2 are situated in gently sloping areas with an inclination of 3-4°. The *Olivacea* limit varies between 0.9-1.3 m for the four stands, indicating a rather light snow cover. During springtime even these areas have a water-level lying close to the surface.

The soil profile of type W1 is a podsol (transitional between an iron podsol and a humus podsol) with a 3 cm thick raw humus layer; the mean pH for five samples of humus shows the low value of 3.8. The soil profile of type W2 is a more typical humus podsol, with a ca. 9 (6-12) cm thick layer of humus; the pH of the humus layer was 3.8 (3.6-4.0).

Clearance of birch and juniper, scything, and grazing by farm stock (cf. sub-section 3.4.2.3) have affected the wiry grass heaths in former times.



Scything has been recommenced in some of the quadrats of type W1. In the first year of scything, the total herbage production was 147 g/m<sup>2</sup> (3 samples), of which ca. 50% was litter. Scything every second year gave a mean value of 63 g/m<sup>2</sup> (3 samples), litter being estimated to be ca. 30%.

The quadrats 44 and 46 of W2 have only been scythed once (i.e. in 1978). The first-mentioned quadrat (*Nardus*-dominated) had a yield of 131 g/m<sup>2</sup> (ca. 50% litter), the very sparse field layer of no. 46 (see photo in Fig. 9.5.2) yielded only 13 g/m<sup>2</sup>. This vegetation type represents rather poor hay land, with low production and a high proportion of litter (small twigs, branches, dead leaves of birch etc.); no scything has been done since 1978.

## 9.5.2 Dwarf-shrub/grass heaths

### 9.5.2.1 The clusters W3-4

W3. *Betula pubescens*-*Empetrum hermaphroditum*-*Pleurozium schreberi* type  
4 samples (57, 80, 270, 271) in cluster 3.

An open birch woodland representing the driest heath communities of Sølendet. *Juniperus communis* forms a dense, tall-growing, shrub layer in places; *Betula pubescens*-scrub also occurs. The field layer is dominated by dwarf-shrubs, *Empetrum hermaphroditum* predominates, but always accompanied by a number of other dwarf shrubs, e.g. *Vaccinium vitis-idaea*, *V. myrtillus* and *Calluna vulgaris*. *Deschampsia flexuosa* is another dominant species. *Pohlia nutans* is a constant species only in this forest community, and *Linnaea borealis* only occurs in this community.

*Pleurozium schreberi*, *Barbilophozia lycopodioides* and *Hylocomium splendens* are the dominants in the bottom layer. A number of lichen species, e.g. *Cetraria islandica* and *Peltigera aptosa*, also occur exclusively in this community.

The cluster is heterogeneous, with a low within-cluster similarity (0.64). The samples do not form a well-defined cluster, as seen also in the TWINSpan dendrogram and DCA diagrams. Sample 270 is somewhat isolated in cluster 3, and in the TWINSpan classification this sample was grouped closer to the samples of clusters 2 and 4 than to the other samples of cluster 3.

Cluster 3 is most like clusters 5 (resemblance 0.64) and 4 (resemblance 0.62). Its resemblance to cluster 2 is low (0.46).

W4. *Betula pubescens*-*Vaccinium myrtillus*- wiry grass type  
4 samples (28, 41-43) in cluster 4.

*Betula pubescens* forms a rather dense forest, with scattered *Betula*, and *Juniperus* occurring in the shrub layer. *Betula pubescens*, *Nardus stricta*,



Fig. 9.5.1 *Nardus stricta*-dominated vegetation in a small depression fed by melt-water in springtime. Locality no. 49 seen in the foreground; no. 55 in the background; together with the last remaining patches of snow. 19840523.



Fig. 9.5.2 *Deschampsia flexuosa*-*Polytrichum commune* dominated woodland. Locality no. 46. 19780803.

*Deschampsia flexuosa*, *Solidago virgaurea*, *Vaccinium myrtillus*, *Barbilophozia floerkei* and *Polytrichum commune* are dominant species. *Hieracium* sect. *Piloselloidea* and *Tritomaria quinquedentata* are constant taxa only in this forest type.

The type represent a community which is very common in the northern part of the reserve. Three of the stands are from the same area, the fourth (no. 28) is from an atypical, more species-rich, *Nardus*-dominated stand.

The within-cluster similarity is 0.69, and the cluster is most similar to clusters 5 and 3 (both with resemblance 0.62).

#### 9.5.2.2 Habitat conditions, field layer production

The stands of type W3 are found on the top of dry morainic ridges and sand deposits; stand no. 57 lies on a steep slope (inclination of 12°, see photo in Fig. 9.5.3), the other stands have an inclination of only 1-2°. The tree layer is low (ca. 5 m in height) and formed of scattered birches. The snow cover is rather light (*Olivacea* limit of 1 m or less for three of the four localities, and a mean value of 1.1 m, i.e. the lowest value recorded for all the types).

The stands of type W4 are from dry morainic areas, three stands from flat ground (see photo in Fig. 9.5.4), one with an inclination of 4°. The tree layer is rather low (6 m) and a number of small birch trees occur in three of the four stands. The *Olivacea* limit is at 1.5 m.

The soil profiles of both W3 and W4 are iron podsoles with a raw humus layer of 4-5 cm, followed by a bleached soil layer of ca. 10 cm and a redbrown deposition layer. The mean pH of W3 was 4.8 (4.6-5.0), a high value for this poor type of vegetation; that for type W4 was 4.1 (3.9-4.3).

Cultural influence on the dwarf-shrub types of vegetation seems to have been less intensive than on all the other wooded types and on the fen types. However, timber cutting, clearance and grazing by farm stock have certainly had some effect. The structure of the birch forest, with numerous small trees (13-25 in 25 m<sup>2</sup>, mean circumference of ca. 15 cm in the stands nos. 41-43) indicates previous clear-felling, or at least heavy timber cutting.

It seems reasonable to assume that most of the areas of types W3 and W4 have never been scythed. Even so, when the four quadrats of type W4 were scythed in 1976, the mean production value was 135 g/m<sup>2</sup>. It is noteworthy that this figure also includes the standing crop of dwarf-shrubs, and a rather heavy litter layer etc. Two years later, the mean field layer production was 78 g/m<sup>2</sup>, even then including a high proportion of litter (ca. 50%). Scything of this low quality hay land was discontinued after 1978.



Fig. 9.5.3 *Empetrum*-dominated birch forest, situated on the south-facing slope near the top of a low morainic ridge. Locality no. 57. 19770510.



Fig. 9.5.4 *Deschampsia flexuosa*-*Vaccinium myrtillus* birch forest. Locality no. 42. 19780803.



### 9.5.2.3 Comments on the scarcity of *Vaccinium myrtillus*

*Vaccinium myrtillus* is not predominant in the oligotrophic-mesotrophic woodland vegetation at Sølendet as is usually the case in the upland areas of Central Norway, cf. e.g. Nordhagen (1928), B.F.Moen (1978). In the higher-lying part of the reserve especially, the wiry grasses *Deschampsia flexuosa* and *Nardus stricta* are dominant in large areas of woodland, e.g. in the stands of type W4. In such areas *Vaccinium myrtillus* occurs scattered, but often (e.g. in the samples of cluster W4) it is dominant in small patches close to the stems of the birches. The dominant occurrence of *Deschampsia flexuosa* and *Nardus* indicates that this forest ecosystem has been altered by human influence, e.g. timber cutting, clearance, scything, grazing by farm stock etc.

The scarcity of *Vaccinium myrtillus* may also be explained climatically: a long-lasting snow cover and high groundwater-levels in springtime generally inhibit colonisation by dwarf-shrubs. The grass species mentioned are predominant in natural chionophilous communities in the low alpine and even in the sub-alpine regions (e.g. Nordhagen 1943).

The predominance of the wiry grasses and the scarcity of dwarf-shrubs may also be a result of the influence of caterpillars; mainly *Oporinia autumnata* (Norw. fjellbjørkemåler) in this area. In 1976, for example, these caterpillars heavily attacked the birches and dwarf-shrubs, including *Vaccinium myrtillus*. It is a well-known fact that after heavy caterpillar attacks *Deschampsia flexuosa* increases, and the dwarf-shrubs are reduced (e.g. Sonesson & Lundberg 1974).

To conclude: The reason for the predominance of the two wiry grasses, *Deschampsia flexuosa* and *Nardus stricta* in the heath woodlands of Sølendet seems to be a combination of a climatic effect (heavy, long-lasting snow cover), cultural influence (clear-felling, clearance, scything, grazing) and other biological factors, e.g. recurrent caterpillar attacks decimating the dwarf-shrubs.

## 9.5.3 Small-fern heaths

### 9.5.3.1 The clusters W5-6

W5. *Betula pubescens*-*Gymnocarpium dryopteris*-*Deschampsia flexuosa* type.  
7 samples (23, 24, 25, 30, 32, 39, 48) in cluster 5.

Tall-growing, rather open, birch woodland with a dense shrub layer of *Juniperus* in most stands. In addition to *Betula* and *Juniperus*, *Deschampsia flexuosa*, *Gymnocarpium dryopteris*, *Polytrichum commune* and *Barbilophozia lycopodioides* are also dominant species. Of all the woodland types, *Gymnocarpium dryopteris* and *Listera cordata* are constants only in types 5 and 6.



A number of common forest species are constants in this type, as in a majority of the foregoing communities, e.g. *Solidago virgaurea*, *Melampyrum pratense*, *Dicranum scoparium*, *Pleurozium schreberi* and *Hylocomum splendens*. In addition, some more nutrient-dependent species (not common in communities W1-4) are constants: *Dactylorhiza fuchsii*, *Geranium sylvaticum*, *Gnaphalium norvegicum*, *Melampyrum sylvaticum*, *Oxalis acetosella*, *Brachythecium salebrosum* and *Rhodobryum roseum*. *Maianthemum bifolium* is also common, and is a dominant in some stands. Most of these more nutrient-dependent afore-mentioned species are also common in the following forest types (nos. W6-10).

The cluster has a high within-cluster similarity (0.74) and the most similar cluster is no. 6 (resemblance 0.68). As seen in the figures, all the samples in cluster 5 are grouped together by the TWINSpan classification, and the DCA-ordination also shows a close group of samples along the first three axes.

W6. *Betula pubescens*-*Gymnocarpium dryopteris*-*Convallaria majalis* type  
2 samples (31, 33) in cluster 6.

Tall-growing birch woodland (12-15 m), with scattered trees and some scattered shrubs of *Juniperus*. This type may be regarded as a subtype of no. 5, and the same dominant species etc. described for no. 5 are common. The following constants are characteristic species: *Cicerbita alpina*, *Convallaria majalis*, *Maianthemum bifolium*, *Ranunculus plataniifolius*, *Silene dioica* and *Milium effusum*. Some of these species are also common, but not constants, in type no. 5. Type 6, compared to type 5, has more the character of a grassland series, since it also includes species such as *Viola biflora* and *Mnium spinosum*.

The two samples came from the same area and may be regarded as belonging to the same stand s.lat., a fact which also explains the high within-cluster similarity (0.78). Cluster 6 has a great resemblance to no. 5 (0.68); but that to the other clusters is low (nearest is no. 7 with 0.47).

Both the TABORD and TWINSpan dendrograms (Figs. 9.2.2-3) show the same delimitation between the heath series and the grassland series. Cluster 6 is the heathland type most similar to the grassland types, as is also shown by the DCA-ordination.

#### 9.5.3.2 Habitat conditions, field layer production

A majority of the stands of type W5 are situated on south and eastfacing slopes of 3-7°, two stands (nos. 25, see photo in Fig. 9.5.5, and 32) lie on the flat tops of low morainic ridges. The two stands of type W6 have an inclination of 12° (see photo in Fig. 9.5.6). All the stands have a tree layer of a few (1-3) old birch trees, usually 8-12 m in height, mean values of 9 m and 12 m, respectively, for the stands of W5 and W6. The mean *Olivacea* limits for the stands of W5 and W6 were 1.9 m and 1.7 m, respectively, i.e. indicating a heavy snow cover.



Fig. 9.5.5 *Deschampsia flexuosa*-dominated small-fern heath. Locality no. 25 seen in the centre. Photo taken after clearance of the *Juniperus*-scrub from the 25 m<sup>2</sup> quadrat. 19770730.



Fig. 9.5.6 A low-herb/small-fern community. The 25 m<sup>2</sup> quadrat of locality no. 31 in the foreground, after scrub clearance and scything. *Dalbua* visible in the background. 19810721.

The soil profiles of both types are iron podzols, with a humus layer of 5(2-6) cm and a bleached layer of 7(5-10) cm. The mean pH of the humus layer for 14 soil samples of W5 was 4.5; and 4.8 (4 samples) for the W6 type.

The vegetation of types W5 and W6 produces a larger quantity of grass and herb species attractive for grazing and haymaking than the samples of types W3 and W4. It is therefore reasonable to assume that the vegetation of the small-fern types has been more intensively utilized in former times than that of the dwarf-shrub/grass heaths. However, the information given by the farmers (cf. section 3.4.2) and the dense cover of *Juniperus communis* in many places, indicate that these are areas that have not been scythed or cleared for many decades.

Scrub clearance (mainly *Juniperus*) and scything recommenced in 1976 in 5 localities of type W5 and in the two localities of type W6. The mean production values for W5 were 99 g/m<sup>2</sup>, for W6 136 g/m<sup>2</sup>, including litter fractions of ca. 50% and ca. 40%, respectively. The respective values for field layer production with scything every second year were 55 g/m<sup>2</sup> for W5 and 70 g/m<sup>2</sup> for W6; the litter fractions were ca. 30% and 20%, respectively.

## 9.6 THE 5 TYPES OF WOODED GRASSLAND VEGETATION (W7-11) AND THEIR ECOLOGY

Types W7-10 represent birch woodlands of the grassland series with either no shrub layer, or only a very sparse one, and a dense field layer dominated by herbs and graminoids; type no. 11 represents a transitional community between damp grasslands and rich fens. These grassland communities were formerly mown for hay, and the absence of a shrub layer and the composition of the recent vegetation cover are very much due to these previous human activities.

### 9.6.1 Birch woodland types

#### 9.6.1.1 The clusters W7-10

##### W7. *Betula pubescens*-*Geranium sylvaticum*-*Rubus saxatilis* type

9 samples (22, 34-38, 250, 251, 272) in cluster 7. Locality 35 is represented by three separate samples, nos. 35, 250, 251, the last two being reanalyses of 12,5 m<sup>2</sup> quadrats of the first sample stand after clearance and scything (see photos in Figs. 9.6.1-2).

*Betula pubescens* forms open woodlands mainly of trees 5-10 m in height. Some localities have a dense shrub layer of *Betula pubescens* that has invaded the grassland community after regular scything ceased. Scattered *Juniperus communis* and *Salix* spp. also occur.



Fig. 9.6.1      Wooded, herb-dominated grassland with *Geranium sylvaticum* and ca. 50 bushes of birch in the 25 m<sup>2</sup> quadrat. Locality no. 35. 19770620.



Fig. 9.6.2      Exactly the same area as that shown above (and the same as in Figs. 3.4.4 & 5); after clearance and scything. The newly scythed 12.5 m<sup>2</sup> of locality no. 35A (=sample stand no. 250) in the centre. 19850804.



The field layer is dominated by herbs and graminoids, and a large number of species are constants. *Geranium sylvaticum* is the species with the highest cover value. In addition, *Alchemilla* spp. (mainly *A. glabra*, *A. glomerulans* and *A. wickuriae*), *Viola biflora* and *Solidago virgaurea* are dominant herb species. Of all the forest types, *Pyrola rotundifolia* and *Rubus saxatilis* are constants only in this one. In addition some other grassland herbs (not occurring in the foregoing types) are constants, e.g.: *Filipendula ulmaria*, *Geum rivale*, *Myosotis decumbens*, *Ranunculus acris* and *Saussurea alpina*. A number of graminoids occur in (nearly) all stands, with cover values 1–3, e.g. *Agrostis capillaris*, *Anthoxanthum odoratum*, *Carex vaginata*, *Deschampsia cespitosa* (dominant), *D. flexuosa* (dominant), *Festuca rubra*, *Luzula multiflora*, *L. pilosa* and *Phleum alpinum*.

A number of bryophytes are constants, but no single one is dominant; e.g. *Brachythecium salebrosum*, *B. reflexum*, *Barbilophozia lycopodioides*, *Mnium spinosum* and *Rhodobryum roseum*.

The within-cluster similarity is 0.68, and the cluster is most similar to nos. 8 (resemblance 0.62) and 10 (0.61). The TWINSpan classification groups the samples of cluster 7 (excepting no. 22) together, and in the dendrogram the cluster is placed between clusters 8 and 10, as also in the DCA diagrams.

The grouping of samples 22 and 37 in cluster 7 calls for some explanation: The TABORD classification includes sample 22 in cluster 10 (similarity to this cluster is 0.537; and to clusters 7 and 8, respectively 0.520 and 0.513). Also the TWINSpan classification includes sample 22 together with some of the samples from cluster 10. In the DCA-ordination diagrams, sample 22 falls closest to the samples of cluster 7, a situation that remains unchanged along axis 4 (not shown). The DCA-ordination result was given priority and sample 22 was grouped in cluster 7. Sample 37, too, may be included in cluster 7 or in cluster 10 (similarity values 0.596 and 0.589 respectively), but in this case the results of the TABORD and TWINSpan classifications were followed, even though the DCA diagrams indicated the closest resemblance to cluster 10.

W8. *Betula pubescens*-*Agrostis capillaris*-*Succisa pratensis* type  
4 samples (20, 21, 26, 56) in cluster 8.

Open birch woodland with scattered occurrences of shrubs (see photos in Figs. 9.6.3–4), and a rather low-growing field layer with a mixture of species typical of heathland forest, some typical grassland species and damp woodland species. *Betula pubescens*, *Geranium sylvaticum*, *Potentilla erecta*, *Agrostis capillaris*, *Deschampsia cespitosa*, *D. flexuosa* and *Hylocomium splendens* are dominants. *Pedicularis oederi* and *Molinia caerulea* are constants only in this particular forest community. These two species are typical of damp habitats, as are also some of the species typical of both types 8 and 9: *Bartsia alpina*, *Leontodon autumnalis*, *Succisa pratensis*, *Luzula sudetica*, *Drepanocladus uncinatus* and



*Lophocolea bidentata*. Typical for type 8 (compared to no. 9) is the very rich occurrence of heathland species, e.g. *Vaccinium myrtillus*, *Melampyrum pratense*, *Dicranum scoparium*, *Hylocomium splendens*, *Pleurozium schreberi*, *Polytrichum commune* and *Sphagnum russowii*. A number of graminoids are constants, e.g. all the eight species listed in the description of type 7. The bottom layer contains a number of constants, in addition to those mentioned above, e.g. *Rhodobryum roseum* and *Rhytidiadelphus squarrosus/subpinnatus*. Stand 56 is dominated by *Sphagnum girgensohnii*.

The within-cluster similarity is 0.65, and the cluster is most similar to cluster 9 (resemblance 0.63), and cluster 7 (0.62); the next being cluster 5 (0.47).

The TWINSpan classification places the samples of cluster 8 together, and nearest to cluster 9. The DCA diagrams show a somewhat scattered group of samples, but which together form a rather distinct cluster. Sample 21 represents a transition to the samples in cluster 7, and sample 29 in cluster 9 lies fairly close to the samples of cluster 8.

W9. *Betula pubescens*-*Crepis paludosa*-*Campylium stellatum* type

6 samples (27, 29, 255-258) in cluster 9. Locality 5 is represented by four samples 255-258, in part representing different quadrats, in part reanalysed quadrats after reclamation and recommencement of scything (see photos in Figs. 9.6.5-6).

This is an open birch woodland, with either no shrub layer or only a very sparse one, and a dense, rather tall-growing field layer dominated by herbs and tall-growing graminoids. The composition of the recent vegetation cover has very much to do with the previous human activities. Dominant species are: *Betula pubescens*, *Alchemilla* spp. (mainly *A. glabra*, *A. glomerulans* and *A. subcrenata*), *Crepis paludosa*, *Geranium sylvaticum*, *Saussurea alpina*, *Thalictrum alpinum*, *Deschampsia cespitosa*, *Campylium stellatum* and *Rhytidiadelphus squarrosus/subpinnatus*. This is a species-rich, damp grassland community, with a taller-growing field layer than no. 8, and heathland species are less frequently present. Some rich fen and rich grassland species occur which are absent or scarce in both nos. 8 and 10, e.g. the following bryophytes in addition to *Campylium*: *Chiloscyphus pallescens*, *Climacium dendroides*, *Fissidens adianthoides* and *Rhizomnium magnifolium*. Also *Carex nigra* is a characteristic species of type 9, and *Galium boreale* is a constant species only in nos. 9 and 10 of the woodland types. In addition to the eight characteristic species of types 8 and 9 (listed under the description of no. 8) a number of species are constants in these types and absent or only very scattered in no. 10, e.g.: *Potentilla erecta*, *Carex vaginata* and *Nardus stricta*.

The within-cluster similarity is 0.68, and the cluster is most similar to clusters 8 (0.63) and 7 (0.54). The similarity to clusters 10 and 11 are 0.49 and 0.41, respectively.



Fig. 9.6.3 Damp, low-herb birch forest, with *Juniperus communis* and *Salix* spp. in the shrub layer. A species-rich field layer dominated by *Nardus stricta*. Locality no. 26. 19760804.



Fig. 9.6.4 Damp, fen-like grassland with scattered occurrences of birch; *Salix* spp., *Deschampsia flexuosa*, *Nardus* and *Succisa pratensis* are common species in the field layer. Locality no. 56. 19780803.



Fig. 9.6.5 *Geranium sylvaticum*-dominated, damp wooded grassland. In the centre of the photo the quadrats of locality no. 5 which were scythed the previous year. *Salix* spp. are dominant outside the quadrats. 19760804.



Fig. 9.6.6 The same area as that shown above, a few days after scything of the quadrats and of the surrounding area. Locality no. 5. 19850804.

As seen in the TWINSpan dendrogram and DCA diagrams, samples 27 and 29 are somewhat isolated from the four samples from locality no. 5, and nos. 27 and 29 represent transitional stands between clusters 9 and 8. Sample 85 of cluster 11 lies rather close to some of the samples in cluster 9.

W10. *Betula pubescens*-*Aconitum septentrionale*-*Angelica archangelica* type

9 samples (8, 259-61, 40, 252-54, 50) in cluster 10. Localities 8 and 40 are represented by four samples each, some from different quadrats, some from areas reanalysed after reclamation and scything.

The community represents the typical, tall-herb birch forest. In areas that have not been scythed for decades, a shrub layer is common, and *Salix* spp. may form a dense scrub woodland. In most of the analysed quadrats, however, the shrub layer is either absent or sparse.

Dominant species are: *Betula pubescens*, *Aconitum septentrionale*, *Geranium sylvaticum*, *Alchemilla* spp. (mainly *A. glabra* and *A. glomerulans*), *Crepis paludosa*, *Deschampsia cespitosa*, *Brachythecium salebrosum* and *Mnium spinosum*. Herbs such as *Filipendula ulmaria*, *Geum rivale* and *Viola biflora* are also constants, and occur with high cover-values. *Angelica archangelica*, *Paris quadrifolia*, *Poa nemoralis* and *Mnium stellare*, in addition to *Aconitum*, are characteristic species for this type of woodland.

The within-cluster similarity is high (0.75), and the greatest resemblance is to cluster 7 (0.61), being low to the other clusters (nearest is no. 9 with resemblance of 0.49).

The TWINSpan classification splits the cluster into two, with sample 22 (cf. the comments made in the description of cluster 7) falling into one of these groups. The DCA diagrams show a rather dense cluster, only a small distance away from sample 37 in cluster 7.

#### 9.6.1.2 Habitat conditions, field layer production

Ecological data for the stands and localities of the vegetational types W7-10 are listed in the tables of Appendices A and E, table 9.2.1 and the survey tables 9.4.1-3, cf. also figure 9.4.1.

A majority of the stands of the clusters W7-10 are situated on south to east-facing slopes of 3-8°. The steepest slopes (to 18°), in general occur at the stands of cluster 7.

The mean value for tree height was 7-11 m for all four clusters. The *Olivacea* limit varied between 0.8-2.5 m, the mean values for the localities of the four clusters are 1.5 m, 1.9 m, 1.4 m and 1.2 m, respectively. In general, the height



of the *Olivacea* limit indicates a rather deep to very deep snow cover in wintertime. The localities normally become snow-free in late May or early June.

**Soil profile.** A majority of the stands of clusters W7-10 have a brown earth profile, usually with a 5-15 cm layer of mull, gradually changing to pure morainic material downwards. Some of the stands of clusters 8 and 9 have a peat-like mull (e.g. no. 27, 20 cm deep); some stands of cluster 8 (e.g. nos. 26 & 56) even have a profile transitional to a podsol, with a weak bleached layer and traces of brownish-red depositions. The stands of W10 have a black-coloured mull layer.

The pH in soil for the stands of cluster W7 varied from 5.4 to 6.3, with a mean value of 5.9 (14 measurements). The corresponding pH values for clusters 8 and 9 were 5.4 (5.1-5.7) and 6.0 (5.6-6.3) for 8 and 6 measurements, respectively. The value cited for cluster 8 is the lowest of any of the wooded grassland clusters on Sølendet, but is nonetheless higher than any of the values for the heathland clusters. The pH of the soil at the three localities of cluster W10 ranges from 5.5 to 5.9, with a mean value of 5.7 (6 soil samples).

**Cultural influence.** All the localities of clusters W7-10 have formerly been scythed. In localities 35 (stands 35, 250, 251) and 5 (stands 255-258) of clusters W7 and 9, respectively, some stands represent reanalysed quadrats, after reclamation and the recommencement of scything. Photos of these two localities before and after scything are shown in figures 3.4.4 & 5, 9.6.1 & 2 and 9.6.5 & 6. After cessation of scything, a vegetational succession towards a more tall-herb type takes place. Following clearance and recommencement of scything, in contrast, a reversion commences. This effect of scything over a single decade seems only to be of importance in connection with the typification of transitional stands. Scything does not seem to cause sufficient change in the species composition to lead to any alteration regarding the main cluster to which they belong. This conclusion applies to the stands of localities 35 and 5 and, in addition to the stands of localities 8 and 40 (i.e. stands 8, 40, 252-254, 259-261) of cluster 10.

A large number of the quadrats have been scythed in connection with the production studies of the woodland types. The estimated mean values for the field layer production, in quadrats scythed every other year, were 127 g/m<sup>2</sup>, 122 g/m<sup>2</sup>, 141 g/m<sup>2</sup> and 156 g/m<sup>2</sup> for the quadrats of clusters W7, W8, W9 and W10, respectively. The estimated litter fraction was 18% (mean of 10 samples) for cluster W7, 14% for no. 10, and assessed as being ca. 20% for the two other clusters.

In the year in which scything recommenced, the estimated production values for the field layer were 166 g/m<sup>2</sup>, 183 g/m<sup>2</sup>, 215 g/m<sup>2</sup> and 241 g/m<sup>2</sup>, for the four clusters, respectively, the litter fraction for all was assessed as ca. 20-25%.



In locality no. 37 of cluster W7, mean production, when scythed every year, was estimated to be 96 g/m<sup>2</sup> (including 9% litter).

Scything has been carried out every year in one quadrat of locality 5 (of cluster W9) and every other year in two more quadrats, from 1974 to the present day. In the quadrat scythed every year the mean production stabilized at ca. 85 g/m<sup>2</sup> (litter: 13%), in the quadrats scythed every other year the mean was 182 g/m<sup>2</sup> (litter ca. 20%). The mean value for the first-time scything of these three quadrats was 317 g/m<sup>2</sup> (litter ca. 20%).

Figure 9.4.1 shows the changes in the field layer production for localities nos. 5 and 40 (the last-mentioned belongs to cluster W10; photo in Fig. 9.6.7). The main courses of the curves are representative for the majority of the grassland stands investigated at Sølendet.

In general, the productivity, as estimated by scything, of homogeneous grassland stands at Sølendet, when scythed every year, is about, or a little higher than half the value when scythed only every other year (ca. 55 % is the most usual proportion, also when the litter fraction is subtracted). The production value for scything every other year is about 2/3 of that recorded for the first year after scything recommenced (the first scything usually contains the highest proportion of litter).

#### 9.6.2 Salix-dominated damp grassland/fen margin communities

W11. *Salix* spp. - *Filipendula ulmaria*-*Sphagnum warnstorffii* type

4 samples (82-85) in cluster 11. No. 82 represents 4, no. 83 just 2 and nos. 84 & 85 single quadrats of 4 m<sup>2</sup>.

These *Salix*-dominated stands are also included in the descriptions of the open grassland and the mire vegetation types. The type represents communities transitional between damp wooded grassland, damp scrubby grassland and scrubby rich fen vegetation.

*Salix pentandra* is the dominant in both the tree and shrub layers of stands 82 and 83, with *Salix glauca* and *S. lapponum* dominant in the shrub layer of nos. 84 (see fig. 9.6.8) and 85, respectively. In the type as a whole, a variety of species are dominants (ch = characteristic): *Salix glauca*, *Geranium sylvaticum*, *Alchemilla* spp. (*A. glabra* and *A. glomerulans*), *Caltha palustris* (ch), *Filipendula ulmaria*, *Geum rivale*, *Sphagnum warnstorffii* (ch), *Rhizomnium magnifolium*, *Plagiomnium ellipticum* (ch) and *Pellia neesiana*. In addition the following species are characteristic of the type: *Epilobium palustre*, *Equisetum sylvaticum*, *Calamagrostis purpurea*, *Bryum weigelii*, *Aneura pinguis* and *Marchantia alpestris*.

The four samples can be split into two subtypes (cf. also clusters M14 and 15 of the mire types); nos. 82 and 83 represent the most fen-like type.



Fig. 9.6.7 Tall-herb birch forest with *Geranium sylvaticum* and *Aconitum septentrionale*. Locality no. 40. 19770801.



Fig. 9.6.8 *Salix glauca*-dominated grassland at the margin between rich fen and dry ground. Locality no. 84. 19780810.

The cluster is heterogeneous, with a within-cluster similarity of only 0.50. Even after the division into subtypes, the within-cluster homogeneity is low, e.g. 0.52 for samples 84 and 85. The cluster also shows only a low similarity to other clusters, the most similar one being no. 9 (0.41). The TABORD and TWINS-PAN dendrograms and the DCA-ordination diagrams both reflect the heterogeneity of this cluster, with rather low resemblances to any other clusters.

#### Habitat conditions

The localities constituting the cluster W11 are found on damp ground, on slightly sloping (1-3%) areas. The tree layer height of the birches in locality 85 is 5 m. The tree layer heights of *Salix pentandra* in localities 82 and 83 are 3 and 5 m, respectively (see photo in Fig. 5.5.11). The mean value of the *Olivacea* limit for the localities of W11 is 1.2 m.

The localities 82 and 83 have a peat layer of 0.7-1.0 m. The pH of the peat was 6.2, that of the water 6.7 (both mean values). Localities 84 and 85 have a soil profile transitional between peat and brown earth, the peat/mull layer being 3-5 cm deep; mean soil pH was 5.3 (cf. further comments in section 5.4.6.2).

No estimates of the field-layer production were made at localities 82-85.

### 9.7 THE 5 TYPES OF OPEN GRASSLAND VEGETATION (O1-5) AND THEIR ECOLOGY

The description of the 5 types of open grassland vegetation is based on the results of the multivariate analyses described in section 9.3, including the following tables: Appendix D-table 2 and 9.3.1-2; and figures: 9.3.1-4. No further reference is made to these in the following descriptions. The habitat conditions of the localities and clusters are tabulated in Appendix A and table 9.4.2; cf. also section 9.4.2.

#### 9.7.1 The vegetation

##### O1. *Achillea millefolium*-*Tortula ruralis* type

8 samples (75-79, 287-289) in cluster 1. Nos. 287-289 represent 3 separate 1 m<sup>2</sup> quadrats from the same locality (no. 81), no. 76 is a single 0.25 m<sup>2</sup> quadrat, and the rest are all 1 m<sup>2</sup> quadrats.

This is an open, low-herb vegetation growing on the almost flat, sandy areas in the southeastern part of Sølendet. All the stands come from areas outside the present nature reserve, however.

*Salix* spp. are common in a tall field layer/low shrub layer. These areas have all formerly been either scythed or used as pasture for domestic stock. The scrub has become denser and taller in recent years. *Salix phylicifolia* is a constant species and *Salix starkeana* is a common and characteristic species of this type.

The field layer is low-growing, dense and species-rich, with a variety of herbs and graminoids as constants. *Achillea millefolium* and *Thalictrum alpinum* are dominants, with *Antennaria dioica*, *Botrychium lunaria*, *Campanula rotundifolia*, *Erigeron boreale*, *Gentiana nivalis*, *Nigritella nigra*, *Potentilla crantzii* and *Viola montana* as constant and characteristic herb species. *Vaccinium vitis-idaea* is also a constant and characteristic species. In this type *Luzula multiflora* ssp. *multiflora* is a characteristic taxon, in all other vegetation types the ssp. *frigida* is the only taxon occurring.

In addition to *Nigritella* and *Gentiana nivalis*, some other low-herb species with scattered occurrences in the Brekken area also occur here, e.g. *Botrychium boreale*, *B. lanceolatum*, *B. multifidum*, *Draba incana*, *Gentianella amarella* and *G. campestris*. In this type the designation *Alchemilla* spp. includes *Alchemilla filicaulis*, *A. glabra* and *A. wichurae*. Constant species of types 1 and 2 are: *Leontodon autumnalis*, *Rhinanthus minor* and *Nardus stricta*. Also *Festuca ovina* and *Deschampsia flexuosa* are constants of type 1, in addition to one more of the open grassland types.

*Geranium sylvaticum* and *Saussurea alpina* are constants in all the open grassland types, and another large number of vascular plants occur as constants in a majority of the types, including no. 1: *Alchemilla* spp. *Euphrasia frigida*, *Galium boreale*, *Polygonum viviparum*, *Ranunculus acris*, *Selaginella selaginoides*, *Solidago virgaurea*, *Agrostis capillaris*, *Anthoxanthum odoratum* and *Carex vaginata*.

The bottom layer is also species-rich, representing a mixture of common species of heathlands, e.g. *Hylocomium splendens* (dominant), *Dicranum scoparium*, *Pleurozium schreberi*, *Polytrichum juniperinum*, *Barbilophozia barbata*, *Ptilidium ciliare*, *Cladonia furcata*, *Peltigera canina*, as well as more nutrient-demanding species such as *Tortula ruralis* (dominant), *Bryum* sp. (not incl. *B. pseudotriquetrum*), *Dicranum muehlenbeckii*, *Drepanocladus uncinatus*, *Hylocomium pyrenaicum* and *Peltigera leucophlebia*; all the above-mentioned cryptogams, with the exception of *Hylocomium splendens*, are constants only in this particular type of open grassland vegetation. *Brachythecium salebrosum*, *Mnium spinosum* and *Barbilophozia lycopodioides* are constant species also in other types. This type represents a community transitional between the grassland and heathland vegetational series.

The within-cluster similarity is 0.57. Some of the samples tend to be outliers, especially nos. 78 and 75. When these samples are excluded, the similarity value is 0.65. Sample 79 is also rather isolated, as seen in the ordination diagrams, and lies closest to no. 76. The rest of the cluster, the typical *Nigritella* samples



(nos. 77 & 287-289) form a compact group with a high degree of similarity (0.75). The cluster has only a low resemblance to other clusters, being closest to no. 2 (0.36).

O2. *Nardus stricta*-*Thalictrum alpinum*-*Sphagnum warnstorffii* type

8 samples (54, 88, 273, 290-294) in cluster 2. Nos. 54 and 273 are synthesis samples.

All the analyses of this open, low-herb type of damp grassland vegetation are derived from stands in Vassdalen, in the southeastern part of the nature reserve. There is no tree layer, but some of the analysed stands are situated in the shade of tall birches. The shrub layer is sparse, because all the localities had been scythed up to a few decades before the analyses were made.

*Nardus stricta*, *Thalictrum alpinum*, *Saussurea alpina*, *Succisa pratensis*, *Deschampsia cespitosa*, *Aulacomnium palustre*, *Homalothecium nitens* and *Sphagnum warnstorffii* are dominants, the last-mentioned predominates. A number of constant species occur only in this particular type of grassland vegetation: *Pedicularis oederi*, *Viola epipsila/palustris*, *Scirpus cespitosus*, *Dicranum bonjeanii*, *Plagiomnium ellipticum*, *Rhizomnium pseudopunctatum* and *Tritomaria quinqueidentata*. *Nigritella nigra* occurs in three of the eight samples. In addition to the above-mentioned, a number of species of damp habitats (mainly mire species) are constants, e.g. *Betula nana*, *Equisetum palustre*, *Gymnadenia conopsea*, *Parnassia palustris*, *Succisa pratensis*, *Carex dioica*, *C. panicea* and *Plagiomnium ellipticum*.

As the above-mentioned species and the table data show, a number of grassland, and mire species occur together in this type, and the type represents a community transitional between the grassland and mire (rich fen) vegetational series.

The within-cluster similarity is only 0.54, and the cluster may be divided into at least two subtypes as indicated in the TABORD dendrogram. But even these smaller clusters have rather low similarity values, e.g. 0.58 for the 5 samples: 54, 88, 273, 293, 294.

The classification and ordination figures show a cluster that is easily separated from the other clusters. Most similar is no. 3, with a resemblance of 0.42. The DCA axes 1 & 2 do not separate clusters 2 & 3 very well, but axis 3 does so.

O3. *Betula nana*-*Molinia caerulea*-*Campylium stellatum* type

5 samples (74, 101, 102, 191, 192) in cluster 3. All samples are synthesis samples. Nos. 74, 191 and 192 are from the same locality, nos. 74 and 191 both represent analyses of the same quadrat (before and after clearance). Samples 101 and 102 may be regarded as representing a single stand s.lat.



*Betula nana* (present in both the shrub and field layers), *Molinia caerulea*, *Succisa pratensis*, *Thalictrum alpinum* and *Campylium stellatum* are dominants. In addition to *Molinia* and *Campylium*, the following species are constants only in this type of the open grassland types: *Equisetum variegatum*, *Listera ovata*, *Potentilla erecta*, *Carex capillaris* and *Fissidens adianthoides*.

This type represents a rich fen margin community transitional to damp grassland vegetation. The cluster is a rather heterogeneous one (within-cluster similarity only 0.58) and can be separated into subtypes. The homogeneity value for the three samples of locality 74 is 0.66, and that between 101 and 102 is 0.78. Stand 192 is a less fen-like vegetation than that of the other stands, from which most of the typical fen species are absent. The closest resemblance of cluster 3 is to cluster 2 (0.42).

The samples in this cluster, with the exception of no. 191, have been dealt with in section 5.4 (cf. clusters M7 and 8).

O4. *Geranium sylvaticum*-*Viola biflora* type  
2 samples (72 and 86) in cluster 4.

These stands represent a herb-dominated, wooded grassland vegetation, with open stands of trees. The samples are synthesis samples of small quadrat analyses of the woodland types described under cluster W7 of the section on woodland vegetation, and are included in this section of open grassland vegetation for the sake of comparison. Dominants: *Geranium sylvaticum*, *Alchemilla* spp. (most common: *A. glabra*, *A. glomerulans* and *A. wickströmii*), *Viola biflora*, *Crepis paludosa*, *Agrostis capillaris*, *Mnium spinosum*. In addition to *Viola biflora*, 16 species occur as constants only in this one of the open grassland types.

The within-cluster similarity is 0.58, and the cluster has its greatest resemblance to no. O5 (0.34). As seen in the figures, the cluster is well separated from the other clusters, although sample 5 of cluster 5 lies rather close by.

O5. *Salix* spp.-*Alchemilla* spp.-*Sphagnum warnstorffii* type  
10 samples (5, 84, 85, 103, 281-286) in cluster 5. No. 5 is a synthesis sample of four small quadrats, the others represent analyses of 4 m<sup>2</sup> quadrats.

This cluster represents a damp grassland vegetation forming a transition from a grassland to a fen vegetation. Most of the stands are included in the description of type W11 of the woodland vegetation and types M14 and 15 of the mire vegetation, described in section 5.4.6.

The dominants in the cluster are (ch = characteristic species): *Salix glauca* (ch; shrub and field layer), *Alchemilla* spp. (mainly *A. glabra* and *A. glomerulans*), *Filipendula ulmaria*, *Geranium sylvaticum*, *Geum rivale*, *Plagiomnium*



Fig. 9.7.1. Low-herb grassland, with *Salix phylicifolia* and *S. starkeana*, and a large number of *Nigritella nigra* (dark dots). Locality 81. 19790720.



Fig. 9.7.2

Soil profile, with an upper layer of mull and light-coloured sand basally. A flowering specimen of *Nigritella nigra* is visible in the species-rich low-herb community. Locality near to no. 81. 19780802.

*ellipticum*, *Rhizomnium magnifolium* (ch), *Sphagnum warnstorffii* and *Pellia neesi-ana* (ch). In addition to the three exclusive constants (ch) listed, another 12 species characterize this type, e.g. *Caltha palustris*, *Epilobium palustre* and *Chiloscyphus pallescens*.

### 9.7.2 Habitat conditions

All the localities of the types O1 and O2 are situated in the southeastern, flat, sandy areas of Sølendet. All the stands of O1 are from areas outside the present nature reserve, from the grassland areas flooded by calcareous water during the snowmelt period (cf. section 3.2.4, and Fig. 3.2.6). In summertime the groundwater-level lies far below the surface, the sites are then dry. The stands of O2 are all situated in Vassdalen; they are also flooded in springtime, and even during most of the summertime the groundwater-level lies rather close to the surface, i.e. the sites can be characterized as moist; the habitat conditions are described in section 7.3.4.

The communities of both clusters have no tree layer. Willows form a shrub layer that becomes denser in areas not scythed (see photo in Fig. 9.7.1). The *Olivacea* limits on birches close to the sample localities are 0.7–1 m, i.e. indicating a rather thin snow cover. The areas become snowfree in early May, when they are flooded.

Most of the stands of type O1 have a soil profile with a (2)–4 cm dark-coloured, mull-like humus layer, with an increasing amount of sand grains downwards; from ca. 7–10 cm dominated by light-coloured sand (see Fig. 9.7.2). Dark and rust-coloured spots and stripes occur in this part of the profiles for most of the stands. This gley horizon (e.g. Stålfelt 1965) is formed by the alternation of flooding (in spring) and drying out (in summertime). I regard most of the stands of type O1 to have a gleyed brown earth profile (gley is not here used as a main soil group, as done by e.g. Canada Soil Survey Committee 1983, Ball 1986). Some of the profiles show evidence of podsol formation, locality 75 has even been classified as a podsol (4 cm of humus, 7 cm thick bleached layer and a weak deposition layer, including dark-coloured spots). The pH of the humus of locality 75 was 4.7; the other values varied from 5.0 to 5.8, with a mean of 5.4 for all the ten soil samples representing the stands of cluster O1.

The soils of the stands of cluster O2 include types transitional between brown earth, podsol and peat, gleyed horizons occurred in some of the profiles. The humus/mull layer was 11 cm in mean, the pH = 5.6 (4.7–6.6)

A majority of the localities representing cluster O1 have not been scythed for a long time now (more than 50 years, pers. comm. N. Stenvold), but the areas have been grazed by farm stock up until ca. 1960. The localities of O2, plus nos. 75 and 79 of O1, were scythed up to ca. 1950. At the time of the phytosociological analyses (1975–1978), the vegetation had certainly changed after cessation of the scything/grazing, indicated by e.g. the scrub growth.

After 1978, the quadrats of O2 have been cleared and scythed (see Fig. 7.3.3), but hay yield has not been estimated for any of the quadrats. The stands of cluster O1 (all outside the present boundary of the reserve) have not been scythed.

The localities of **cluster O3** have an inclination of 5-6%, and a peat layer of 14-16 cm in all cases, except no. 192, which had 5 cm of mull-like peat. pH values varied between 5.9 and 6.7, with a mean value of 6.3. Stand 192 represents a transitional type between damp grassland and fen margin communities, the majority of the stands belong to rich fen margin vegetation (cf. section 5.4.3).

The two stands of **cluster O4** have an inclination of 6% and 8%. They represent the same type as W7 (cf. Table 1 of Appendix E, where also the production values of the quadrats in locality 72, estimated by scything, are tabulated).

The ten quadrats of **cluster O5** represent a heterogeneous vegetation transitional between a fen margin vegetation (i.e. samples 281-286 of localities 82 & 83) and a wooded and scrub-covered, tall-herb vegetation. The soil samples of the localities of the cluster as a whole had a mean pH value of 5.9.

## 10 MULTIVARIATE ANALYSES OF THE WOODED GRASSLAND VEGETATION OF UPPER BOREAL AREAS OF CENTRAL NORWAY

### 10.1 THE DATA SET

#### 10.1.1. The samples used in the analyses

Full phytosociological analyses of the data from stands of wooded grasslands in the upper boreal areas (mainly northern boreal region) of Central Norway have already been published for the Sylane area (Nordhagen 1928). In addition, the degree theses of B.F. Moen (1978) and L. Kjelvik (1978) include a number of further analyses from Nerskogen and Øvre Forradal, respectively, as also does my own unpublished material, mainly from Innerdalen and Sølendet. Taken together these amount to ca. 150 samples from wooded grasslands (including some samples transitional to heathland and rich fen vegetation).

A variety of TABORD classifications and DCA ordinations were made, using different data sets and adopting various options for the chosen threshold and fusion levels etc. The evaluation of these results, and of those discussed in section 9, were of fundamental importance regarding the final data set and options chosen, which led to the clustering and ordination results presented in this section. (Seven clusters, U1-7, are defined).

The final data set analysed comprised 101 samples, most of which were of "typical" wooded grassland vegetation from the areas referred to above, together with some stands from vegetation transitional to heathland (cf. description of cluster U1) and damp grassland/rich fen communities (cf. description of clusters U6 and 7). The vegetation of the wooded rich fens has been omitted from consideration (cf. the comments made under the description of the Ner-skogen data set), as also were some willow scrub stands (cf. the Sølendet data set). All the samples from Øvre Forradal were omitted because they had rather low degrees of similarity to the rest of the data set (cf. the comments made in subsection 10.1.6).

The 12 samples from Sylane were all synthesis samples (cf. section 4.3.3), derived from 3-5 quadrats (of 4 m<sup>2</sup>), the remaining samples were all single-quadrat analyses (most of them 16 m<sup>2</sup> or 25 m<sup>2</sup>; a few of the quadrats from Sølendet were 12.5 m<sup>2</sup>, with one quadrat of 4 m<sup>2</sup>).

The original cover scale values for all the samples were transformed to the standard Hult-Sernander-Du Rietz scale, i.e. cover degrees of 1, 2, 3, 4 and 5.

Because the data set included analyses made by three different observers (Nordhagen, B. & A. Moen), a noise factor was introduced into the subsequent analyses (cf. comments made in section 6.1.1 regarding the use of Gaare's data), which has simply to be accepted. However, conversion of the data from Nordhagen's small-sized quadrats into synthesis samples, and alteration of a few taxa (cf. comments made under the description of the Sylane samples) has certainly brought more homogeneity into the final data set analysed.

#### 10.1.2 The Sylane samples

Twelve synthesis samples from Nedalen in Sylane (Nordhagen 1928) were included in the multivariate analyses.

Nordhagen (1928) differentiated between two types of wooded grassland. The "*Geranium silvaticum*-reicher Birkenwald" was described from five stands, two of which included more than five quadrats. The data for these two stands were split to yield two samples, i.e. making seven samples altogether (nos. S25-31, cf. Table 10.1.1). The other woodland type, the "*Agrostis tenuis*-*Deschampsia flexuosa*-reicher Birkenwald" included three stands, one of which did not include any cover values for bryophytes. The two fully-described stands were separated to give two samples each (nos. S34-37).

The most relevant community in Nordhagen's scrub-covered grasslands (the "*Geranium silvaticum*-reiches Weidengebüsch I") also lacked cover values for bryophytes, wherefore none of the stands of the scrub-covered grasslands in the Sylane area have been included in the analyses. One stand of his "*Myrtillus*-reicher Birkenwald", which included grassland species such as *Cicerbita alpina*, *Geranium silvaticum*, *Rubus saxatilis* and *Mnium spinosum*, was included



**Table 10.1.1** Details of the 12 samples from the Sylane area (taken from Nordhagen 1928) used in the data set (S21-37). They are synthesis samples (cf. section 4.3.3) of 3.5 quadrats, each 4 m<sup>2</sup>.

Sample no.	No. of quadrats	Reference to Nordhagen 1928			
		Plant community	Stand no.	Quadrat nos.	Page
S21	5	Myrtillus: Potent. erecta var.	+	21-25	116
S25	4	Geranium sylvatic. birch forest	I	1-4	128
S26	3	Geranium sylvatic. birch forest	II	5-7	128
S27	3	Geranium sylvatic. birch forest	II	8-10	128
S28	4	Geranium sylvatic. birch forest	III	11-14	128
S29	3	Geranium sylvatic. birch forest	IV	15-17	128
S30	3	Geranium sylvatic. birch forest	IV	18-20	128
S31	5	Geranium sylvatic. birch forest	V	21-25	128
S34	5	Agr. ten.-Desc. flex. birch forest	II	11-15	140
S35	5	Agr. ten.-Desc. flex. birch forest	II	16-20	140
S36	5	Agr. ten.-Desc. flex. birch forest	III	21-25	140
S37	5	Agr. ten.-Desc. flex. birch forest	III	26-30	140

in the data set. This stand was chosen as representing one of the most grassland-like of the "Myrtillus" type stands; in addition, Nordhagen included a number of other stands that resembled this one. In the classification, this single sample (S21) chosen, was placed in cluster U1, i.e. a vegetation transitional between grassland and heathland. The other samples from Sylane (11 altogether) became classified within the same subcluster (viz. no. U2b of section 10.4).

I have made some taxonomic changes to Nordhagen's (1928) tables, e.g. the separate species of *Alchemilla* and *Hieracium* were amalgamated and *Empetrum nigrum* changed to *E. hermaphroditum*. Possibly more questionable changes made were:

<i>Brachythecium plumosum</i>	changed to	<i>B. salebrosum</i>
<i>Mnium</i> spp.	changed to	<i>M. spinosum</i>
<i>Mnium cuspidatum</i>	changed to	<i>Plagiomnium ellipticum</i>

### 10.1.3 The Nerskogen samples

Fifty-three stand samples, all derived from 16 m<sup>2</sup> quadrats, have been used in the multivariate analyses. All the stands, analysed by B.F. Moen (1978), are referred in table 10.1.2. A further nine Nerskogen samples were initially included in a larger data set. The TABORD classification placed one of them (N69) in the residual group (threshold level = 0.4). The other eight samples (N124-131), of forested rich fen vegetation transitional to grassland vegetation,

Table 10.1.2 Details of the 54 samples from the Nerskogen area (after B. F. Moen 1978) used in the data set (N55 - N114).

Sample no.	Reference to B. F. Moen (1978)		
	Plant community	Table no.	Stand no.
N55-57	Gymnocarpium community	III	22-24
N64-68	Oxalis-Agrostis community	IV	1-5
N70-84	Geranium-Agrostis community	IV	7-21
N85-90	Geranium community	V	1-6
N91-102	Aconitum community	V	7-18
N103-112	Filipendula-Equisetum community	V	19-28
N113-114	Athyrium community	V	29-30

became classified as two clusters of four samples each (one including moderately rich vegetation, the other extremely rich vegetation). The results of the multivariate analyses indicated that the samples forming these clusters were rather isolated from the remainder described in the present section, and were most closely related to those of cluster U6 (resemblances of 0.29 and 0.26, respectively). These stands from Nerskogen will be published later. The 53 finally chosen samples from Nerskogen yielded the clusters U1, 2, 3 and 5 of the classification.

#### 10.1.4 The Innerdalen samples

A number of phytosociological analyses of the vegetation of Innerdalen, Kvikne were made in 1972-1975, cf. Moen (1976a) which described the vegetation of the area. These analyses, however, have not yet been published. Five of these stands, all of wooded grassland vegetation (viz. nos. 1701-704, 1745), have been included in the data set used in the present paper. All the stands were analyses of 16 m<sup>2</sup> quadrats situated on steep, W- to SW-facing, slopes (30-50°). As the following sections show, all five samples are closely related, falling into the same subcluster (no. U3b) in the classification.

#### 10.1.5 The Sølendet samples

Thirty-one of the samples from Sølendet were included in the multivariate analyses. The initial data set included 34 samples, viz. all the wooded (and scrub-dominated) grassland samples listed in section 9.2 (i.e. the samples of clusters W6-11). During the TABORD classification, the samples nos. 82, 83 and 85 (all included in cluster W11 of section 9.2) fell within the residual group, wherefore they were omitted from the data set finally analysed. The 31 samples from Sølendet yielded six of the seven clusters.

### 10.1.6 The Øvre Forradal samples

None of the samples from Ø. Forradal have been included in the data set analysis described in the following sections.

The wooded grassland samples (35 altogether) from Øvre Forradal (L. Kjølvik 1978) were initially included in the more comprehensive data set of samples representing the upper boreal vegetation of Central Norway. At both the high and median levels of cluster homogeneity (threshold and fusion values exceeding ca. 0.4), the Ø. Forradal samples formed their own clusters in the classification, all having rather low degrees of similarity with the birch woodland clusters described here. The samples from L. Kjølvik's (1978) "grazed *Melico-Piceetum*" showed the greatest resemblance to my grassland types; one of the Ø. Forradal clusters (8 samples) had a similarity of ca. 0.4 to the samples of cluster U2.

The Ø. Forradal samples include some "*Vaccinio-Piceetea*"-species and some oceanic species that are absent from the birch grassland samples, e.g. *Picea abies*, *Dryopteris expansa*, *Thelypteris phegopteris* and *Plagiothecium undulatum*. In contrast, a number of the typical "*Lactucion alpinae* species" (cf. section 11.3) are either absent from, or only occur very scattered, in Ø. Forradal, e.g. *Bartsia alpina*, *Galium boreale*, *Geranium sylvaticum*, *Gnaphalium norvegicum* and *Saussurea alpina*. The wooded grasslands of Ø. Forradal would therefore seem mainly to belong to the *Vaccinio-Piceion* alliance and not to the *Lactucion alpinae*.

## 10.2 CLASSIFICATION

The TABORD classification using the data set comprising 101 samples, separated into seven clusters (U1-7). This involved four samples as the minimum value for cluster size, a threshold level of 0.4 and a fusion level of 0.7.

The full phytosociological table for the 101 samples and 286 taxa is shown in table 3 of Appendix D. The table has been arranged by the FLEXCLUS program, with a subjectively chosen order of the seven clusters. Within each cluster the samples are grouped in numerical order for each of the four study areas (Sølandet, Nerskogen, Innerdalen and Sylane). The species order is that given by the FLEXCLUS program, showing indifferent species and two diagonal structures for the constants (level 70%). Table 10.2.1 presents a synopsis of the full phytosociological table, showing the frequency and characteristic degree of cover for all the constant species in the seven clusters. The degrees of similarity (using the "similarity ratio") within and between the seven clusters are shown in figure 10.2.1.

Table 10.2.1 Synoptic table of the wooded grassland vegetation of upper boreal regions of Central Norway, showing the frequency and characteristic degree of cover. Only species that occur as constants (limit 70%) in at least one cluster are listed. Table 3 of Appendix D provides a complete listing of all species, with cover values for the 101 samples classified into the 7 clusters. I. Indifferent species. II. Constant species of one or two neighbouring clusters. III. Constant species of other clusters. A: tree layer; B: shrub layer.

Cluster no.	U1	U2	U3	U4	U5	U6	U7
No. of samples	15	38	18	9	11	6	4
I <i>Betula pubescens</i> A	100-4	100-4	100-4	100-3	91-3	100-3	100-3
<i>Geranium sylvaticum</i>	93-3	100-4	100-3	100-4	100-4	100-4	100-3
II <i>Gymnocarpium dryopteris</i>	93-4	37-1	28-2	.	9-1	17-1	25-1
<i>Listera cordata</i>	73-1	13-1	22-1	.	36-1	33-1	25-1
<i>Maianthemum bifolium</i>	87-2	26-1	11-1	.	18-1	.	25-1
<i>Luzula pilosa</i>	87-1	47-1	33-1	.	.	33-1	50-1
<i>Lophozia obtusa</i>	93-1	63-1	28-1	67-1	45-1	.	50-1
<i>Equisetum pratense</i>	27-1	34-1	94-1	.	64-1	33-1	.
<i>Rubus saxatilis</i>	13-1	66-1	72-1	22-1	45-2	17-1	.
<i>Stellaria nemorum</i>	27-3	11-1	72-3	.	27-1	.	.
<i>Aconitum septentrionale</i>	13-1	63-1	100-4	100-4	55-2	.	.
<i>Myosotis decumbens</i>	33-1	63-1	89-1	89-1	36-1	33-1	.
<i>Paris quadrifolia</i>	20-1	29-1	78-1	100-1	64-1	67-1	.
<i>Poa nemoralis</i>	7-1	34-1	78-1	100-1	64-1	67-2	.
<i>Angelica archangelica</i>	.	3-1	17-1	100-2	9-1	.	.
<i>Mnium stellare</i>	7-1	5-1	6-1	89-1	9-1	17-1	.
<i>Equisetum sylvaticum</i>	7-1	24-1	17-1	44-1	91-1	67-1	.
<i>Plagiommium ellipticum</i>	.	32-1	22-1	22-1	82-2	33-1	.
<i>Chiloscyphus pallescens</i>	7-1	13-1	17-1	44-2	82-1	100-1	.
<i>Angelica sylvestris</i>	.	34-1	17-1	22-1	18-1	83-1	50-1
<i>Parnassia palustris</i>	.	32-1	.	56-1	.	100-1	25-1
<i>Thalictrum alpinum</i>	.	47-1	.	.	9-1	100-3	25-3
<i>Carex nigra</i>	20-1	8-1	28-1	11-1	27-1	83-1	.
<i>Festuca rubra</i>	.	42-1	28-1	44-1	36-1	83-1	25-1
<i>Bryum</i> sp.	.	13-1	11-1	.	45-1	83-1	25-1
<i>Campylium stellatum</i>	7-1	13-1	6-1	44-1	55-1	100-3	25-2
<i>Climacium dendroides</i>	7-1	16-1	6-1	67-1	45-1	83-1	50-1
<i>Fissidens adianthoides</i>	.	3-1	.	.	.	83-1	25-1
<i>Rhizomnium magnifolium</i>	7-1	8-1	.	44-1	36-3	83-1	.
<i>Pellia</i> sp.	.	5-1	.	44-2	64-1	83-1	.
<i>Bartsia alpina</i>	.	50-1	.	.	.	83-1	100-1
<i>Dactylorhiza fuchsii</i>	13-1	13-1	.	67-1	.	100-1	75-1
<i>Leontodon autumnalis</i>	.	.	.	.	.	83-1	75-1
<i>Potentilla erecta</i>	7-3	39-1	6-1	.	18-1	100-2	75-3
<i>Succisa pratensis</i>	.	.	.	.	.	100-2	100-2
<i>Luzula sudetica</i>	7-1	16-1	.	33-1	.	83-1	100-1
<i>Nardus stricta</i>	7-1	26-1	.	.	.	100-2	100-2
<i>Drepanocladus uncinatus</i>	33-1	29-1	.	44-1	18-1	83-1	100-1
<i>Lophocolea bidentata</i>	.	3-1	6-1	22-1	.	83-1	75-1
<i>Salix glauca</i> B	7-1	32-2	6-2	67-1	18-4	.	75-1
<i>Euphrasia</i> sp.	20-1	32-1	.	.	.	67-1	75-1
<i>Hieracium</i> sp.	53-1	66-1	28-1	44-2	9-1	50-1	100-1
<i>Melampyrum pratense</i>	53-1	32-1	.	.	.	17-1	100-1
<i>Pedicularis oederi</i>	.	5-1	.	.	.	17-2	75-1
<i>Rhinanthus minor</i>	13-1	55-1	.	.	.	.	100-1
<i>Festuca ovina</i>	20-1	8-1	11-1	.	.	50-1	75-1
<i>Luzula multiflora</i>	13-1	66-1	11-1	.	.	33-1	75-1
<i>Molinia caerulea</i>	.	3-1	.	.	.	50-1	75-2
<i>Phleum alpinum</i>	47-1	50-1	22-1	44-1	.	50-1	100-1
<i>Pleurozium schreberi</i>	33-2	39-1	.	.	9-1	.	100-1
<i>Polytrichum commune</i>	60-2	18-1	.	.	.	.	100-2
<i>Sphagnum russowii</i>	.	.	.	.	.	.	75-1

Table 10.2.1 continued

Cluster no. No. of samples	U1 15	U2 38	U3 18	U4 9	U5 11	U6 6	U7 4
III <i>Vaccinium myrtillus</i>	100-3	89-1	28-1	44-1	.	33-1	100-1
<i>Melampyrum sylvaticum</i>	73-1	61-1	28-1	67-1	.	33-1	100-1
<i>Oxalis acetosella</i>	87-2	50-1	94-2	78-2	36-1	.	.
<i>Pyrola minor</i>	73-1	92-1	39-1	56-1	45-1	83-1	75-1
<i>Rumex acetosa</i>	87-1	84-1	94-1	100-1	91-1	67-1	75-1
<i>Solidago virgaurea</i>	87-2	92-2	78-1	89-2	64-1	100-1	100-2
<i>Trientalis europaea</i>	93-1	82-1	33-1	78-1	64-1	50-1	75-1
<i>Anthoxanthum odoratum</i>	100-2	95-3	72-1	89-1	36-1	100-1	100-2
<i>Deschampsia flexuosa</i>	100-3	97-2	72-1	78-1	18-1	67-1	100-2
<i>Brachythecium reflexum</i>	73-1	53-1	56-2	100-1	27-1	17-1	25-1
<i>Brachythecium salebrosum</i>	100-2	82-1	83-1	100-3	64-1	.	25-1
<i>Dicranum scoparium</i>	73-1	42-1	6-1	.	.	67-1	100-1
<i>Hylocomium splendens</i>	80-1	63-1	22-1	67-1	18-1	100-1	100-3
<i>Mnium spinosum</i>	80-1	76-2	89-1	100-3	18-1	17-1	.
<i>Rhodobryum roseum</i>	93-1	87-1	83-1	100-1	45-1	100-2	100-2
<i>Rhytidiadelphus sq./subp.</i>	73-1	58-2	44-1	100-1	45-1	83-3	75-1
<i>Barbilophozia lycopodioides</i>	100-1	95-1	50-1	78-1	9-1	50-1	100-2
<i>Alchemilla sp.</i>	40-1	87-2	83-1	100-3	100-4	100-4	100-2
<i>Geum rivale</i>	.	74-2	61-1	100-2	82-3	100-2	25-1
<i>Polygonum viviparum</i>	67-1	92-1	22-1	78-1	18-1	100-1	100-1
<i>Ranunculus acris</i>	53-1	89-1	72-1	100-1	82-1	100-2	50-1
<i>Saussurea alpina</i>	20-1	79-2	61-1	89-1	73-1	83-3	75-1
<i>Selaginella selaginoides</i>	.	76-1	11-1	11-1	.	50-2	100-1
<i>Viola biflora</i>	33-1	84-3	78-2	100-2	9-1	.	25-1
<i>Agrostis capillaris</i>	67-1	89-2	72-1	89-2	64-1	100-2	100-3
<i>Carex vaginata</i>	20-1	74-1	39-1	.	55-1	100-2	100-1
<i>Deschampsia cespitosa</i>	33-1	89-2	100-3	100-3	100-2	100-4	100-3
<i>Filipendula ulmaria</i>	7-1	66-1	89-1	100-2	100-3	83-1	.
<i>Crepis paludosa</i>	13-1	61-1	50-2	100-2	91-2	100-3	100-1
<i>Galium boreale</i>	.	66-2	50-1	78-1	45-1	100-1	50-2
<i>Gnaphalium norvegicum</i>	20-1	61-1	6-1	89-1	.	.	100-1
<i>Plagiochila porell./aspl.</i>	33-1	50-1	44-1	100-1	45-1	100-2	75-1

Cluster no. 4 shows the highest degree of internal homogeneity (within-cluster similarity of 0.73) of all seven clusters, and no. 7 the lowest (similarity of 0.55). Clusters 2 (similarity of 0.61) and 3 (similarity of 0.64) include the largest number of samples, (38 and 18, respectively). A bipartition of each of these large clusters (based on the TABORD clustering results) yielded four subclusters with similarity values varying from 0.61 (subcluster 2a) to 0.75 (3b). The degrees of similarity within and between these subclusters are shown in figure 10.2.2. Subclusters 2a and 2b show the greatest between-cluster similarity (0.76) of all the (sub)clusters. Figure 10.2.3 shows the TABORD dendrogram for the 9 (sub)clusters. At a similarity level of 0.54, a single cluster contained all the samples. The dendrogram indicates that the wooded grassland samples possess a fairly high degree of homogeneity. A separate TABORD trial using a fusion value of 0.67 (with all other options unchanged) resulted in four clusters; one of them comprised 60 samples (viz. most of the samples forming the clusters 2, 3 and 4), clusters 1 (15 samples) and 5 (11 samples) reappeared unchanged, and the fourth cluster comprised the original clusters 6 and 7, together with samples 251, 272 and N104.



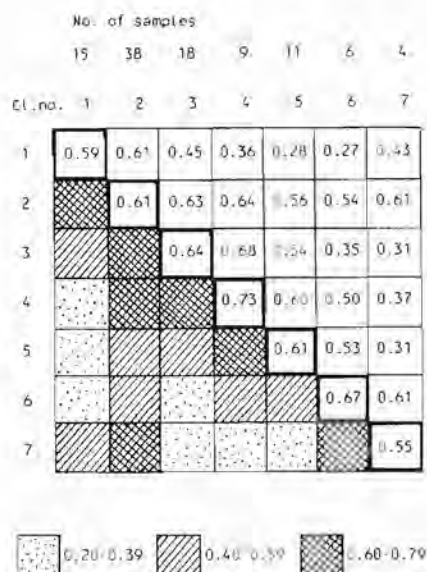


Fig. 10.2.1

Resemblance between the 7 clusters (U1-7) of the wooded grassland vegetation of the boreal uplands of Central Norway, calculated from the "similarity ratio" values. The diagonal shows the within-cluster similarity.

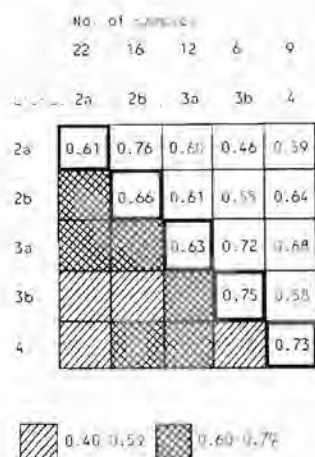


Fig. 10.2.2

Resemblance between four of the subclusters (nos. 2a, 2b, 3a, 3b) and one cluster (no. 4) of the herb-dominated woodland vegetation; cluster nos. etc. as in figure 10.2.1.

### 10.3 ORDINATION

The DCA-ordination diagrams for the 101 samples, grouped along the axes nos. 1 & 2 and 1 & 3, respectively, are shown in figure 10.3.1 (A & B). Clusters 1-7 were delineated by hand and assigned their TABORD cluster numbers. All the 286 "taxa" were included in the ordination, with the rare species down-weighted (cf. section 4.4.3). Ordination without downweighting of rare species yielded a somewhat different picture, wherein the distal samples were more widely separated (these diagrams are not presented here).

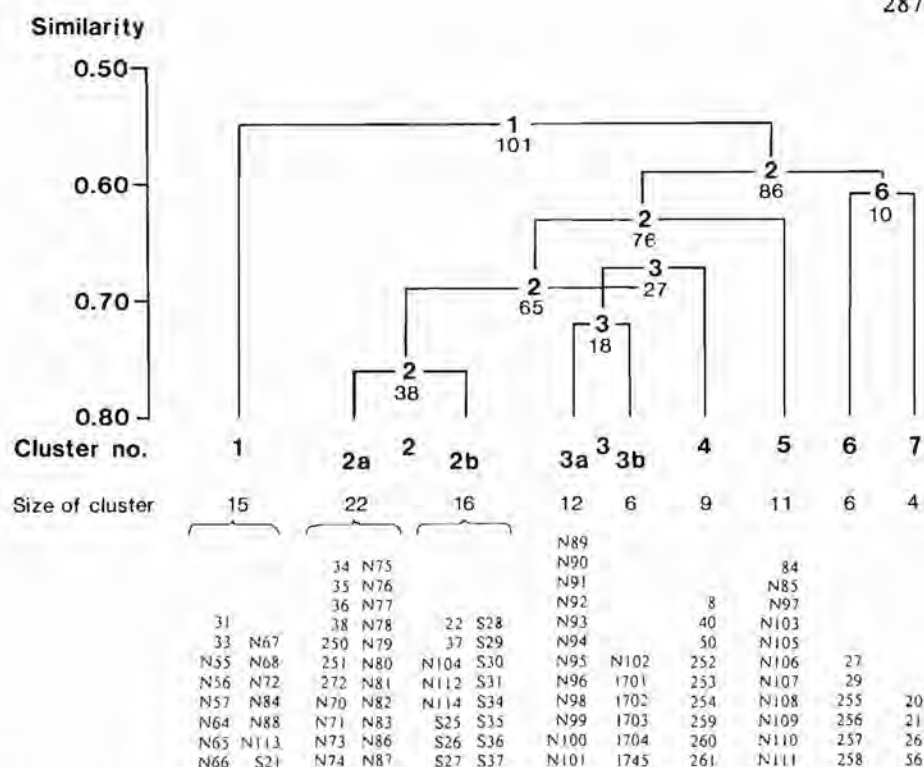


Fig. 10.2.3 TABORD dendrogram for the clusters (U1-7) and subclusters derived from the 101 samples of wooded grassland vegetation of the boreal uplands of Central Norway. The initial (sub)clusters (nos 1, 2a, 2b, 3a, 3b, 4, 5, 6, 7) are identical with those shown in table 10.2.1 and in figures 10.2.1-2. The seven clusters are separated at a fusion level of 0.7 (threshold level of 0.4, minimum size of clusters: 4 samples). The dendrogram shows how the (sub)clusters agglomerate at zero threshold and fusion levels, with no sample relocation allowed during the agglomerative process. Key to derivations: 5 samples from Innerdalen (I), 53 samples from Nerskogen (N), 12 samples from Sylane (S) and 31 from Sølendet (no prefix). Index: similarity ratio.

Table 10.3.1 presents the scores for the 60 chosen species (41 species in each column) arranged along the first three axes of the DCA-ordination. The species selected were among those that occurred in at least four of the samples. Stress was placed on selecting species situated peripherally along the axes, i.e. the species with high values and those with low values. The characteristic species of the *Lactucion alpinae* (cf. section 11.3) are included among the 30 species listed for all three axes.

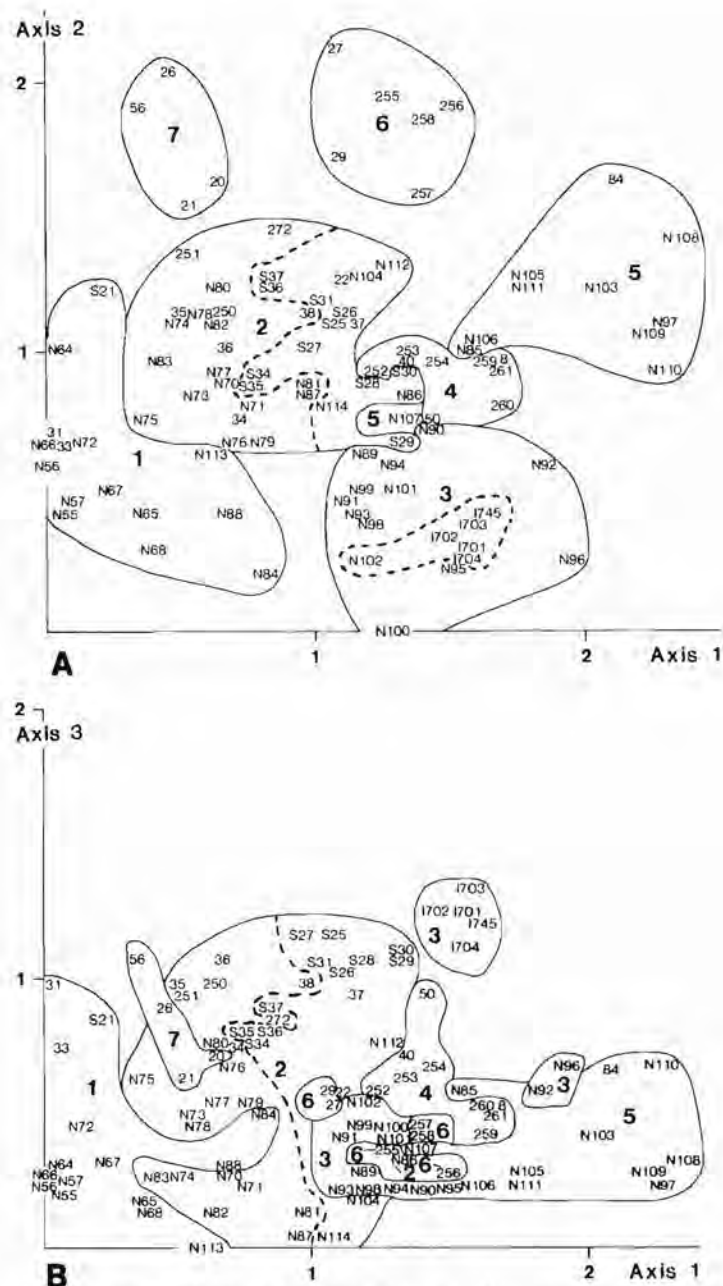


Fig. 10.3.1

DCA-ordination diagrams for the 101 samples of wooded grassland vegetation of the boreal uplands of Central Norway (rare species downweighted). A: axis 1 & 2; B: axis 1 & 3). Eigenvalues of the axis: 1:0.223; 2:0.173; 3:0.093. The TABORD clusters U1-7 are ringed with solid lines; the results of the partition of clusters 2 and 3 into two subclusters each (cf. section 10.2) are shown by the dashed lines.

Table 10.3.1 The species scores (in standard deviation units) for the 60 chosen species along the first three axes of the DCA-ordination of the wooded grassland vegetation of Central Norway. Values for all three axes are listed for 30 of these species (including the characteristic species of *Lactucion alpinae*), the remainder are frequent species with high or low values along at least one axis. A: tree layer; B: shrub layer.

First axis (ranked) Eigenvalue: 0.222	Second axis (ranked) Eigenvalue: 0.173	Third axis (ranked) Eigenvalue: 0.093
<i>Bryum weigelii</i> 5.61	<i>Leontodon autumnalis</i> 4.88	<i>Roegneria canina</i> 5.25
<i>Caltha palustris</i> 5.01	<i>Succisa pratensis</i> 4.72	<i>Salix lanata</i> B 4.80
<i>Poa remota</i> 3.98	<i>Fissidens adianthoides</i> 4.63	<i>Melica nutans</i> 4.62
<i>Pellia</i> sp. 3.65	<i>Molinia caerulea</i> 4.57	<i>Ranunculus platanifolius</i> 3.92
<i>Chiloscyphus pallescens</i> 3.41	<i>Sphagnum warnstorffii</i> 4.44	<i>Silene dioica</i> 3.68
<i>Calamagrostis purpurea</i> 3.36	<i>Gymnadenia conopsea</i> 4.25	<i>Botrychium lunaria</i> 3.35
<i>Sphagnum warnstorffii</i> 3.30	<i>Nardus stricta</i> 3.63	<i>Carex pallescens</i> 3.27
<i>Equisetum sylvaticum</i> 3.15	<i>Carex capillaris</i> 3.58	<i>Polygonatum verticillatum</i> 3.14
<i>Angelica archangelica</i> 2.97	<i>Campylium stellatum</i> 3.31	<i>Valeriana sambucifolia</i> 2.51
<i>Filipendula ulmaria</i> 2.80	<i>Thalictrum alpinum</i> 3.30	<i>Circium helenioides</i> 2.25
<i>Alnus incana</i> A 2.67	<i>Potentilla erecta</i> 2.93	<i>Poa remota</i> 2.21
<i>Mnium stellatum</i> 2.65	<i>Dactylorhiza fuchsii</i> 2.91	<i>Gymnadenia conopsea</i> 2.15
<i>Poa nemoralis</i> 2.64	<i>Chiloscyphus pallescens</i> 2.40	<i>Gnaphalium norvegicum</i> 2.12
<i>Aconitum septentrionale</i> 2.60	<i>Crepis palludosa</i> 2.15	<i>Rubus saxatilis</i> 2.05
<i>Geum rivale</i> 2.59	<i>Geum rivale</i> 1.83	<i>Angelica archangelica</i> 1.81
<i>Valeriana sambucifolia</i> 2.53	<i>Gnaphalium norvegicum</i> 1.66	<i>Viola biflora</i> 1.74
<i>Paris quadrifolia</i> 2.43	<i>Saussurea alpina</i> 1.64	<i>Cicerbita alpina</i> 1.59
<i>Campylium stellatum</i> 2.41	<i>Circium helenioides</i> 1.50	<i>Stellaria nemorum</i> 1.55
<i>Stellaria nemorum</i> 2.31	<i>Calamagrostis purpurea</i> 1.35	<i>Saussurea alpina</i> 1.45
<i>Crepis paludosa</i> 2.30	<i>Filipendula ulmaria</i> 1.02	<i>Aconitum septentrionale</i> 1.11
<i>Cicerbita alpina</i> 1.81	<i>Angelica archangelica</i> 0.42	<i>Thalictrum alpinum</i> 1.10
<i>Circium helenioides</i> 1.76	<i>Cicerbita alpina</i> 0.41	<i>Filipendula ulmaria</i> 0.95
<i>Saussurea alpina</i> 1.63	<i>Ranunculus platanifolius</i> 0.39	<i>Calamagrostis purpurea</i> 0.78
<i>Myosotis decumbens</i> 1.44	<i>Vaccinium myrtillus</i> 0.38	<i>Geum rivale</i> 0.55
<i>Polygonatum verticillatum</i> 1.09	<i>Luzula pilosa</i> 0.34	<i>Vaccinium myrtillus</i> 0.30
<i>Viola biflora</i> 0.97	<i>Polygonatum verticillatum</i> 0.31	<i>Paris quadrifolia</i> 0.31
<i>Thalictrum alpinum</i> 0.62	<i>Paris quadrifolia</i> 0.15	<i>Milium effusum</i> 0.07
<i>Gnaphalium norvegicum</i> 0.50	<i>Viola biflora</i> 0.06	<i>Sphagnum warnstorffii</i> -0.09
<i>Carex capillaris</i> 0.42	<i>Maianthemum bifolium</i> 0.04	<i>Myosotis decumbens</i> -0.16
<i>Gymnadenia conopsea</i> 0.31	<i>Myosotis decumbens</i> -0.17	<i>Gymnocarpium dryopteris</i> -0.18
<i>Milium effusum</i> 0.18	<i>Valeriana sambucifolia</i> -0.28	<i>Maianthemum bifolium</i> -0.26
<i>Ranunculus platanifolius</i> -0.55	<i>Milium effusum</i> -0.65	<i>Crepis paludosa</i> -0.44
<i>Vaccinium myrtillus</i> -0.74	<i>Gymnocarpium dryopteris</i> -0.67	<i>Luzula pilosa</i> -0.84
<i>Luzula pilosa</i> -0.81	<i>Veronica officinalis</i> -0.78	<i>Campylium stellatum</i> -0.89
<i>Pleurozium schreberi</i> -1.15	<i>Aconitum septentrionale</i> -0.80	<i>Carex capillaris</i> -0.90
<i>Gymnocarpium dryopteris</i> -1.22	<i>Oxalis acetosella</i> -0.82	<i>Chiloscyphus pallescens</i> -1.31
<i>Maianthemum bifolium</i> -1.38	<i>Poa remota</i> -0.93	<i>Cirriphyllum piliferum</i> -2.04
<i>Melampyrum pratense</i> -1.49	<i>Roegneria canina</i> -1.06	<i>Alnus incana</i> A -2.12
<i>Empetrum hermaphroditum</i> -1.51	<i>Alnus incana</i> A -1.13	<i>Linnaea borealis</i> -2.32
<i>Alchemilla alpina</i> -1.56	<i>Athyrium filix-femina</i> -1.26	<i>Athyrium filix-femina</i> -2.97
<i>Thelypteris phegopteris</i> -2.02	<i>Stellaria nemorum</i> -2.02	<i>Veronica officinalis</i> -3.46

The first axis (no. 1; eigenvalue 0.222, length 2.37 s.d.) represents a gradient from types transitional between grasslands and heathlands to, firstly, typical dry grasslands and thereafter to tall-herb and damp grasslands. Heathland species showing low values are e.g. *Empetrum hermaphroditum*, *Gymnocarpium dryopteris*, *Maianthemum bifolium*, *Melampyrum pratense*, *Thelypteris phegopteris*, *Pleurozium schreberi* and a number of lichens. The values for all the above-mentioned species have s.d.'s of less than -1. The values for all three *Vaccinium* spp. were also negative. The highest values along the first axis belong to species indicative of damp habitats, such as *Caltha palustris* and *Bryum weigelii*. Among the more frequent species that have high values (i.e.

higher than 3.0 s.d.) are *Equisetum sylvaticum*, *Calamagrostis purpurea*, *Chiloscyphus pallescens* and *Pellia* sp.. Even *Aconitum septentrionale*, *Filipendula ulmaria*, *Geum rivale* and *Mnium stellatum* have values higher than 2.5. The progression along axis 1 is mainly from poorer to richer vegetation; however, the damp grassland samples of cluster 5 do not represent richer vegetation than the samples of clusters 3, 4 and 6.

**The second axis** (no. 2; eigenvalue 0.173, length 2.25 s.d.) distinguishes between (xerophilous-)mesophilous communities/species, with low values, and more hygrophilous communities/species, with high values. Species with the lowest values (below -1 s.d.) include *Stellaria nemorum* and *Roegneria canina*. The more frequently occurring species *Aconitum septentrionale*, *Gymnocarpium dryopteris* and *Oxalis acetosella* also have low values. A number of rich fen/damp grassland species, e.g. *Gymnadenia conopsea*, *Leontodon autumnalis*, *Succisa pratensis*, *Thalictrum alpinum*, *Carex capillaris*, *Molinia caerulea* and *Campyllum stellatum* are found at the other end of the gradient. Axis 2 thus represents a gradient from rather dry to damp habitats.

Axes 1 and 2 both have relatively high eigenvalues and the samples are spread out fairly evenly over the diagram, as seen in figure 10.3.1.A. The TABORD clusters separate the 101 samples into fairly distinct groups with the exception of a few samples (e.g. sample N107 in cluster 5, which lies close to samples in clusters 2, 3 and 4).

The samples of small-fern and heathland-type vegetation are all located in the left hand bottom corner of the diagram; with those of fen-like vegetation at the top of the diagram, the poorest types (i.e. samples of cluster 7) on the left, the extremely rich types on the right. The samples of rather dry, tall-herb vegetation are grouped together in the right-hand bottom corner of the diagram (cluster 3), the wet tall-herb samples lying furthest to the right. The samples of medium-tall herb and graminoid-dominated grassland are grouped in the centre of the diagram. They represent communities intermediate between low- and tall-herb types, and occupy an intermediate position along the dry-damp and poor-rich habitat gradients.

**The third axis** (no. 3; eigenvalue 0.093, length 1.39 s.d.) has lower eigenvalues than axes 1 and 2. Even so, the axis distinctly separates the samples according to their geographical derivation. The Nerskogen samples, that account for more than half of the entire data set, all have low values, i.e. are placed at the bottom of the diagram (Fig. 10.3.1 B). The Sølendet samples occupy an intermediate position, with most of them situated towards the middle of the axis. All the Sylane samples lie along the upper half of the axis, and the Innerdalen samples are grouped together uppermost. The species ordination includes a number of lowland species that occur, with low values, only at Nerskogen e.g. *Athyrium filix-femina*, *Veronica chamaedrys*, *V. officinalis* and *Vicia sylvatica* (values below -2.5 s.d.). A number of species exclusive to Innerdalen constitute the other end of this axis, e.g. the following ones (also mainly lowland species) all with values above 5: *Fragaria vesca*, *Avenula pubescens* and *Roegneria canina*. All the species listed are absent from the Sølendet samples.



The fourth axis (eigenvalue 0.058, length 1.246 s.d.) is less important, and thus has not been included in any of the diagrams. However, this axis does show a trend suggesting a gradient from lowland types/species, comprising some of the samples from the lowest-lying and south-facing sites (e.g. *Veronica chamaedrys*, *V. officinalis* and *Vicia sylvatica* all with low values) to more alpine types/species (including e.g. *Carex bigelowii* with a high value).

#### 10.4 THE SEVEN VEGETATIONAL TYPES (= CLUSTERS U1-7)

The description of the seven woodland types is based on the results shown in table 10.2.1, Appendix D-table 3 and figures 10.2.1-3 and 10.3.1. The first type (U1) forms a transition between the dry grassland communities and the small-fern communities. Additional samples exist from Sylane and Nerskogen that also resemble the ones included in cluster U1, so further multivariate analyses will have to be made before arriving at a final decision on typification (cf. also the comments in section 11.2.3 in regard to the *Melico-Piceetum*).

The types U4, U6, and U7 are identical with the types W10, W9 and W8, respectively, already described in section 9.6. These types will therefore only be briefly described here.

Figures 10.4.1-2 show photos of the types U1 (from Nerskogen) and U3 (Innerdalen). Photos of some Sølendet stands are included in section 9.

- U1. *Betula pubescens*-*Vaccinium myrtillus*-*Gymnocarpium dryopteris* type  
15 samples: 31 & 33 (from Sølendet), S21 (from Sylane), N55-57, N64-68, N72, N84, N88, N113 (from Nerskogen).

Dominant species: *Betula pubescens*, *Vaccinium myrtillus*, *Geranium sylvaticum*, *Gymnocarpium dryopteris*, and *Deschampsia flexuosa*. Species that are only constants (level 70%) in this one of all the clusters: *Gymnocarpium*, *Listera cordata*, *Maianthemum bifolium*, *Luzula pilosa* and *Lophozia obtusa*. (The two last-mentioned species are also constants in subcluster 2a). Altogether 24 species are constants in this cluster. Some other species have frequency values of 60-70%, among which is *Milium effusum* with cover value of 3. Cluster 1 is most like cluster 2 (resemblance 0.61); its resemblance to the subcluster 2a (0.60) is higher than that to subcluster 2b (0.55). As seen in the DCA diagrams, some of the samples of cluster 1 are situated close to some samples of subcluster 2a. Cluster 1 bears only a low degree of resemblance to the other clusters (and subclusters); its within-cluster similarity (0.59), also is rather low, i.e. it represents a somewhat heterogeneous cluster.



Fig. 10.4.1 Graminoid-dominated vegetation (grazed) of the cluster type U1. Stand N64, Nerskogen. 19740722. (Inset: *Geranium sylvaticum*).

Fig. 10.4.2 *Aconitum septentrionale*-dominated woodland of the cluster type U3b. Innerdalen. 19730713. (Inset: Brown earth profile).  
Photos in figures 10.4.1-2 from Moen (1982b).

U2 *Betula pubescens*-*Geranium sylvaticum*-*Deschampsia flexuosa* type  
38 samples altogether, of which 22 form subcluster 2a and 16 subcluster 2b.  
2a: 34-36, 38, 251, 252, N70-71, N73-83, N86, N87.  
2b: 22, 37, N104, N112, N114, S25-31, S34-37.

Dominants in cluster 2: *Betula pubescens*, *Geranium sylvaticum*, *Viola biflora* and *Anthoxanthum odoratum*. In addition, 19 species are constants: *Vaccinium myrtillus*, *Alchemilla* spp., *Geum rivale*, *Polygonum viviparum*, *Pyrola minor*, *Ranunculus acris*, *Rumex acetosa*, *Saussurea alpina*, *Selaginella selaginoides*, *Solidago virgaurea*, *Tridentalis europaea*, *Agrostis capillaris*, *Carex vaginata*, *Deschampsia cespitosa*, *D. flexuosa*, *Brachythecium salebrosum*, *Mnium spinosum*, *Rhodobryum roseum* and *Barbilophozia lycopodioides*. Following the separation into two subclusters, additional constant species found in 2a are: *Hieracium* spp., *Myosotis decumbens*, *Luzula multiflora*, *L. pilosa*, *Hylocomium splendens* and *Lophozia obtusa*. Additional constants of subcluster 2b are: *Cirsium helenioides*, *Crepis paludosa*, *Filipendula ulmaria*, *Galium boreale*, *Gnaphalium norvegicum*, *Rubus saxatilis* and *Rhytidadelphus squarrosus/subpinnatus*.

The species lists for cluster 2 show a mixture of heathland and grassland species, subcluster 2a representing the most heathland-like type. The similarity value for the entire cluster is rather low (0.61), those for the subclusters 2a and 2b being 0.61 and 0.66, respectively. The resemblance between the two subclusters is high (0.76), however.

Cluster 2, as a whole, bears the greatest resemblance to clusters 4 (0.64) and 3 (0.63), as well as exhibiting fairly great similarities with some other clusters, e.g. 0.61 to both clusters 1 and 7. The similarity values and the results of the DCA ordination show that cluster 2 represents a "central" cluster of the analysis treatment. Subcluster 2a lies closest to cluster 1 and subcluster 2b closest to nos. 4 and 3a (similarity values of 0.64 and 0.61 respectively).

U3. *Betula pubescens*-*Aconitum septentrionale*-*Stellaria nemorum* type  
18 samples altogether, of which 12 form subcluster 3a and 6 subcluster 3b.  
3a: N89-96, N98-101.  
3b: N102, I701-704, I745 (I = Innerdalen).

Dominants in cluster 3: *Betula pubescens*, *Aconitum septentrionale*, *Geranium sylvaticum*, *Stellaria nemorum* and *Deschampsia cespitosa*. Characteristic species:

*Equisetum pratense*, *Rubus saxatilis* and *Stellaria nemorum*. *Aconitum septentrionale*, *Myosotis decumbens*, *Paris quadrifolia* and *Poa nemoralis* occur as constants only in types 3 and 4.

An additional 13 species occur as constants in cluster 3, including: *Alchemilla* spp., *Filipendula ulmaria*, *Oxalis acetosella*, *Ranunculus acris*, *Rumex acetosa*, *Solidago virgaurea*, *Viola biflora*, *Agrostis capillaris*, *Anthoxanthum odoratum*, *Deschampsia flexuosa*, *Brachythecium salebrosum*, *Mnium spinosum* and *Rhodobryum roseum*. A number of other species are fairly common in the cluster, e.g. *Milium effusum* which occurs in 67% of the samples.

*Crepis paludosa* is a fully constant species (with cover value of 2) in subcluster 3a, it is lacking in 3b. Some other species occur as constants in the 6 samples of subcluster 3b, e.g. *Galium boreale*, *Saussurea alpina*, *Valeriana sambucifolia* and *Melica nutans*. In addition to *Melica*, some other lowland/warmth-demanding species occur commonly in 3b, e.g. the following ones, all with frequency of 67%: *Daphne mezereum*, *Fragaria vesca*, *Rubus idaeus*, *Avena pubescens* and *Roegneria canina*.

The within-cluster similarity of cluster 3 is 0.64; the values for subclusters 3a and 3b are 0.63 and 0.75, respectively. The latter value indicates a subcluster with a high degree of homogeneity, considering that it includes 6 samples from different localities. The DCA ordination diagrams also indicate a close interrelationship of the five Innerdalen samples. The samples forming subcluster 3a are widely distributed in both the diagrams.

Cluster 3 is most closely related to clusters 4 (0.68) and 2 (0.63). The degree of similarity between the two subclusters 3a and 3b is as high as 0.72, and each of these two subclusters has a great similarity with cluster 4 (0.68 and 0.58, respectively) and with subcluster 2b (0.61 and 0.55, respectively).

U4. *Betula pubescens*-*Aconitum septentrionale*-*Angelica archangelica* type  
9 samples: 8, 40, 50, 252-54, 259-61, all from Sølendet. The cluster is identical with cluster W10 of section 9.6.

Dominants: *Betula pubescens*, *Aconitum septentrionale*, *Geranium sylvaticum*, *Alchemilla* spp., *Deschampsia cespitosa*, *Brachythecium salebrosum* and *Mnium spinosum*. Characteristic species are: *Angelica archangelica* and *Mnium stellatum*. Altogether 33 species occur as constants in cluster 4.

The within-cluster similarity is high (0.73), and its greatest resemblance is to clusters 3 (0.68) and 2 (0.64). The DCA diagrams also indicate a close resemblance between the samples of cluster 4 and those of subclusters 2b and 3a, respectively. Even some of the samples of cluster 5 closely resemble some of the samples of cluster 4. In the DCA-ordination diagrams (see Fig. 10.3.1 A), the samples of cluster 4 are centrally situated, and are surrounded by the samples forming clusters 2, 3 and 5.



- U5. *Betula pubescens*-*Filipendula ulmaria*-*Equisetum sylvaticum* type  
11 samples: 84, N85, N97, N103, N105-111.

Dominants: *Betula pubescens*, *Alchemilla* spp., *Filipendula ulmaria*, *Geranium sylvaticum* and *Geum rivale*. Characteristic species are: *Equisetum sylvaticum* and *Plagiomnium elatum*; *Chiloscyphus pallescens* occurs as a constant only in clusters 5 and 6. Altogether 13 species occur as constants in cluster 5. Additional species are: *Crepis paludosa*, *Ranunculus acris*, *Rumex acetosa*, *Saussurea alpina* and *Deschampsia cespitosa*. The samples of the cluster include a large number of species indicative of damp habitats, e.g. the characteristic species mentioned above, together with such ones as *Caltha palustris*, *Calamagrostis purpurea*, *Campylium stellatum* and *Pellia* sp., all with frequencies of 50-70%.

The within-cluster similarity is rather low (0.61), and the DCA diagrams also show a cluster in which the samples are well separated from one another, no. N107, especially, is situated rather a long way away from the remainder, along axis 1. The resemblance to the other clusters is rather low, the greatest being to cluster 4 (0.60).

- U6. *Betula pubescens*-*Crepis paludosa*-*Campylium stellatum* type  
6 samples: 27, 29, 255-258, all from Sølendet. The cluster is identical with cluster W9 of section 9.6.

Dominants: *Betula pubescens*, *Alchemilla* spp., *Crepis paludosa*, *Geranium sylvaticum*, *Saussurea alpina*, *Thalictrum alpinum* (ch), *Deschampsia cespitosa*, *Campylium stellatum* (ch) and *Rhytidiadelphus squarrosus/subpinnatus*. In addition to the two species marked (ch), a further nine are characteristic species in this cluster. *Chiloscyphus pallescens* is a common constant species for both clusters 5 and 6; another nine species are common constants of clusters 6 and 7. Altogether there are 41 constant species in cluster 6, 24 of which occur in all 6 samples.

The within-cluster similarity is 0.67. The closest resemblance of this cluster is to no. 7 (0.61), with rather low resemblance values to the remaining clusters (greatest to subcluster 2b: 0.57).

- U7. *Betula pubescens*-*Agrostis capillaris*-*Succisa pratensis* type  
4 samples: 20, 21, 26, 56, all from Sølendet. The cluster is identical with cluster W8 of section 9.6.

Dominants: *Betula pubescens*, *Geranium sylvaticum*, *Potentilla erecta*, *Agrostis capillaris*, *Deschampsia cespitosa* and *Hylocomium splendens*. There are 13 characteristic species in addition to the 9 which occur as constants only in clusters 6 and 7; altogether 47 species are constants in cluster 7, of which 30 occur in all four samples.



The within-cluster similarity is low (0.55), and the samples forming the cluster are spread out fairly widely in the DCA diagrams. The cluster is most similar to clusters 2 and 6, with resemblance values of 0.61 in both cases.

## 11 COMPARISON WITH SIMILAR TYPES OF HEATHLAND AND GRASSLAND VEGETATION ELSEWHERE: A SYNSYSTEMATIC SURVEY

### 11.1 CLASSIFICATION OF UPLAND BOREAL VEGETATION

#### 11.1.1 Comparisons with alpine and lowland vegetation

The phytosociological analyses of the material presented in this monograph are derived from one relatively small area, in addition the wooded grassland vegetation of three more areas of Central Norway have been described in section 10. A more complete synsystematic treatment of the mire, spring and some woodland communities of the boreal uplands of Central Norway will be given in future (cf. section 1.2 for a survey of this more ambitious project).

The results of studies and classification of the vegetation of the upper boreal areas of Norway, together with the alpine vegetation, have been published in a number of phytosociological publications (e.g. Resvoll-Holmsen 1920, Nordhagen 1928, 1936, 1943, Dahl 1957, Økland & Bendiksen 1985). The term "alpine - subalpine plant communities" is commonly used in Scandinavian phytosociological literature (e.g. the titles of the papers by Nordhagen 1936 and Dahl 1987). The occurrence of alpine plants in northern boreal areas has been used as an argument in favour of classifying the vegetation of this region together with the alpine vegetation. Dahl (1987) pointed out that of all the vegetational regions of Norway "the most important phytogeographical division is between the middle boreal and the northern boreal regions". The lowlands include floral elements of eurasian and circumpolar species which immigrated from the south after the deglaciation. The floral elements restricted to the northern boreal and the alpine regions are primarily northern amphiatlantic and northern circumpolar species which survived the last Ice Age in unglaciated refugia (Dahl 1987). However, the occurrence of "alpine" and "lowland" species varies very much from one area to another in the northern boreal region, and there is also a wide variation from one vegetational type to another. The variation between different geographical areas can be due to different migration routes after the last glaciation and in part, can also be explained by differences in the migration patterns of alpine species after the postglacial warmth period. Sølendet is situated close to areas that possess a rich alpine vegetation and, after the postglacial warmth period it will have been quite easy for alpine species to migrate to Sølendet. In other upland areas that possess a rich boreal vegetation, but lack areas of calcareous bedrock in the alpine region, (e.g. Nordmarka, Moen 1970), a number of calcicole alpine species are certainly

absent because of geographic barriers, and the poor dispersal powers of their diaspores.

As pointed out earlier (cf. section 2.4.2), it seems reasonable to postulate that during the postglacial warmth period (ca. 9000 B.P. - 4000 B.P., a very long period with a warm climate that nonetheless varied from dry to moist, thereby favouring different plant communities at different times) lowland vegetation types will have dominated the vegetation at Sølendet. A relatively short time has elapsed since the close of the warmth period, and the present-day ecosystems still show certain signs of this period, e.g. in the soil profile. It seems reasonable to assume that the rich, brown earths of the grasslands at Sølendet were partly formed under *Alnus incana*-dominated communities. When comparing the vegetation of different vegetational regions (or more generally in different areas), differences related to the vegetational history should always be taken into consideration, although such knowledge is usually very limited.

Økland & Bendiksen (1985) have compared "parallel" vegetation types growing on mineral soil in the middle boreal, northern boreal, low alpine and middle alpine regions of an area in Telemark. They found that there was a fully continuous intergradation between the middle boreal, northern boreal and low alpine types of vegetation within three of their four vegetational series. In the fourth (viz. the xeric) series they found that the most pronounced change in floristic composition occurred between the middle and the northern boreal site-types (a number of alpine, chionophobous species occur from the northern boreal upwards).

As referred to above, the upper boreal vegetation is included in the classification systems of alpine vegetation in a number of phytosociological papers. The "lowland look" of forest vegetation has been held by Kielland-Lund (e.g. 1967, 1971, 1973, 1981). Several of the classification systems adopted for vegetational mapping (cf. e.g. Hesjedal 1973, Moen & Moen 1975, Fremstad & Elven 1987) stress the occurrence/absence of forests, wherefore, in the classification systems for the vegetation found on mineral soils, a main distinction is made between forested vegetation (i.e. mainly boreal vegetation) and open alpine vegetation. In the classification systems of mire and spring vegetation, the limit between the boreal and the alpine areas has not been stressed, and the regional vegetational types very often do not coincide with the climatic forest limit (cf. section 8.2; cf. also the comments on the classification of tall-herb grasslands = *Lactucion alpinae*, in section 11.3).

Because the flora and vegetation change only gradually from the lowlands up to the high alpine areas, the upper boreal vegetation needs to be compared with both the alpine and the lowland types of vegetation.

#### 11.1.2 References to the upper boreal woodlands in the literature

A large number of phytosociological studies of the birch forest vegetation of the upper boreal areas in Fennoscandia have been published; some of the more

important ones are: Fries (1913), Samuelsson (1917), Resvoll-Holmsen (1918, 1920), Nordhagen (1928, 1936, 1943), Mork & Heiberg (1937), Kalliola (1939), Kalela (1939, 1961), Fries (1949), Hämet-Ahti (1963), Kielland-Lund (1971, 1973, 1981), Sonesson & Lundberg (1974), Odland (1981), Økland & Bendiksen (1985).

The Sylane monograph of Nordhagen (1928), and his later publications (1936, 1943), are regarded as being those most relevant in making comparisons with the forest vegetation of Sølendet. The unpublished thesis presented by B. F. Moen (1978), also describes a similar type of vegetation as that occurring at Sølendet. In addition, stress is laid on comparisons with the forest system of Kielland-Lund. Comments and reference to other publications have only been made in more special cases.

### 11.1.3 Survey of the phytosociological system

Table 11.1.1 presents a survey of the phytosociological system used in this paper, related to the clusters distinguished for the vegetation found on the mineral soils at Sølendet (cf. the descriptions given in section 9), and the wooded grassland vegetation of Central Norway (section 10). The woodland system is mainly based on Kielland-Lund (1981), with minor alterations and supplements taken from Kielland-Lund (1986a) and Dahl (1987). The associations, subassociations and other types of heathland and wooded grassland vegetation are presented schematically in figure 11.1.1, plotted along two main ecological gradients.

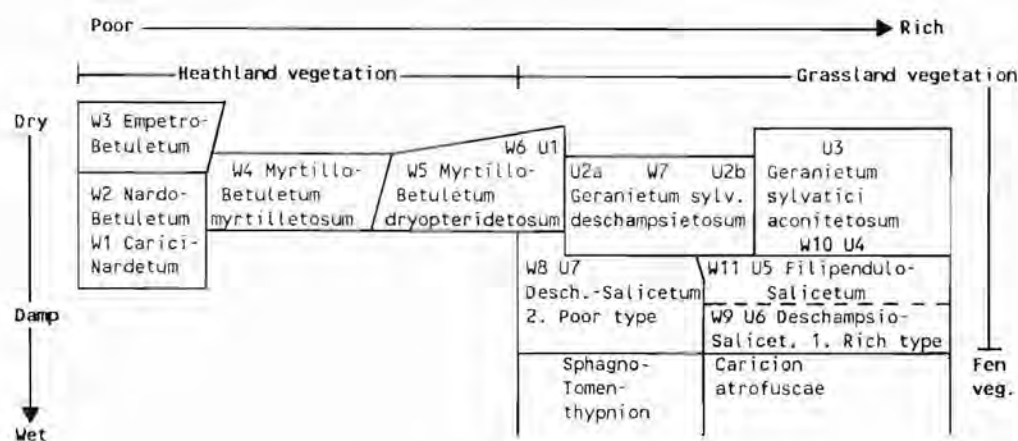


Fig. 11.1.1 The phytosociological units (associations, subassociations) of heathland and wooded grasslands, grouped schematically along the poor-rich and the dry-wet gradients. Numbers and names as in table 11.1.1.

Table 11.1.1 Survey of the hierarchical, phytosociological classification system (Classes - Orders - Alliances - Associations - Subassociations) adopted for the vegetation found on mineral soils at Sølendet (W1-11, 01-5), and on the wooded grasslands of the boreal uplands of Central Norway (U1-7). Syntaxa in brackets [] include questionable vegetation types for Sølendet.

	Description in	
	sect. 9	sect. 10
Cl. Vaccinio-Piceetea Br.-Bl.39		
Ord. Deschampsio-Vaccinietalia myrtilli Dahl 87		
All. Nardo-Caricion bigelowii Nordh. 36		
Ass. Carici bigelowii-Nardetum (Samuels. 16) Nordh. 28	W1	
Ord. Cladonio-Vaccinietalia K.-Lund 67		
All. Cladonio-Pinion K.-Lund 86		
Ass. Empetro-Betuletum (Nordh. 43) K.-Lund 71	W3	
[Ass. Barbilophozio-Pinetum Br.-Bl. et Siss. 39 em. K.-Lund 67]	[W3]	
Ord. Vaccinio-Piceetalia Br.-Bl. 39 em. K.-Lund 67		
All. Vaccinio-Piceion Br.-Bl. et al. 39		
Ass. Nardo-Betuletum ass. nov.	W2	
Ass. Myrtillo-Betuletum (Nordh. 43) K.-Lund 71		
Subass: myrtilletosum subass. nov.	W4	
Subass: dryopteridetosum subass. nov.	W5,W6	U1
[Ass. Chamaemoro-Piceetum K.-Lund 62]		
[Ass. Melico-Piceetum Caj. 21 K.-Lund 62]		[U1]
Cl. Betulo-Adenostyletea (Br.-Bl. et Tx.43) Br.-Bl. 48		
Ord. Adenostyletalia Br.-Bl. 31		
All. Lactucion alpinae Nordh. 43		
Ass. Geranietum sylvatici (Nordh. 43) Dahl 87		
Subass: deschampsietosum subass. nov.	W7,04	U2
Subass: aconitetosum subass. nov.	W10	U3,U4
Ass. Filipendulo-Salicetum phylicifoliae (Nordh. 43) Dahl 87	W11(05p.p)	U5
Ass. Deschampsio cespitosae-Salicetum Nordh. 43 nom.nov.		
Comm. Betula-Crepis-Campylium type	W9(05p.p)	U6
Comm. Betula-Agrostis-Succisa type	W8	U7
Cl. Seslerietea albicantis Br.-Bl. 48 em. Oberd. 78		
Ord. Seslerietalia albicantis Br.-Bl. in Br.-Bl. et Jenny 26		
[Cl. Carici rupestris-Kobresietea bellardii Ohba 74]		
[Ord. Kobresio-Dryadetalia Br.-Bl. 48]		
All. Potentillo-Polygonion vivipari Nordh. 36		
Comm. Achillea-Tortula type	01	
Comm. Nardus-Thalictrum-Sphagnum type	02	
[Cl. Molinio-Arrhenatheretea Tx.37]		
[Ord. Arrhenatheretalia Pawl. 28]		
[All. Nardo-Agrostion Sill. 33]	[W7,01,02]	[U2]

## 11.2 HEATHLAND VEGETATION

### 11.2.1 Classification systems

#### 11.2.1.1 The Nordhagen-Dahl system

Nordhagen (1943) classified the northern boreal birch forest (together with the low alpine vegetation) into three alliances (comprising four associations): *Loiseleurieto-Arctostaphylion* (*Betuletum empetro-cladinosum*); *Phyllodoco-Myrtillion* (*Betuletum empetro-hylocomiosum*, *Betuletum myrtillo-hylocomiosum*); *Mulgedion* (= *Lactucion*) *alpini* (*Betuletum geraniosum subalpinum*). (The last-mentioned type includes the wooded grasslands described in the next section). In addition there is the *Nardeto-Caricion*, which includes the subalpine *Nardus*-dominated communities (*Nardetum chionophilum*).

Nordhagen (1943) did not classify the alliances any further in a hierarchical system. Dahl (1957, 1987) by and large, used the same system of classification for the alpine vegetation, even though some name changes were made. The first-mentioned alliance (called *Arctostaphylo-Cetrarion nivalis* by Dahl 1987) was consigned to the class *Juncetea trifidi*, the second alliance (called *Phyllodoco-Vaccinion myrtilli* by Dahl 1987) to the class *Vaccinio-Piceetea*, in the order *Deschampsio-Vaccinietalia myrtilli*; and the *Nardus*-dominated communities (*Nardo-Caricion bigelowii* of Dahl 1987) were also consigned to that order.

These alliances of Dahl referred to above, however, are restricted mainly to the alpine vegetation. He classified the vegetation of the forested heathlands in the northern boreal region mainly with the forest vegetation types of Kielland-Lund (1981), as was also done by Vevle (1983, 1986); cf. also Fremstad & Elven (1987).

#### 11.2.1.2 The Kielland-Lund system

In the classification system of Kielland-Lund (1967, 1971, 1973, 1981) the coniferous forest vegetation of Eastern Norway was classified as part of the Central European hierarchical system. Kielland-Lund, following the Tüxen tradition (cf. section 8.2.2), employed very broad phytosociological units. The larger parts of the forested area in Norway were placed in the class *Vaccinio-Piceetea*. This "boreal forest class" was separated into two orders: *Cladonio-Vaccinietalia* (the oligotrophic pine types) with the alliances *Dicrano-Pinion* (the association *Vaccinio-Pinetum* is not present in the upland areas of Central Norway) and *Phyllodoco-Vaccinion*. This latter alliance included the forest (and even the alpine heath) vegetation from dry to wet types, e.g.: *Cladonio-Pinetum*, *Barbilophozio-Pinetum* and *Oxycocco-Pinetum*.

The second order of the "boreal forests" is the *Vaccinio-Piceetalia*, with one alliance *Vaccinio-Piceion*. This order includes the typical spruce forests (meso-eutrophic types), i.e. *Chamaemoro-Piceetum*, *Eu-Piceetum* and *Melico-Piceetum*.



Within the *Eu-Piceetum*, the vicarious association *Myrtillo-Betuletum* (= *Betuletum myrtillo-hylocomiosum* Nordh. 1943) has been proposed for the upland birch forests (Kielland-Lund 1973: 187); by analogy, the *Empetro-Betuletum* (= *Betuletum empetro-cladinosum*, Nordh. 1943) has been considered as the vicarious equivalent of the *Barbilophozio-Pinetum* association.

In addition to the two vicarious northern boreal associations mentioned above, a number of similar geographically vicarious associations are proposed for more oceanic types, e.g. the *Bazzanio-Pinetum* and the *Corno-Betuletum* of West Norway (cf. e.g. Kielland-Lund 1981). For the upper boreal areas, however, the system of vicarious associations is incomplete (e.g. there is no association for the birch forest "parallel" to the *Chamaemoro-Piceetum*). Nevertheless, in comparing the forest communities of Sølendet with Kielland-Lund's units, the "primary units" in his system will generally be used.

#### 11.2.1.3 Comments on the alliance *Phyllodoco-Vaccinion*

As referred to above, Kielland-Lund (1981) classified the most oligotrophic (= *Pinus*) forests as part of the alliance *Phyllodoco-Vaccinion*. This alliance was described by Nordhagen (1936) as including the typical *Vaccinium myrtillus* dominated vegetation of the low alpine region (i.e. the open *Vaccinium myrtillus* heath found on lee slopes, and the *Betula nana*/*Juniperus communis*-dominated *Vaccinium*-heath) and the *Vaccinium myrtillus* birch forest of the northern boreal region. This alliance has been further outlined by e.g. Nordhagen (1943, 1954) and Dahl (1957, 1987). Braun-Blanquet et al. (1939), too, used the concept *Phyllodoco-Vaccinion* in this more mesotrophic sense, and it seems illogical of Kielland-Lund to use this alliance for the purely oligotrophic forest types, excluding e.g. the *Betuletum myrtillo-hylocomiosum* of Nordhagen (1943). Following Kielland-Lund, the alliance includes the oligotrophic boreal forests and the more mesotrophic (= *Vaccinium myrtillus*-dominated) alpine heaths (cf. also the comments made by Økland & Bendiksen 1985). The alliance *Phyllodoco-Vaccinion* is therefore employed in different ways by different phytosociologists.

I personally agree with Vevle (1983, 1986), Dahl (1987) and Fremstad & Elven (1987), in considering the *Phyllodoco-Vaccinion* as an alliance of alpine vegetation and the forested types as represented by the alliance *Cladonio-Pinion* (as was also recently suggested by Kielland-Lund (1986a)).

#### 11.2.2 Wiry grass heaths

Vegetational types (= clusters) of section 9.5: W1 Open *Nardus stricta*-*Polytrichum juniperinum* type; W2 *Betula pubescens*-*Nardus stricta*-*Rubus chamaemorus*-*Polytrichum commune* type.

*Nardus*-dominated types of vegetation in upper boreal areas have been described in a number of papers published in the first half of the present century, e.g.

Samuelsson (1917), Resvoll-Holmsen (1920), Smith (1920), Nordhagen (1928, 1943), Mork & Heiberg (1937). During the investigations of the plant communities in connection with an evaluation of their grazing value, the *Nardus* communities have been described in many other publications, e.g. Vigerust (1934, 1949) and Selsjord (1966); but, on the whole, only a few full phytosociological analyses have been published. B.F. Moen (1978) described the *Nardus* birch forest at Nerskogen, and included full phytosociological analyses of 11 stands.

In the northern boreal region, the *Nardus*-dominated communities are mainly secondary communities, and it is certainly difficult to separate primary and secondary types. For these complex vegetational types, even today, Nordhagen's (1943: 236) view, that the northern boreal *Nardus*-dominated vegetation is poorly investigated, remains valid.

#### 11.2.2.1 Open *Nardus stricta* type (W1)

Resvoll-Holmsen (1920: 122) described the same vegetational types (dominated by *Nardus*) and the same type of landscape (= Finnskjeoggrye) as that found at Sølendet. The "Storryen" of Resvoll-Holmsen is situated at Tolga, ca. 40 km S of Sølendet; the species composition of the Storryen locality (no. 7 in table 13 of Resvoll-Holmsen 1920) bears a great resemblance to that present in the quadrats of type W1 at Sølendet.

Nordhagen (1928: 321) described the vegetation of open, *Nardus*-dominated, seasonally wet, depressions in the northern boreal region of Sylane. His three stands investigated of the "Haupttypus Subalpine *Nardus*-Ass" show a great resemblance to the two stands of Sølendet; common constants are: *Carex brunescens*, *Deschampsia flexuosa*, *Nardus stricta*, *Dicranum scoparium*, *Pleurozium schreberi*, *Polytrichum commune* and *Barbilophozia floerkei*. Nordhagen (1943: 236) classified this subalpine *Nardus stricta*-sociation to the *Nardetum chionophilum*; Dahl (1957) provided a comprehensive survey of this association, which mainly included alpine communities (the alpine, primary *Nardus* communities are rather well investigated, as referred by Dahl 1957).

In conclusion, the W1 type of Sølendet has to be included in the association *Nardetum chionophilum* described by Nordhagen (valid name, cf. Dahl 1987: *Carici bigelowii*-*Nardetum strictae*), the association belongs to the alliance *Nardo-Caricion bigelowii*.

#### 11.2.2.2 *Nardo strictae*-*Betuletum pubescentis* ass. nov.

Nomenclatural type: Sample 47, cf. Appendix D-table 1. Vegetational type W2 (section 9.5) represents the association.

*Nardus*-dominated birch forests occur mainly as secondary communities (cf. e.g. Nordhagen 1928: 329, Mork & Heiberg 1937: 638), that include both poor

heathland types and rather rich grassland types (e.g. the *Nardus*-dominated stand no. 26 of cluster W8). The stands of W2 represent the poor type of wooded heathland.

Mork & Heiberg (1937: 638) described *Nardus*-dominated poor heathland birch forest from Hirkjølén, and they concluded that their "*Nardus*-*Polytrichum commune*-*Betula tortuosa* sociation" was very similar to the *Nardetum chionophilum* subalpine type described by Nordhagen (1928). B.F. Moen (1978), however, found that the *Nardus*-birch woodlands of Nerskogen and Hirkjølén had many features in common, but that they were rather different from the alpine/northern boreal types of the *Nardetum chinophilum*; she proposed a specific association for them, the *Nardo-Betuletum*.

Table 11.2.1 summarizes the compositions of the *Nardo-Betuletum*-communities of Nerskogen, Hirkjølén and Sølendet (the W2 samples). The Hirkjølén analyses are based on smaller quadrats than those of the other two areas. Constants in all the areas (or at least two of them) are: *Betula pubescens*, *Vaccinium myrtillus*, *V. vitis-idaea*, *Solidago virgaurea*, *Trientalis europaea*, *Deschampsia flexuosa*, *Nardus stricta*, *Dicranum scoparium*, *Pleurozium schreberi*, *Polytrichum commune*, *Barbilophozia floerkei* and *B. lycopodioides*. The common occurrence (even dominance in some quadrats) of *Solidago*, *Trientalis*, *Deschampsia flexuosa*, *Nardus* and *Barbilophozia* spp. is typical of the upland birch forest communities, compared to the lowland coniferous forests (Nordhagen 1943: 154). Occurrences of alpine/upland species, e.g. *Sphagnum russowii*, *Nephroma arcticum*, are also typical.

The samples from the three areas differ considerably. The Nerskogen samples (A in table 11.2.1) are the most species-rich and include a number of hemerophilous species (favoured by grazing, cf. B.F. Moen 1978), e.g.: *Polygonum viviparum*, *Potentilla erecta*, *Pyrola minor*, *Anthoxanthum odoratum*, *Carex vaginata*, *Luzula multiflora* coll. and *Drepanocladus uncinatus*. Some hepatics (perhaps overlooked?) are missing from the Hirkjølén samples (column B), e.g. *Barbilophozia* spp. The Sølendet samples (cluster W2, summarized in column C) differ from the other analyses in including scattered occurrences of some damp-site indicators (e.g. *Rubus chamaemorus*, *Juncus filiformis*) and by the absence of a number of dry-demanding species (e.g. *Festuca ovina*, dwarf-shrubs and lichens). Also species indicative of more mesotrophic conditions and/or indicators of grazing (e.g. *Anthoxanthum odoratum*) are not present in the Sølendet samples. The predominance of *Deschampsia flexuosa* in two of the samples from Sølendet is a further difference from those of the other areas, where *Nardus* is predominant.

The samples of W2 show certain similarities with the poorest (most oligotrophic) types of *Eu-Piceetum* communities of Kielland-Lund (in the northern boreal area: *Myrtillo-Betuletum*), and also to his *Chamaemoro-Piceetum*. The samples also show similarities with the northern boreal type of open *Nardus* communities (viz. *Carici bigelowii-Nardetum strictae*, cf. the foregoing subsection). As described in section 9.5, the closest resemblance of the samples of cluster W2

Table 11.2.1

Synoptic table of the *Nardo-Betuletum*, from: A. Nerskogen (B. F. Moen 1978), B. Hirkjølén (Mork & Heiberg 1937) and C. Sølendet (type W2). Frequency and mean cover values are shown. Only species that occur at a frequency of at least 50 % in one of the localities are listed.

No. of quadrats - size in m <sup>2</sup> :		A	B	C
		11-16	40-1	4-25
	A	91-2	25-1	75-3
<i>Betula pubescens</i>	B	45-1	-	50-1
	C	91-1	-	25-1
<i>Juniperus communis</i>	B	55-1	55-4	-
	C	55-1	-	25-1
<i>Empetrum hermaphroditum</i>		55-1	60-1	-
<i>Vaccinium myrtillus</i>		100-1	100-1	75-1
<i>V. vitis-idaea</i>		73-1	100-1	100-1
<i>Hieracium</i> spp.		73-1	15-1	50-1
<i>Polygonum viviparum</i>		64-1	5-1	-
<i>Potentilla erecta</i>		55-1	-	-
<i>Pyrola minor</i>		64-1	-	-
<i>Rubus chamaemorus</i>		-	-	100-1
<i>Solidago virgaurea</i>		100-2	100-1	50-1
<i>Trientalis europaea</i>		82-2	85-1	100-1
<i>Anthoxanthum odoratum</i>		82-1	10-1	-
<i>Carex vaginata</i>		82-1	-	-
<i>Deschampsia flexuosa</i>		100-2	90-3	100-3
<i>Festuca ovina</i>		64-1	100-1	-
<i>Juncus filiformis</i>		-	-	50-1
<i>Luzula multiflora</i> coll.		82-1	55-1	-
<i>Nardus stricta</i>		100-5	90-4	100-4
<i>Dicranum majus</i>		-	-	50-1
<i>D. scoparium</i>		91-1	65-1	100-1
<i>Drepanocladus uncinatus</i>		73-2	-	-
<i>Hylocomium splendens</i>		91-2	60-1	25-1
<i>Pleurozium schreberi</i>		82-3	95-2	100-1
<i>Polytrichum alpinum</i>		55-1	-	-
<i>P. commune</i>		82-3	100-1	100-5
<i>P. juniperinum</i>		64-1	35-1	100-3
<i>Sphagnum russowii</i>		36-2	-	100-3
<i>Barbilophozia floerkei</i>		100-3	-	100-2
<i>B. kunzeana</i>		36-1	-	75-1
<i>B. lycopodioides</i>		100-1	1-1	75-2
<i>Lophocolea minor</i>		-	-	50-1
<i>Lophozia ventricosa</i> coll.		27-1	-	50-1
<i>Cetraria islandica</i>		18-1	80-1	-
<i>Cladonia arbuscula</i> coll.		36-1	50-1	-
<i>C. rangiferina</i>		55-1	25-1	-
<i>Nephroma arcticum</i>		36-2	50-1	-

is to this open *Nardus* community, compared to all the other Sølendet types (similarity ratio: 0.54). The community also shows some similarity with the *Nardetalia* communities (e.g. Ellenberg 1988), but the anthropogenically influenced communities of this class are so far too poorly investigated in Norway for further comparisons to be made.

In conclusion, the W2 samples, together with those for the *Nardus* birch woodlands of Nerskogen and Hirkjølén (cf. Table 11.2.1) require inclusion in a new association, the *Nardo-Betuletum*. This northern boreal association, furthermore, has to be included in the alliance *Vaccinio-Piceion*. Further documentation and description will be given later in a separate publication.

### 11.2.3 Dwarf-shrub/grass heaths and small-fern heaths

Vegetational types (=clusters) of section 9.5: W3 *Betula pubescens*-*Empetrum hermaphroditum*-*Pleurozium schreberi* type; W4 *Betula pubescens*-*Vaccinium myrtillus* wiry grass type; W5 *Betula pubescens*-*Gymnocarpium dryopteris*-*Deschampsia flexuosa* type; W6 *Betula pubescens*-*Gymnocarpium dryopteris*-*Convallaria majalis* type.

#### 11.2.3.1 *Empetro*-*Betuletum*

The typical, dry, *Calluna*- or *Empetrum*-dominated, birch forests of the northern boreal region of the eastern part of Central Norway (e.g. Nordhagen 1928) are not well-developed at Sølendet; the main reason is that there are no prominent sand, gravel or boulder-covered morainic ridges (Norw. "Ås") in the area. Few analyses were made of the vegetation of the driest heathlands at Sølendet, the most representative being stands nos. 57 and 270 of cluster W3. The samples of this cluster show a great resemblance to the "*Empetrum*-reicher Birchenwald" of Nordhagen (1928), included in the *Betuletum empetro-hylocomiosum* of Nordhagen (1943).

Some of the samples (e.g. no. 80) are transitional to the *Betuletum myrtillo-hylocomiosum*. It is well known that the changes between the "*Empetrum*" and the "*Vaccinium*" types are gradual, e.g. the intermediate "*Empetrum*-*Vaccinium* type" of Sonesson & Lundberg (1974). A large number of publications include descriptions of the upper boreal birch forests of dry heathlands, cf. the xeric and subxeric series of Økland & Bendiksen (1985), who also included a full literature survey.

According to Kielland-Lund's system (e.g. 1981), the samples of cluster W3 have to be included in the *Barbilophozio-Pinetum* (some samples, e.g. no. 80 are transitional to the *Eu-Piceetum*), though more precisely W3 belongs to the vicarious association *Empetro-Betuletum*.

#### 11.2.3.2 Classification of the "*Myrtillus*-*Dryopteris*" forests

The classification systems of Nordhagen and Kielland-Lund have been referred to in subsection 11.2.1, where comments were also made on the hierarchical phytosociological system of forest classification.

It seems reasonable to establish a vicarious upland association, paralleling the association *Eu-Piceetum*, characterized by the presence of alpine species, a dominance/common occurrence of upper boreal/alpine species, and an absence of lowland/southern species. Kielland-Lund has proposed an association *Myrtillo-Betuletum*. Further separation of the *Vaccinium myrtillus*-dominated forests into subunits (subassociations) has been a common practice in most of the



Fennoscandian classification systems; a distinction is usually made between a typical *Myrtillus* type and a more eutrophic type, that includes ferns and some herbs, viz. the *Dryopteris* type (e.g. Cajander 1921, Kujala 1929, Malmström 1949). Kielland-Lund (e.g. 1981) further separates a tall-fern subtype, i.e. three subassociations of the *Eu-Piceetum* are defined: *myrtilletosum*, *dryopteridetosum* and *athyrietosum*. For the western part of Central Norway, E.I. Aune (1973) distinguished between these three subtypes (in addition, a *thelypteridetosum* was defined as a fourth subassociation of his *Corno-Betuletum*). The tall-fern subtype represents a transition to the wooded grasslands, although this subtype is not present at Sølendet.

It has not been commonplace for phytosociologists working in the northern boreal region to differ about the main level of separation between a *Myrtillus* type and a *Dryopteris* type. Nordhagen (1943) stressed that the main types of *Vaccinium myrtillus* birch forests are mesotrophic, and form a parallel to the *dryopteridetosum* subassociation of the spruce forests. He explained the difference between the spruce and the birch forests by the nature of the litter deposited by these two tree species, the litter of *Betula pubescens* is "better, not so acid". Recently, Mehus (1986) in his studies of (birch) forest types of N. Norway, stated that the above-mentioned subdivision into subassociations could not be supported. However, a number of investigations made in the past decades have led to the opposite conclusion; e.g. B.F. Moen (1978), Fremstad & Elven (1987). Rodvelt & Sekse (1980) made a parallel distinction into subassociations (and even variants) for the associations *Eu-Piceetum* and *Myrtillo-Betuletum*. However, they did not indicate the nomenclature type; i.e. their names were not validly published.

#### 11.2.3.3 *Myrtillo-Betuletum myrtilletosum* subass. nov.

Nomenclatural type: Sample 42, cf. Appendix D-table 1. Vegetational type W4 (section 9.5) represents the subassociation.

The samples of cluster W4 are dominated by the wiry grasses *Deschampsia flexuosa* and *Nardus stricta*; *Vaccinium myrtillus* also occurs, though more scattered. The reason for the scarcity of *Vaccinium myrtillus* and the dominance of the wiry grasses has been discussed in section 9.5.2.3. Nordhagen (1943: 160) described a sociation in his *Betuletum myrtillo-hylocomiosum* dominated by *Deschampsia flexuosa*. This sociation of Nordhagen has much in common with the samples of W4, even though the Sikilsdalen stands are somewhat more species-rich.

In my system the samples of cluster W4 represent a poor type (without any ferns or the other more nutrient-demanding species). In Nordhagen's system the cluster belongs to the *Betuletum myrtillo-hylocomiosum*. In Kielland-Lund's system it belongs to the *Eu-Piceetum*, subassociation *myrtilletosum*.

#### 11.2.3.4 *Myrtillo-Betuletum dryopteridetosum* subass. nov.

Nomenclatural type: Sample 25, cf. Appendix D-table 1. Vegetational type W5 (section 9.5) represents the subassociation.

The two samples of cluster W6 (as also the samples of cluster U1 of section 10) are intermediate between those of the typical small-fern type and of the dry grassland type of birch forests. The samples of these clusters even include some warmth-demanding/southern species, and should be regarded as categorising a type transitional between the *dryopteridetosum* type of the *Eu-Piceetum* and the *Melico-Piceetum* association in the system of Kielland-Lund (1981). The link with the last-mentioned association is shown by e.g. some of the characteristic species (of W6): *Cicerbita alpina* (sterile), *Convallaria majalis* (regarded as a *Melico-Piceetum pinetosum*-species), *Ranunculus platanifolius*, *Silene dioica* and *Milium effusum*. *Melampyrum sylvaticum*, *Pyrola minor* and *Mnium spinosum* are also constants, all species listed by Kielland-Lund as characteristic of the *Melico-Piceetum*. In the upper boreal region of Central Norway, however, *Melampyrum* and *Pyrola* are very common in typical small-fern communities. As described in section 9.5, the samples of cluster W6 most closely resemble the samples of cluster W5 (i.e. the *dryopteridetosum*).

In Sylane, Nordhagen (1928) separated four variants of "Myrtillus-reicher Birchenwald". The *Gymnocarpium dryopteris* variant (i.e. *Gymnocarpium*-dominated small patches; no phytosociological analyses were presented from Sylane) Nordhagen describes as unimportant, with a low phytosociological value. However, *Gymnocarpium* is a constant species (but with low cover values) in the three other variants, and in addition *Melampyrum sylvaticum* is a constant species, and also a large number of additional "small-fern species" (e.g. *Maianthemum bifolium* and *Geranium sylvaticum*) are common species in this type of forest at Sylane. Compared with the woodland types of Sølendet, the "Myrtillus-reicher Birchenwald" of Sylane covers the same vegetational types as W5 and W6.

In Nordhagen's system, cluster W6 would have to be included in the association *Betuletum myrtillo-hylocomiosum*. A few stands of the Sylane "Myrtillus-reicher Birchenwald" include typical "*Melico-Piceetum*-species", such as *Convallaria majalis*, *Rubus saxatilis* and *Mnium spinosum* (Nordhagen 1928: 113, 117), and a few of these stands bear a close resemblance to the stands of W6 (cf. Fig. 10.3.1, sample S21). The Nerskogen vegetation survey also includes samples that show a great resemblance to the samples of cluster W6, e.g. samples of the *Oxalis-Agrostis* community (cf. B.F. Moen 1978: Table IV). Further comments were given in section 10.4, cf. also subsection 11.3.6.

In conclusion, the clusters W5 and W6 should be included in the *Myrtillo-Betuletum dryopteridetosum* subassociation; cluster W6 is transitional to the *Melico-Piceetum*.

### 11.3 THE WOODED GRASSLANDS, *LACTUCION ALPINAE*

#### 11.3.1 Regional occurrence and general considerations

The wooded grassland vegetation covers wide areas in those parts of the northern boreal region in Central Norway underlain by Cambro-Silurian strata, e.g. 17%-30% of the vegetation maps of Nerskogen, Sølendet and Innerdalen (cf. Table 2.2.1). The vegetation of almost the entire grassland area comprises herb-rich communities of the *Lactucion alpinae*, as defined in this monograph (cf. subsection 11.3.3). In general, the communities of the *Lactucion alpinae* are most commonly found on sloping ground, often occurring on steep hillsides; on flat areas the community occurs at the margins of streams and in other nutrient-rich habitats.

The *Lactucion alpinae* vegetation covers only small areas in the western parts of Central Norway (cf. section 2.2) and in West Norway as a whole, mainly because the predominant bedrocks in these areas are hard, and very resistant to weathering, producing acidic soils in the wet climate. This rich grassland vegetation also covers smaller areas on the fringes of the more continental parts of Fennoscandia, as pointed out by Fries (1949) in his discussion of the geological, topographical and climatic conditions that favour these tall-herb communities in Fennoscandia. The upper boreal and low alpine regions of Central Norway certainly form one of the main areas in Fennoscandia of rich grassland vegetation.

The wooded grassland vegetation of Sølendet has already been described in section 9.6, including a description of the habitat conditions, estimates of the field layer production as affected by scything, etc. The wooded grasslands have always been among the most valuable for hay production of all the scything lands; many of these areas in fact have been utilised, scythed for hay and/or grazed, up to the present day.

The results of the multivariate analyses of the samples of wooded grassland vegetation at Sølendet, Innerdalen, Nerskogen and Sylane have been dealt with in section 10; the seven clusters so delineated and the results of DCA-ordination of 101 samples are there described. Here the clusters (and individual samples) will be compared with previously published descriptions of such vegetation, including a review of the relevant literature. A synsystematic survey will be presented in subsection 11.3.3 (cf. also Table 11.1.1).

#### 11.3.2 Survey of the classification systems of Nordhagen, Dahl and Kielland-Lund

Nordhagen (1943) presented a comprehensive and systematic description of the tall-herb communities of the upper boreal and alpine regions in Fennoscandia. He proposed the alliance *Lactucion alpinae* (with one birch forest association: *Betuletum geraniosum subalpinum*) for the eutrophic tall-herb communities. In

a previous paper (Nordhagen 1936), he had called the alliance the *Aconition septentrionalis*, and if the principle of priority (Barkman et al. 1986) is to be followed then this name is strictly speaking the correct one. In 1943, however, Nordhagen himself put forward the arguments in favour of changing it to the *Mulgedion alpini* (= *Lactucion alpinae* = *Cicerbition alpinae*), and I intend here to use the name *Lactucion alpinae* (cf. also Dahl 1987).

Nordhagen (1943) drew attention to the problems connected with the delimitation of this alliance from more oligotrophic communities and the transition to the lowland tall-herb types. He recognised the existence of different geographical types (facies) of associations within the *Lactucion alpinae* in Fennoscandia: a **subpolar** facies in North Fennoscandia, an **oceanic** facies in West Norway and an **eu-scandinavian** facies in Central Scandinavia. The communities described in this monograph all belong to the last-mentioned type. Some comments on the other facies and a more detailed description of Nordhagen's full classification system are given in subsequent sections.

Dahl (1957, like Nordhagen) included both the alpine and the northern boreal vegetation in the alliance *Lactucion alpinae*, placing the alliance in the order *Adenostyletalia*, of the class *Betulo-Adenostyletea*. Dahl (1987) divided the *Lactucion alpinae* into three suballiances: 1. *Athyrienion distentifolii*, a calcifuge snow-bed community with one association. 2. *Dryopterido-Calamagrostienion purpureae*, defined as mainly oligotrophic/mesotrophic communities, including two associations: *Rumici-Salicetum lapponum*, a community mainly found in the low alpine region, and *Filipendulo-Salicetum phylicifoliae*, essentially a subalpine community in areas of high groundwater-levels. 3. *Lactucion alpinae*, representing the most eutrophic types of the tall-herb grasslands. The alpine and subalpine types are all included in a single association, viz. the *Geranietum silvatici* (= *Myosoto-Aconitetum* of Kielland-Lund 1981) which includes open types, willow scrub, birch forest and even spruce forest.

Kielland-Lund (e.g. 1981) classified the tall herb boreal forest vegetation in the alliance *Lactucion alpinae* of the class *Betulo-Adenostyletea* (as also done by Dahl); Kielland-Lund (1981: 76) also argued in favour of classifying the alpine-subalpine tall-herb communities (open, scrub-covered and forested types) in one association, the *Myosoto-Aconitetum*. The main boreal association of the *Lactucion alpinae* in the study area of Kielland-Lund (op. cit.) is the *Poa remotae-Aconitetum septentrionalis*. In addition, the *Viola selkirkii-Aconitetum* is described as a spruce forest association.

Kielland-Lund also included upper boreal forest vegetation in his association *Calamagrostio purpureae-Salicetum pentandrae* belonging to the alliance *Alno incanae-Salicion pentandrae* of the class *Alnetea glutinosae*. The *Alno-Padion* alliance of the class *Querco-Fagetea* occurs in the middle boreal region up to its border with the northern boreal region.



### 11.3.3 Comments on the order *Adenostyletalia* and the alliance *Lactucion alpinae*

The perennial tall-herb and scrub communities of the upper boreal and alpine regions of Europe all fall within the class *Betulo-Adenostyletea* and the order *Adenostyletalia*. (Tall-herb communities of anthropogenically influenced vegetation are assigned to the *Molinio-Arrhenatheretea* class). The Central European communities are described by Braun-Blanquet (1950), Oberdorfer (1978) and Ellenberg (1988), amongst others. The phytosociological level of separation between the Central European tall-herb communities and the Fennoscandian equivalents is questionable. Braun-Blanquet (1950) and Oberdorfer (1978) separated the geographical types at the order level (*Betulo-Aconitetalia* was used as the Nordic order), whereas in the Norwegian systems (e.g. Kielland-Lund 1981 and Dahl 1987) the communities are separated at the alliance level (cf., however, Nordhagen 1936: 31, 1943: 307; who favoured changing *Adenostyletalia* to *Aconitetalia*).

In Central Europe three alliances of the order *Adenostyletalia* are recognised (cf. Oberdorfer 1978): The *Adenostylon alliariae* is a tall-herb and damp scrub community (including three associations); the *Salicion arbusculae* (= *Salicion pentandrae*) is a willow scrub community (often in spring-water influenced habitats; one association); the *Calamagrostion arundinaceae* is a mesophilous and mesotrophic community (one association).

Dahl (1957) provided a comprehensive survey of the literature describing the tall-herb communities of Scandinavia, Iceland and Greenland. However, Dahl (1957, 1987) used *Lactucion alpinae* in a wide sense, splitting the alliance into three suballiances (cf. the foregoing subsection).

Hundt (1963), in his study of the tall-herb communities at different altitudes in the Abisko area, N. Sweden, found the *Lactucion alpinae* communities to differ from the more southern types of N. and C. Europe. He also found the *Lactucion alpinae* communities to be separated from the more heavily anthropogenically influenced types, e.g. those described by Knapp (1959) from boreal areas of Sweden. Blažkova (1981), in a study of *Filipendula ulmaria* tall-herb communities from lowlands in North Norway, assigned the described *Deschampsio-Filipenduletum ulmariae* association to the *Molinio-Arrhenatheretea* class. Both Hundt (1963) and Blažkova (1981) stressed the large number of "arcto-alpine" and "boreal-montane" species in the *Lactucion alpinae* communities, in contrast to the large number of "boreomeridionale" species in the lowland types.

In this paper, the *Lactucion alpinae* is defined as an alliance that includes the rich types of tall and medium-tall herb and broad-leaved grass communities of the upper boreal (mainly the northern boreal) and low alpine regions. So defined, the *Lactucion alpinae* represents a Nordic alliance within the order *Adenostyletalia*. I regard the *Dryopterido-Calamagrostion purpureae* as another alliance within the same order, one which includes the grasslands that lack



the calcicole species. The separation of the two alliances correspond with the suggestions made by Nordhagen (1943: 310) and Kielland-Lund (1981). Kalela (1939) also differentiated between "Eutrophe und Oligotrophe Hochstaudewiesen", and at least some of his oligotrophic types have to be included in the *Dryopterido-Calamagrostion*. The association *Rumici-Salicetum lapponum* of Dahl (1957, 1987) also belongs to this alliance, likewise the *Athyrium distentifolium*-communities of Odland (1981). The *Athyrium distentifolium*-communities, however, have to be separated into two types (as stated by Nordhagen 1943: 303), one being included in the *Dryopterido-Calamagrostion*, (as mentioned above, cf. Odland 1981), and the other in the snowbed communities (*Cryptogrammo-Athyrium alpestre*, cf. Nordhagen 1943, Gjærevoll 1956). In addition, the species *Athyrium distentifolium* also occurs in oceanic types of the *Lactucion alpinae* (cf. Odland 1981).

The separation of the *Lactucion alpinae* and the *Dryopterido-Calamagrostion* at the alliance level parallels the separation of the *Adenostylion alliariae* and *Calamagrostion arudinaceae* alliances of Central Europe. The wooded grasslands of Sølendet (and even those other types of wooded grasslands in Central Norway described in section 10) are all rich, herb-dominated communities belonging to the *Lactucion alpinae* alliance. The *Dryopterido-Calamagrostion* alliance will not be further described here.

#### 11.3.4 Geographical differentiation

##### 11.3.4.1 Subpolar facies

The northern type of *Lactucion alpinae* is characterised by the presence of *Trollius europaeus* as a dominant species, by occurrences of northern species, and by an absence of "southern" species, e.g. *Aconitum septentrionale* and *Ranunculus platanifolius*. The subpolar facies has been described by e.g. Kujala (1929), Kalela (1939), Kalliola (1939), Hundt (1963) and Sonesson & Lundberg (1974). Hämet-Ahti (1963) included analyses from North Norway (her "Meadow forest" is the most relevant; the "Tall ferns" type is a more lowland type) and also provided a comprehensive literature survey. Fremstad & Øvstedal (1979) mainly described the middle boreal *Alnus incana* types, but they also included descriptions of the damp types of northern boreal, forested grasslands.

##### 11.3.4.2 Oceanic facies

This facies is characterised by the absence of *Trollius europaeus*, *Aconitum septentrionale* and *Viola biflora*, and the presence of *Athyrium distentifolium*, and a number of suboceanic species, e.g. *Thelypteris limbosperma*. Odland (1981) has described different communities from Røldal (SW Norway) which he classified to the *Lactucion alpinae* alliance (s.lat.). He suggested recognising two suballiances: the *Dryopterido-Calamagrostion* (in my opinion, these mesotrophic communities are not included in the *Lactucion alpinae*, cf. the preceding sub-

sections) and the *Lactucion alpinae* (= *Lactucion alpinae* s.str.). The *Lactucion alpinae* suballiance Odland (op.cit.), separated into one association and two subassociations. These communities belong to the oceanic facies, but Odland also included a type that is transitional between the oceanic and the eu-scandinavian facies (*Aconitum*-dominated "Geranium sylvaticum meadow"), this type bears a great similarity to samples of cluster U3a of section 10.4 (cf. Odland 1981: 680).

Types transitional between the oceanic and the eu-scandinavian facies are typical of the vegetation of the inland mountainous areas of West Norway, described by e.g. Skogen (1972), Odland (1979, 1981), Berthelsen & Huseby (1981) and Rodvelt (1983).

The tall-herb communities of the *Melico-Betuletum* as described by E. I. Aune (1973) are more lowland types, with a greater resemblance to some of the spruce forest associations (i.e. those belonging to the *Vaccinio-Piceion*) than to the *Lactucion alpinae*. The wooded grassland types of Øvre Forradal (L. Kjelvik 1978) also include some suboceanic species and the greatest resemblance of this vegetation is again to the spruce forest types (cf. section 10.1.2).

#### 11.3.4.3 Comments on the literature about the Eu-Scandinavian facies

Samuelsson (1917), in his monograph on the vegetation of the upland areas of Dalarna, Central Sweden, described various types of wooded grasslands that resemble the Central Norwegian types described here in section 10. Some of his analysed quadrats (of undefined size, incomplete listings of the bryophytes) derive from sites less than 100 km S of Sølendet (at least one quadrat is even from a site in Norway). Samuelsson (op. cit.: 197) tabulated 5 analyses of a graminoid-dominated type (resembling my cluster no. U2), 6 analyses of a tall-herb type (some of them resembling clusters U3-5), and one quadrat of a *Thalictrum alpinum*-*Carex capillaris* type (resembling cluster U6). He also stressed the difference between the dry and the moist types.

Nordhagen (1943) provided a review of the older literature, and Dahl (1957: 189) has a list of all relevant references. Later descriptions include a number of inventory reports from sites in Central Norway (e.g. Moen & Kjelvik 1981, Holten 1983, 1984) and unpublished theses (e.g. B.F. Moen 1978).

Holmen (1965) described five types of tall-herb communities in Jämtland, but no phytosociological analyses were ever published. Holmen estimated the mean value of the standing crop of the field layer of an *Aconitum septentrionale*-*Lactuca alpina* community to be 360 kg/daa, with a maximum value of 620 kg/daa; *Lactuca* was the most important species (further comments in section 13.3).

#### 11.3.4.4 Comments on the lowland types

Nordhagen (1943: 321) stressed the importance, in regional phytosociology, of defining the boundary between the *Lactucion alpinae* and the lowland types of tall-herb communities. Nordhagen (1943) included low alpine, northern boreal and middle boreal types in his *Lactucion alpinae* alliance. At least four of his 12 associations include middle boreal vegetation, because they are characterized by typical lowland species (i.e. ones that do not occur as dominants above the altitude of the middle boreal region, cf. Moen 1987a: 208) e.g.: *Athyrium filix-femina*, *Dryopteris filix-mas* and *Matteuccia struthiopteris*. The four typical middle boreal associations of Nordhagen (1943: 325) are: *Betuletum struthiopterosum subalpinum*, *Betuletum mulgedio-athyrionum*, *Alnetum struthiopterosum subarcticum* and *Piceetum mulgedio-athyrionum*.

Kielland-Lund (1981) also included some lowland communities in his *Lactucion alpinae*, viz. the associations *Poa remotae-Aconitetum septentrionalis* and *Viola selkirkii-Aconitetum septentrionalis*.

Fremstad & Øvstedal (1979) however, stressed the importance of restricting the *Lactucion alpinae* to the vegetation of upland areas. In North Norway they included the *Alnus incana* tall-herb woodlands in the *Alno-Padion* alliance, as also Odland (1981) did.

Dahl (1987) regarded the phytogeographical boundary between the middle boreal and the northern boreal regions as the most important limit between any two vegetation regions (cf. subsection 11.1.1). The most widely-distributed wooded grassland communities of the middle boreal region, i.e. the *Alno-Prunetum* (in the *Alno-Padion* alliance) and the *Melico-Piceetum* (in the *Vaccinio-Piceion*), reach their upper limit at this boundary. These communities, together with a number of woodland species, have formed some of the most important criteria used to separate the middle boreal and northern boreal regions (cf. Moen 1987a).

Furthermore, in my opinion, the communities of the association *Calamagrostio purpureae-Salicetum pentandrae* (in the *Alno incanae-Salicion pentandrae* alliance, Kielland-Lund 1981) ought to be included in the vegetation belonging to the lowlands, i.e. none of the communities belonging to the class *Alnetea glutinosae* occur in the northern boreal region.

According to my definition, the lower altitudinal limits of a number of alpine-northern boreal communities (those of the *Lactucion alpinae* being among them) and species lie close to the same boundary (i.e. define the separation between the middle and the northern boreal regions).

### 11.3.5 Nordhagen's types compared with those of Central Norway

#### 11.3.5.1 The *Lactucion alpinae*, with its associations

Nordhagen (1928) differentiated two main types of grassland birch forest in Sylane (cf. section 10.1.2); however, in 1943 he included only one of these types in his *Lactucion alpinae*, the other one (*Agrostis tenuis*-*Deschampsia flexuosa*-reicher Birkenwald) he classified among the anthropogenic communities of the alliance *Nardo-Agrostion tenuis*, in the order *Arrhenatheretalia* of the class *Molinio-Arrhenatheretea*. Notwithstanding, the wooded grassland samples from Sylane that I included in the multivariate analyses (section 10) proved to be very similar and all fell into the same cluster in the classification (even within same subcluster, viz. 2b).

In my opinion, from a phytosociological viewpoint, all these samples have to be included with the communities in the alliance *Lactucion alpinae* (cf. the description of cluster U2 in section 10.4).

The *Lactucion alpinae* communities of Nordhagen (1943) were divided into three main types, on a basis of their shrub and tree layers: 1. Open grasslands, 2. Grasslands dominated by willow scrub, 3. Forested grasslands with a tree-layer of birch, spruce or grey alder. The first two are mainly low alpine, the last-mentioned belongs to the upper boreal regions. The tall-herb communities of all these three types were found to be rather closely related, especially when compared with the types found in the same area (e.g. Sikilsdalen). Nordhagen (op.cit.) listed 12 associations of *Lactucion alpinae*, a number of them are parallel associations split off according to differences in the tree and/or shrub layers; e.g. resulting in four different associations of "*Geranium sylvaticum* grasslands" (viz. *Geranietum silvatici alpicolum*, *Salicetum geraniosum alpicolum*, *Betuletum geraniosum subalpinum* and *Piceetum geraniosum subalpinum*). Despite making these subdivisions, Nordhagen stressed the gradual nature of the changes from one to another, and the difficulties involved in defining distinct subtypes within the alliance *Lactucion alpinae*.

#### 11.3.5.2 The birch forest association

*Betuletum geraniosum subalpinum* includes the birch forest types of tall-herb communities recognised by Nordhagen (1943); this association is included in the much wider associations of the *Myosoto-Aconitetum* and the *Geranietum silvatici* of Kielland-Lund (1981) and of Dahl (1987), respectively. Nordhagen (1943) suggested making a bipartition of his association, into one mesophilous sociation and one more hygrophilous sociation. He characterized the latter by the presence of moist habitat indicator species: *Cicerbita alpina*, *Cirsium helenioides*, *Crepis paludosa*, *Filipendula ulmaria* and *Viola palustris*. Nordhagen (1943: 357) listed some stands from the Sylane area that represent this hygrophilous type; these are the samples S25, S28, S29, S30 that were included in



the multivariate analyses described here in section 10. The results of the classification and ordination of all the samples from Central Norway, however, showed that these samples bore a great similarity to the other samples from Sylane, and were even included in the same subcluster (viz. 2b). The DCA diagrams (Fig. 10.3.1), however, show that the four samples referred to above lie somewhat closer to the tall-herb/hygrophilous side of the diagrams (along axis 1) than the majority of the Sylane samples. The four samples from Sylane representing the *Nardo-Agrostion*, i.e. samples S34-S37, lie within the mesotrophic/mesophilous sector of subcluster 2b.

Nordhagen (1943: 345) separated the tall-herb birch forest stands of Sikilsdalen into two variants: The *Deschampsia flexuosa* var. occurs on north-facing slopes, the *Aconitum-Polygonatum verticillatum* var. occurs on south-facing slopes (Table 11.3.1 provides a synopsis, cf. types A and B, respectively).

Nordhagen (1943) found that the tall-herb birch woodlands of Sylane (his *Galium boreale* var., i.e. samples S25-S31 described here in section 10) were intermediate between the two variants described from Sikilsdalen, and that they were more similar in character to the *Aconitum-Polygonatum verticillatum* var. than to the *Deschampsia flexuosa* var. Nordhagen (1943) also found that a fairly high degree of similarity existed between this *Galium boreale* var. from Sylane and the two variants he described from Hallingdal (*Aconitum* var. and *Cicerbita* var.). Generally speaking, he recognised that great similarities existed between the tall-herb birch woodlands found in all these three areas. The Sylane samples, however, were the only ones that were included in the multivariate analyses, the results which are described in section 10; it is noteworthy that Nordhagen (1943) found these particular samples to be quite representative of the tall-herb communities in the eu-scandinavian facies.

Nordhagen (1943: 354) explained the scarcity of *Aconitum septentrionale* in the analysed stands from Sylane as being due to cultural influence, since most of the stands used to be scythed every second year, a process which is highly deleterious to *Aconitum*.

The samples from Sylane are very similar to the samples from Sølendet that form cluster W7 (cf. section 9.5; i.e. they are all from communities dominated by medium- to tall-herbs and graminoids that have been influenced in the past by regular scything (cf. further comments under type U2 in section 10).

### 11.3.6 Classification of the Central Norwegian types

#### 11.3.6.1 The *Lactucion alpinae* alliance

The *Lactucion alpinae* is defined as an alliance comprising the rich communities, of herbs and broad-leaved grasses of the upper boreal and low alpine regions (cf. previous sections). Table 11.3.1 lists the characteristic and differential species of the *Lactucion alpinae* (cf. also Nordhagen 1936, 1943), among which





Table 11.3.1 continued

Cluster no./Types No. of samples	Geranietum sylvatici					Filipendulo- Salicetum		Deschampsio- Salicetum	
	deschampsio- etosum		aconitetosum			U5	C	U6	U7
	U2	A	U3	B	U4 Angelica arch. var.				
	38	4	18	8	9	11	4	6	4
(rc) <i>Paris quadrifolia</i>	29-1	.	78-1	63-1	100-1	64-1	75-1	67-1	.
<i>Parnassia palustris</i>	32-1	.	.	63-1	56-1	.	.	100-1	25-1
rc <i>Polygonatum verticill.</i>	37-1	.	33-1	100-1	.	.	.	17-1	.
<i>Potentilla erecta</i>	39-1	.	6-1	.	.	18-1	.	100-2	75-3
<i>Pyrola minor</i>	92-1	100-1	39-1	75-1	56-1	45-1	.	83-1	75-1
<i>Pyrola rotundifolia</i>	45-1	50-1	28-1	25-1	11-1	9-1	.	33-1	50-1
<i>Ranunculus acris</i>	89-1	100-1	72-1	100-1	100-1	82-1	.	100-2	50-1
<i>Rubus saxatilis</i>	66-1	25-1	72-1	75-1	22-1	45-2	75-1	17-1	.
(d) <i>Rumex acetosa</i>	84-1	100-2	94-1	100-1	100-1	91-1	100-2	67-1	75-1
d <i>Saussurea alpina</i>	79-2	100-1	61-1	88-2	89-1	73-1	.	83-3	75-1
<i>Solidago virgaurea</i>	92-2	100-2	78-1	100-1	89-2	64-1	75-1	100-1	100-2
<i>Succisa pratensis</i>	.	.	.	.	.	.	.	100-2	100-2
d <i>Thalictrum alpinum</i>	47-1	25-1	.	13-1	.	9-1	.	100-3	25-3
<i>Trientalis europaea</i>	82-1	100-2	33-1	100-1	78-1	64-1	100-1	50-1	75-1
rc <i>Valeriana sambucifolia</i>	16-1	50-2	50-1	75-1	44-1	9-1	100-1	.	.
(rc) <i>Viola biflora</i>	84-3	.	78-2	25-1	100-2	9-1	100-2	.	25-1
<i>Agrostis capillaris</i>	89-2	.	72-1	88-1	89-2	64-1	50-1	100-2	100-3
<i>Anthoxanthum odoratum</i>	95-3	100-1	72-1	100-1	89-1	36-1	.	100-1	100-2
<i>Calamagrostis purpurea</i>	24-1	75-1	6-1	50-1	44-3	64-3	100-2	.	.
(d) <i>Carex vaginata</i>	74-1	75-1	39-1	100-1	.	55-1	.	100-2	100-1
<i>Deschampsia cespitosa</i>	89-2	75-2	100-3	100-1	100-3	100-2	100-1	100-4	100-3
<i>Deschampsia flexuosa</i>	97-2	100-3	72-1	100-1	78-1	18-1	.	67-1	100-2
d <i>Luzula sudetica</i>	16-1	25-1	.	25-1	33-1	.	.	83-1	100-1
rc <i>Milium effusum</i>	24-1	75-1	67-1	100-1	56-1	18-1	25-1	.	.
d <i>Phleum alpinum</i>	50-1	75-1	22-1	63-1	44-1	.	.	50-1	100-1
(rc) <i>Poa nemoralis</i>	34-1	.	78-1	100-2	100-1	64-1	50-1	67-2	.
rc <i>Poa remota</i>	.	.	6-1	13-1	.	9-1	.	.	.
(rc) <i>Brachythecium salebro.</i>	82-1	100-3	83-1	38-2	100-3	64-1	100-1	.	25-1
<i>Calliergon cordifolium</i>	3-1	.	.	.	.	36-1	100-2	.	.
<i>Campylium stellatum</i>	13-1	.	6-1	.	44-1	55-1	.	100-3	25-2
(rc) <i>Climacium dendroides</i>	16-1	.	6-1	.	67-1	45-1	100-1	83-1	50-1
rc <i>Mnium spinosum</i>	76-2	25-1	89-1	.	100-3	18-1	.	17-1	.
rc <i>Mnium stellare</i>	5-1	.	6-1	.	89-1	9-1	.	17-1	.
<i>Plagiommium ellipticum</i>	32-1	.	22-1	38-1	22-1	82-2	100-1	33-1	.
rc <i>Rhodobryum roseum</i>	87-1	75-1	83-1	38-1	100-1	45-1	50-1	100-2	100-2
<i>Barbilophozia lycopod.</i>	95-1	100-3	50-1	25-1	78-1	9-1	.	50-1	100-2
<i>Chiloscyphus pallescens</i>	13-1	.	17-1	.	44-2	82-1	50-1	100-1	.

the following are regarded as full characteristic species: *Angelica archangelica*, *Cicerbita alpina*, *Myosotis decumbens* and *Ranunculus platentifolius*. Weaker species (= preferential species) that also occur (but more scattered) in other plant communities of the upper boreal/alpine regions include: *Salix lanata*, *Epilobium lactiflorum*, *Gnaphalium norvegicum* and *Stellaria calycantha*. A number of other species are regionally characteristic species, i.e. they occur in the *Lactucion alpinae* and also in lowland communities. *Aconitum septentrionale* occurs as a dominant species mainly in the *Lactucion alpinae*; it has more scattered occurrences in the lowland boreal communities, e.g. in the *Alno-Prunetum* and *Alno-Ulmetum* communities of Central Norway (cf. Fremstad 1979, Aune & Holten 1985). *Stellaria nemorum*, similarly, has its main occurrence in the *Lactucion alpinae* but also occurs commonly in the lowland types, cf. Kielland-Lund (1981), who classifies it as a species belonging to the *Quercus-Fagetum*.

*Cirsium helenioides*, *Geum rivale*, *Polygonatum verticillatum*, *Valeriana sambucifolia*, *Milium effusum*, *Poa remota*, *Mnium spinosum*, *M. stellare* and *Rhodobryum roseum* are all regionally characteristic species of the *Lactucion alpinae*. Regionally preferential species include: *Filipendula ulmaria*, *Geranium sylvaticum*, *Paris quadrifolia*, *Viola biflora*, *Poa nemoralis*, *Brachythecium salebrosum* and *Climacium dendroides*.

*Aconitum* is the most common of the characteristic species mentioned above, although *Geranium sylvaticum* is the most common of all of them, being even regarded by some authors as a characteristic species of the order *Adenostyletalia*, (e.g. Ellenberg 1988); in Fennoscandia as a whole it occurs much more widely.

Some minor species of the aggregates *Hieracium* spp. and *Alchemilla* spp. (e.g. *A. subcrenata*) may have their main occurrences in the *Lactucion alpinae*. Since *Rumex acetosa* agg. is exclusively represented by subspecies *lapponicus* at Sølendet, it would seem reasonable to regard this subspecies as a preferential species in the *Lactucion alpinae* (cf. also Nordhagen 1943).

A number of calcicole species are differential species towards the poorer communities (viz. those forming the *Dryopterido-Calamagrostion*) e.g.: *Salix arbuscula*, *S. hastata*, *S. myrsinites*, *Bartsia alpina*, *Coeloglossum viride*, *Crepis paludosa*, *Gymnadenia conopsea*, *Leucorchis albida*, *Listera ovata*, *Parnassia palustris*, *Pedicularis oederi*, *Rubus saxatilis*, *Saussurea alpina*, *Selaginella selaginoides*, *Thalictrum alpinum*, *Carex capillaris*, *Campylium stellatum*, *Cirriphyllum piliferum*, *Fissidens* spp. and *Hylocomium pyrenaicum*.

Species that do not occur in the *Lactucion alpinae*, but are present in the *Dryopterido-Calamagrostion* include e.g. *Alchemilla alpina*, *Athyrium distentifolium* (as a dominant), *Dryopteris expansa*, *D. oreopteris* (as a dominant), *Rubus chamaemorus*, *Carex brunnescens*, *Juncus filiformis*, *Sphagnum girgensohnii* and *S. russowii* (both as dominants).

A number of differential species towards the lowland tall-herb communities (excluding characteristic and preferential species) are: *Salix arbuscula*, *S. borealis*, *S. glauca*, *S. hastata*, *S. lapponum*, *S. myrsinites*, *Bartsia alpina*, *Coeloglossum viride*, *Epilobium hornemanii*, *Pedicularis oederi*, *Petasites frigidus*, *Rumex acetosa* ssp. *lapponicus*, *Saussurea alpina*, *Selaginella selaginoides*, *Thalictrum alpinum*, *Carex capillaris*, *Luzula sudetica* and *Phleum alpinum*. In addition, the common, or even dominant, occurrences of *Galium boreale*, *Solidago virgaurea*, *Trientalis europaea*, *Carex vaginata* and *Deschampsia flexuosa* are typical for the vegetation of the upland areas, compared to the lowland types (cf. also Nordhagen 1943: 154). Differential communities and a few species of lowland type (absent from the *Lactucion alpinae*) were listed in subsection 11.3.4.4 (cf. also the list of lowland species restricted to the upper limit of the middle boreal region given in Moen 1987a: 209).

The stated limitation of the *Lactucion alpinae* to include only the rich communities is in agreement with the suggestion made by Nordhagen (1943) and also also by Kielland-Lund (1981), but is not in accordance with those made by Dahl (1957, 1987), Vevle (1983, 1986) or Fremstad & Elven (1987). Its delimitation to the northern boreal and alpine regions agrees with the opinions of Fremstad & Øvstedal (1979) and Odland (1981), but not with those of Nordhagen (1943), Dahl (1957, 1987), Kielland-Lund (1981), Vevle (1983, 1986) and Fremstad & Elven (1987).

#### 11.3.6.2 The associations of the *Lactucion alpinae*

The alliance may be subdivided into associations on a basis of the "conformity principle" (cf. Nordhagen 1943: 49), i.e. the different layers of vegetation represented (tree, i.e. forested, shrub i.e. scrub-covered, field layer only = open), used by Nordhagen (1943) and followed by Odland (1981). However, in my opinion, the entire species composition needs to be taken into consideration; the occurrence or absence of only one, or of just a few species, of shrubs/trees (often dependent of cultural influence) can not, on their own, be used as a basis for defining the separate associations. Nordhagen's (1943) tables show that his different associations include samples that possess very high degrees of similarity (e.g. the samples of the *Aconitum-Polygonatum verticillatum* variants of the *Geranietum sylvatici alpicolum* (Nordhagen 1943: Table 54, quadrats 9-20) and the *Betuletum geraniosum subalpinum* (Table 57b, quadrats 1-32)). In fact, the similarity between the two parallel variants of the different associations described by Nordhagen (1943) is greater than that between the two variants of one and the same association. In consequence I have here reorganised Nordhagen's Sikildalen associations (cf. the description of the subassociations of the *Geranietum sylvatici* in the next subsection).

In the present monograph (section 10) only the data for the vegetation of the wooded grassland areas were included in the multivariate analyses, as also in the main comparisons made with references found in the literature. However, some comparisons will be made with the tree-less types, mainly with those in Nordhagen (1943).

A partition of the *Lactucion alpinae* into three associations is proposed. One of the associations, the *Geranietum sylvatici* has been further split into two new subassociations. Table 11.3.1 provides a survey of the occurrence of the main species in the different subunits, and table 11.3.2 a schematic representation of the differential species. A complete survey of the hierarchical system was presented in table 11.1.1 and the main units were schematically presented in relation to the poor-rich and dry-wet ecological gradients in figure 11.1.1.

#### 11.3.6.3 The association *Geranietum sylvatici* (Nordh. 1943) Dahl 87

The association comprises the vegetational types U2-4 of section 10. Complete phytosociological table in Appendix D-table 3. The samples from Sølendet are represented by types W7 and 10 in section 9.6.

... and further comments made later under the description of the *aconitosum*). The subassociation's difference from the *aconitosum* is shown by the



Table 11.3.2 Schematic representation of the occurrence of the main plant species used for differentiating the phytosociological types of the *Lactucion alpinae*.

common occurrence of a number of species that belong to the *Vaccinio-Piceetea*, e.g. *Vaccinium myrtillus*, *Gymnocarpium dryopteris* and *Barbilophozia lycopodioides*. Graminoids (*Anthoxanthum odoratum*, *Agrostis capillaris* and *Deschampsia flexuosa*) are very common and in places are dominants. The most exclusive tall-herbs (*Aconitum septentrionale*, *Angelica archangelica* and *Cicerbita alpina*) do not occur as dominants.

The subassociation can be separated into two variants (called "Dry" and "Typicum" in Table 11.3.2). The former is found on drier, heathland-type habitats (cf. subcluster 2a in section 10) and the latter in more fertile habitats (subcluster 2b).

Regular scything of the grassland vegetation in former times has undoubtedly led, at certain stands, to a reduction in the cover of tall-herbs. The cessation of such scything may in future lead to a change in the vegetation towards that typical of the following subassociation, the *aconitetosum*.

#### 11.3.6.5 *Geranietum sylvatici aconitetosum* subass. nov.

Nomenclatural type: Nordhagen (1943), *Betuletum geranium subalpinum*, *Aconitum-Polygonatum verticillatum* variant, stand V (quadrat no. 1) pp. 348-351.

The subassociation comprises the vegetational types U3 and 4 of section 10, the Sølendet stands are described in cluster W10 (in section 9.6).

Additional, typical, phytosociological analyses include e.g. the *Betuletum geranium subalpinum*, *Aconitum-Polygonatum verticillatum*-var. of Nordhagen (1943: Table 57b, including 8 stands (32 quadrats), summarized in my Table 11.3.1, type B) and the *Geranietum sylvatici alpicolum*, *Aconitum-Polygonatum verticillatum* var. of Nordhagen (1943: Table 54; including 5 stands (12 quadrats)).

The subassociation is characterized by the occurrence of *Aconitum septentrionale* as a dominant, and by the dominance or common occurrence of some other tall-herbs and grasses, e.g. *Angelica archangelica*, *Stellaria nemorum*, *Poa nemoralis*. Typical heathland species are either absent or occur only very scattered.

This subassociation can also be separated into two variants (cf. Tables 11.3.1 & 2). The var. *Typicum* includes *Equisetum pratense*, *Rubus saxatilis*, *Stellaria nemorum* and a number of thermophilous and xerophilous species. Nordhagen (1943: 327-28) listed a number of warmth-demanding species even in his low alpine stands in Sikilsdalen, e.g. *Convallaria majalis*, *Rubus idaeus* and *Turritis glabra*. The var. *Typicum* occurs on south-facing, generally steep, slopes. The vegetation of the *Aconitum-Polygonatum verticillatum* variants of Nordhagen's two associations mentioned above belong to this variant.



The *Angelica archangelica* var. comprises the tall-herb communities of flatter areas and includes a number of hygrophilous species (e.g. a number of willows (*Salix* spp.), *Angelica*, *Crepis paludosa* and *Filipendula ulmaria*) and an absence of the xerophilous species found in the aforementioned variant. The tall-herb stands from Sølendet (i.e. cluster U4) all belong to this variant.

The *Angelica archangelica* var. represents a type that is transitional between the richest (most fertile) stands of the *deschampsietosum* and the stands of the *Filipendulo-Salicetum* (cf. the DCA-diagram in Fig. 10.3.1 A). Where no clearance or scything have been carried out, the Sølendet stands include a rather dense shrub layer of *Salix* spp. The most similar communities described in the literature would seem to be those of the *Salix*-dominated grasslands, mainly found in the lowalpine region, described by e.g. Nordhagen (1928: 153: *Geranium silvaticum*-reiches Weidengebusch I) and Nordhagen (1943: 333: *Salicetum geraniosum alpicolum*). The stands from the communities referred to above were not included in the multivariate analyses of the data for tall-herb birch forest communities described in section 10, and further multivariate analyses will have to be made in the future, including data for the low alpine communities of the *Lactucion alpinae*, before the precise syntaxonomic level of the var. *Angelica archangelica* can be assessed. It would seem natural, however, to separate these community, together with some of the *Salix*-dominated stands referred to above, as a discrete subassociation, the name of which should then be the *salicetosum*.

#### 11.3.6.6 The association *Filipendulo-Salicetum phyllicifoliae* (Nordh. 43) Dahl 87

Vegetational type U5 of section 10. Complete phytosociological table in Appendix D-table 3. The vegetation at Sølendet belonging to this association is described under type M14 of section 5, i.e. samples 84 and 85. These two samples are also included in cluster W11 of section 6.

The association was described by Nordhagen (1943: 344) as the *Salicetum ulmariosum alpicolum*. It included the *Ulmaria pentapetala*-reiches *Salix lapponum*-Gebüsch from Sylane of Nordhagen (1928: 166-167; it is summarized as type C in my Table 11.3.1). Dahl (1987) renamed this association and included it in his suballiance *Dryopterido-Calamagrostenion* (cf. subsection 11.3.2). In Dahl's system it should, however, in my opinion, have been placed in the suballiance *Lactucionion*, primarily because of the common occurrence of calcicolous species in the samples of this community (i.e. in agreement with Nordhagen 1943). One of Kalliola's (1939) communities (*Salix-Comarum-Ulmaria*-Soz., Table 15) also belongs to this association.

The association is characterized by the dominance or common occurrence of willows (*Salix* spp.) and tall-herbs such as *Crepis paludosa*, *Filipendula ulmaria* and *Geum rivale*. A number of additional hygrophilous species, e.g. *Caltha palustris*, *Stellaria calycantha*, *Poa remota* and *Climacium dendroides* also occur

(cf. further lists in Table 11.3.2). However, the *Salix*-dominated communities are badly documented as a whole,, so further analyses need to be made before any further descriptions and/or separation of subunits can be contemplated.

11.3.6.7 The association *Deschampsio cespitosae-Salicetum lapponae* Nordh.  
43 nom. nov.

Nomenclatural type: Nordhagen (1928), *Deschampsia caespitosa*-reiches *Salix lapponum*-Gebüsch, stand no. 2, p. 177. Vegetational types U6 and 7 of section 10 (identical with the Sølendet clusters W9 and 8, respectively, of section 9.6). Complete phytosociological table in Appendix D-table 3.

The association includes the two associations described by Nordhagen (1943: 333 and 344-345): the *Deschampsietum caespitosae alpicolum* and the *Salicetum deschampsiosum alpicolum*; these associations were included in his *Lactucion alpinae*. However, these associations have subsequently not been considered by Norwegian phytosociologists as distinct; e.g. Dahl (1987) included these two associations of Nordhagen (op.cit) in his *Filipendulo-Salicetum* association (of the suballiance *Dryopterido-Calamagrostienion*).

Nordhagen's (1943) description of the two associations is mainly based on his phytosociological analyses from Sylane (1928), although he also referred to previous descriptions from other parts of Fennoscandia, e.g. Resvoll-Holmsen (1920) and Smith (1920). All the analyses referred to above comprised stands from low alpine communities only, and no analyses that included woodland vegetation have been published.

I have myself been somewhat in doubt about the correct phytosociological classification of the vegetation represented by clusters U6 & 7. Further multivariate analyses of all the data for the samples of the rich, damp grassland vegetation found in the boreal and alpine regions, including the wooded rich fen vegetation, will need to be made before we can come to a final decision on the detailed typification of these communities. However, great similarities exist between typical stands of Nordhagen's associations and those forming my clusters U6 & 7. I would thus suggest that these clusters should be included in a single association, common to the vegetational communities of both the northern boreal and low alpine regions, to be called the *Deschampsio cespitosae-Salicetum lapponae*. This would be the third association within the alliance *Lactucion alpinae*. Some of the Central Norwegian, wooded grassland samples show transitional features, even though the association is fairly distinct, as represented by the 2 clusters described in section 10.

Differential species for separating the *Deschampsio-Salicetum* association from the other associations and subunits of the *Lactucion alpinae* alliance are shown in tables 11.3.1 & 2. The association includes a large number of damp grassland/rich fen species, as well as species favoured by the effects of grazing and/or scything. The dominant occurrence of *Deschampsia caespitosa*, *Nardus*

*stricta*, and other grass species, depends mainly on such past and/or present utilisation of this vegetation.

The most typical tall-herbs of the *Lactucion alpinae* are absent, but the communities in question have nonetheless to be included in that alliance, as defined in the present paper (cf. also Nordhagen 1943). A number of medium-tall herb species are dominant or common species in this association, e.g. the following: *Alchemilla* spp. (mainly *A. glabra*, *A. glomerulans* and *A. subcrenata*), *Angelica sylvestris*, *Crepis paludosa*, *Geranium sylvaticum*, *Geum rivale*, *Ranunculus acris* and *Saussurea alpina*.

The vegetation of clusters U6 & 7 included some "lowland" species that were not present in the alpine communities described by Nordhagen (1928, 1943) and others, e.g. *Crepis paludosa*, *Dactylorhiza fuchsii* and *Succisa pratensis*. Alpine species, e.g. *Astragalus* spp., occur in the alpine communities, where types transitional to the communities of the alliance *Ranunculo-Poion alpinae* (cf. Gjærevoll 1956) can be found.

The communities forming the *Deschampsio-Salicetum* association are also transitional to the fen margin communities belonging to the alliances *Caricion atro-fuscae* and *Sphagno-Tomenthyphnion*.

Along the rich-poor gradient, the clusters U6 and 7 represent different types. I regard cluster U7 as a community close to the "poor" end of this gradient within the association, viz. some samples (e.g. no. 58) are transitional to communities of the alliance *Dryopterido-Calamagrostion*. The clusters U6 and 7 could be defined as representing two subassociations. However, since the two clusters comprise only a few samples from a single area (viz. Solendet), further data and analyses (also including samples from the low alpine region) are needed before any formal phytosociological subunits can be defined (cf. the suggestions made by Barkman et al. 1986). Here, I simply distinguish between two types:

**Type 1 (rich).** *Betula-Crepis-Campylium* type (cluster U7 = W9) includes a number of extremely rich fen species, e.g. *Thalictrum alpinum* (dominant), *Carex capillaris* and *Fissidens adianthoides*.

**Type 2 (poor).** *Betula-Agrostis-Succisa* type (cluster U6 = W8) includes a number of intermediate fen/heathland species, e.g. *Sphagnum* spp.

Communities belonging to this association have been described previously in a number of publications in addition to those already mentioned above, e.g. Samuelsson (1916: 66; 1917: Table 21f) described open, alpine communities resembling subtype 1 (transitional to the *Ranunculo-Poion alpinae*); Resvoll-Holmsen (1920: 52-54 and 106-107) described *Deschampsia cespitosa*-dominated shrub communities from Hummelfjell and "urtelier" from Knutshø, an area that includes some extremely rich vegetation, resembling type 1; and finally Mork & Heiberg (1937: Table 8, Sociation no. 3): the *Agrostis tenuis-Deschampsia cespitosa-Carex Goodenowii-Betula* soc. from Hirkjølén.

## 11.4 THE OPEN GRASSLANDS

### 11.4.1 General

The area covered by open grassland vegetation in the upper boreal areas of Scandinavia was greater some decades ago, when summer-farming and haymaking were still practised on the outlying lands. The most important publication on these utilised grasslands is that of Nordhagen (1943) who described a special alliance, the *Nardeto-Agrostion tenuis* (Sætervollenes forbund). In addition, a large number of Norwegian publications have dealt with the grazing/fodder value of the different plant species/communities for farmlive-stock, though usually without providing complete phytosociological analyses. Baadshaug (1974) has summarised the results from some of these literature sources. The phytosociologically well-documented snow-bed grasslands (e.g. Gjærevoll 1956) represent quite different communities, and it must be said that our knowledge of the plant communities of the open boreal grasslands in Scandinavia is so far very limited. Some comparisons will therefore also be made with the more well-defined types to be found in the Alps. Special attention will be paid to the *Nigritella nigra* communities.

### 11.4.2 Phytosociological survey of the clusters (nos. O1-5)

Five separate clusters (O1-5) were distinguished during the multivariate analyses of the 33 samples of open grassland vegetation s.lat. from Sølendet, as described in sections 9.3 and 9.7. The clusters O1 and O2 represent distinct types of vegetation that will be further dealt with in the following subsections. Most of the samples of the clusters O3-5 were also included in the clusters of mire vegetation and/or wooded grasslands, (cf. sections 8.4 and 11.3) under which headings can be found comments on their phytosociological classification and literature. Here only a brief summary will be given of the phytosociological classification of the clusters.

#### Cluster O1. *Achillea millefolium*-*Tortula ruralis* type

The eight samples of this cluster are synedria analyses of *Nigritella nigra* (5 samples), *Botrychium lanceolatum* (2 samples) and *Botrychium multifidum* (1 sample). The cluster is rather heterogeneous, as some of the samples tend to be outliers. The "typical" *Nigritella* samples form a compact group with a high degree of similarity. I regard the alpine alliance *Potentillo-Polygonion vivipari* as the closest for Norway of all the alliances described. However, the samples of cluster O1 represent a boreal type, that includes a number of "lowland" species and lacks the typical alpine species. The samples of the cluster also show some similarity with the anthropogenically influenced vegetation of the alliance *Nardo-Agrostion*. Compared with the communities found in the Alps, the samples of cluster O1 show a certain similarity also with the *Seslerion* alliance, in which *Nigritella nigra* is a characteristic species.



Cluster O2. *Nardus stricta*-*Thalictrum alpinum*-*Sphagnum warnstorffii* type

The eight samples are all derived from stands in Vassdalen. Two of the samples (nos. 54 and 88) represent synedria analyses of *Nigritella nigra*, the rest are from quadrats along the Vassdalen transect (cf. Fig. 7.3.1), one of which includes *Nigritella*. The samples of cluster O2 represent a community transitional between the *Potentillo-Polygonion vivipari*, *Nardo-Agrostion* and *Sphagno-Tomenthypnion* alliances. I am inclined to place it provisionally in the first-mentioned alliance. Communities belonging to the Central-European *Caricion ferrugineae* alliance show certain features in common with the samples forming cluster O2.

Cluster O3 (*Betula nana*-*Molinia caerulea*-*Campylium stellatum* type) represents communities of the *Caricion atrofuscae* alliance (cf. section 8.4.3).

Cluster O4 (*Geranium sylvaticum*-*Viola biflora* type) has to be included in the *Geranietum sylvatici deschampsietosum* subassociation (cf. section 11.3.6.4).

Cluster O5 (*Salix* spp.-*Alchemilla* spp.-*Sphagnum warnstorffii* type) is a heterogeneous cluster that includes samples belonging to the *Filipendulo-Salicetum* association (viz. samples nos. 84 & 85), the *Deschampsio cespitosae-Salicetum* association (no. 5) and communities of the *Sphagno-Tomenthypnion* alliance (samples 281-286).

#### 11.4.3 Comments on the phytosociological classification

##### 11.4.3.1 The Central European classification of the *Nigritella nigra* communities

*Nigritella nigra* is an European boreal-alpine, calcicolous species of open grasslands and heathlands (cf. the next subsection). In Central Europe *Nigritella nigra* is regarded, by e.g. Wilmanns (1978) and Ellenberg (1988), as a characteristic species of the order *Seslerietalia albicantis*. Oberdorfer (1978, 1983) goes further down in the hierarchy, he lists *Nigritella nigra* as a characteristic species of the *Seslerion* alliance, and even as a (weak) characteristic species of the *Seslerio-Caricetum sempervirentis* association. Phytosociological names (additional to Table 11.1.1) after Oberdorfer (1983), where also names of the authors can be found.

The above-mentioned communities are all included in the class *Seslerietea*. This class represents the alpine/subalpine communities of Central Europe; it comprises one order (*Seslerietalia*) and two alliances (*Seslerion* and *Caricion ferrugineae*). The *Seslerion* communities represent the vegetation of dry habitats on shallow calcareous soils, the *Caricion ferrugineae* communities occur on



deeper soils. The *Seslerietea* class is not included in the present-day Norwegian phytosociological classifications (e.g. Vevle 1983, 1986, Dahl 1987).

The *Nigritella nigra*-communities of the alpine/subalpine regions in the Alps and the same communities at Sølendet have many features and species in common, e.g. the following, taken from the Oberdorfer's (1978: 184) phytosociological table for the "*Nigritella*-association": *Bartsia alpina*, *Botrychium lunaria*, *Gentianella campestris*, *Gymnadenia conopsea*, *Leontodon autumnalis*, *Nigritella nigra*, *Parnassia palustris*, *Polygonum viviparum*, *Selaginella selaginoides*, *Solidago virgaurea*, *Viola biflora*, *Anthoxanthum odoratum*, *Carex capillaris*, *Deschampsia cespitosa*, *Poa alpina* and *Tortella tortuosa*.

As well as being a characteristic species of the alliance *Seslerion*, Oberdorfer (1983) mentioned that *Nigritella nigra* also occurs, although more rarely, in the alliances *Nardion* (in the class *Nardo-Callunetea*) and *Mesobromion* (in the class *Festuco-Brometea*). Both of these alliances are also represented in Norway (cf. Vevle 1983, 1986; the *Nardion* mainly includes poor types of vegetation, whilst the *Mesobromion* includes those of dry habitats and warmth-demanding communities, i.e. lowland/southern types).

#### 11.4.3.2 The *Potentillo-Polygonion vivipari* alliance

The chionophobic communities found on calcareous soils in the alpine region in Norway (cf. Dahl 1987) are all included in the class *Carici rupestris-Kobresietea bellardii*. This class has a world-wide distribution, occurring also (with only one association) in Central Europe (Oberdorfer 1978, 1983). In the Norwegian classification system (Dahl 1987) the class has one order (*Kobresio-Dryadetalia*), which includes two alliances, the *Kobresio-Dryadion* and the *Potentillo-Polygonion vivipari*. The former alliance includes the vegetation of a wide range of heathland communities, from those of snow-free, wind-exposed ridges to more snow-protected communities. The latter alliance includes alpine grassland communities which become snow-free fairly early in the spring. This alliance was first defined by Nordhagen (1936), who suggested that it represented a parallel to the Central-European alliance of the *Caricion ferrugineae*.

It seems reasonable to me, again as a parallel to the Central-European classification (cf. also Ohba 1974 defining the *Carici-Kobresietea* class) to suggest making a differentiation, at the class level, between the two Nordic alliances mentioned above. The *Potentillo-Polygonion vivipari* should thus be classified as belonging to the class *Seslerietea* and the *Kobresio-Dryadion* as belonging to the class *Carici rupestris-Kobresietea*.

I regard the *Potentillo-Polygonion vivipari* alliance to be the most relevant of all the Fennoscandian alliances in which to include the samples forming clusters O1 and O2. Typical species which are common to both the alliance and the Sølendet samples are e.g.: *Parnassia palustris*, *Pedicularis oederi*, *Polygonum viviparum*, *Potentilla crantzii*, *Saussurea alpina*, *Selaginella selaginoides*,

*Thalictrum alpinum* and *Festuca ovina*. Compared with the description given by Nordhagen (1936), Sølendet lacks a number of alpine species e.g.: *Astragalus* spp., *Cerastium alpinum*, *Draba* spp. and *Silene acaulis*, so that cluster O1 has to be regarded as a dry, boreal type and cluster O2 as a damp, boreal type. The two clusters should therefore be separated at least at the association level. However, before a final decision can be made about the formal phytosociological units to which these Scandinavian types of vegetation belong, more comparative work needs to be done on further samples from the alpine and the northern boreal grasslands. Communities of the *Nardo-Agrostion*, the *Lactucion alpinae* (anthropogenically-influenced, low-herb types) and those found on the margins of rich fens should also be included in these comparative analyses.

#### 11.4.4 *Nigritella nigra* in Norway

##### 11.4.4.1 Notes on its general distribution in Scandinavia

Holmboe (1936) mapped the Scandinavian localities of *Nigritella nigra*. A new distribution map of *Nigritella* in Norway, and a brief description of its distribution and ecology are given (by me) in Gjærevoll (1990).

The Scandinavian populations of *Nigritella nigra* are regarded as belonging to the same taxon as the most widely distributed *Nigritella* taxon in C. and S. Europe (*Nigritella nigra* of Oberdorfer 1983, *N. nigra* subsp. *nigra* of Tutin et al. 1980). However, *Nigritella nigra* has a disjunct distribution in Scandinavia, and it has been included in the list of "glacial survivals" (e.g. Holmboe 1936, Gjærevoll 1963). Some differences in its reproductive biology and in chromosome numbers have also been reported. The Scandinavian populations (at least those of the boreal region) seem to be apomictic (e.g. Afzelius 1932).

*Nigritella nigra* has disappeared from a number of its previously-known localities in Norway. The actual situation for *Nigritella* in Norway is: one locality in Opland county, a few localities in the northern part of Hedmark and the southern part of Sør-Trøndelag counties (altogether ca. 30 localities), in addition to the northernmost locality in Nordreisa in the county of Troms. The last-mentioned population comprises about 150 specimens (Sætra 1987).

In Sweden, *Nigritella* has been collected from a large number of localities in Jämtland and Härjedalen, and in addition it has been recorded in some other provinces of Central Sweden (even on the Baltic coast); the northernmost known locality is in Lycksele lappmark. Björkback et al. (1976, 1982, 1986) have summarised the present situation and described the measures taken to protect *Nigritella*. Both the numbers of localities and the numbers of specimens in each locality in Jämtland have fallen dramatically from the beginning of the 20th century up to the present day. An attempt has been made to save and restore a number of *Nigritella* localities in Jämtland, and the effects of different management procedures (scrub clearance, mowing, grazing and the use of fertilizers) have been studied.

In Norway, the traditional use of the outlying lands by the farmers continued longer than in Jämtland. Consequently, the process of overgrowth and crowding out of *Nigritella* is less advanced, which partly explains why the reduction has been less dramatic. Nevertheless, even in Norway, *Nigritella* has disappeared from a number of its former localities in this way, and a large number of habitats have been destroyed, e.g. by ditching and by building dams for hydro-electric reservoirs (e.g. Innerdalen, Moen 1976a).

The highest-lying locality in Scandinavia is situated in the Gjevilvasskammene mountains in Oppdal, in the low alpine region. It was recorded for the first time by O. Gjærevoll & N. A. Sørensen in 1948 and was subsequently visited by Gjærevoll on a number of occasions, the last being in 1957; it has not been recorded since then, despite extensive searches (in 1988 by myself).

The following description of the highest-lying locality (at 1270 m above s.l., not at 1330 m as reported by Sørensen 1949) can be given (O. Gjærevoll pers. comm.): A south-facing, species-rich slope, which includes the following species in addition to *Nigritella*: *Anthyllis vulneraria*, *Draba daurica*, *D. incana*, *Dryas octopetala*, *Equisetum variegatum*, *Erigeron boreale*, *Euphrasia lapponica*, *Gentianella campestris*, *Oxytropis lapponica*, *Roegneria borealis*, *Salix reticulata*, *Saxifraga oppositifolia* and *Veronica fruticans*. In 1948, ca. 50 specimens of flowering *Nigritella* were counted at this locality, and in the same year thousands of *Gymnadenia conopsea* were counted in the lowest-lying *Nigritella* localities and further downslope.

At Sølendet, *Nigritella* occurs in a number of "small-patch" localities (q.v. Table 11.4.1, which shows the number of specimens found in four such patches over the past twelve years). Flowering frequency varies greatly. In the above-mentioned localities only 34 specimens were found flowering in 1988, compared to more than 700 in the same areas in 1979. (1979 was also a "good" year for *Nigritella* in Jämtland, cf. Björkback et al. 1986). The same specimens do not usually flower two years in succession (cf. Moen 1985b, and Fig. 11.4.2). Over 2000 specimens occur at Sølendet, making it one of the largest populations of *Nigritella* found in Scandinavia today. However, as seen in table 11.4.1 and in figure 11.4.1, the number of flowering specimens shows a clear declining trend from 1979 to 1989. The reduction in the number of flowering specimens is most striking at locality no. I; the main reason seems to be overgrowth by shrubs on previously open grassland. The localities nos. I, II and IV are situated outside the present-day nature reserve. Figure 11.4.2 shows the flowering frequencies 1982–1989 of *Nigritella* in two quadrats, representing clusters O1 and O2, respectively. The figure shows that even in the dry stand (A), most of the specimens are still alive, although none flowered in 1988 and 1989. Further results of the population studies of *Nigritella nigra* at Sølendet will be published in a separate paper.

Table 11.4.1 Number of flowering specimens of *Nigritella nigra* in four "small-patch" localities at Sølendet. Areas I and II represent the "dry" type (described in cluster 01), III and IV the damp type (cluster 02). Locality III is situated within the present-day nature reserve (cleared and scythed), the other localities are situated in the proposed extension of the reserve to the southeast.

	I	II	III	IV	Total
1978	260	?	10	?	ca. 400
1979	410	260	39	12	720
1980	200	120	64	23	405
1981	115	140	65	25	345
1982	160	110	50	6	325
1983	120	45	36	4	205
1984	265	130	60	14	470
1985	245	130	13	9	395
1986	130	55	14	2	200
1987	50	35	13	2	100
1988	3	20	10	0	35
1989	30	60	25	8	125

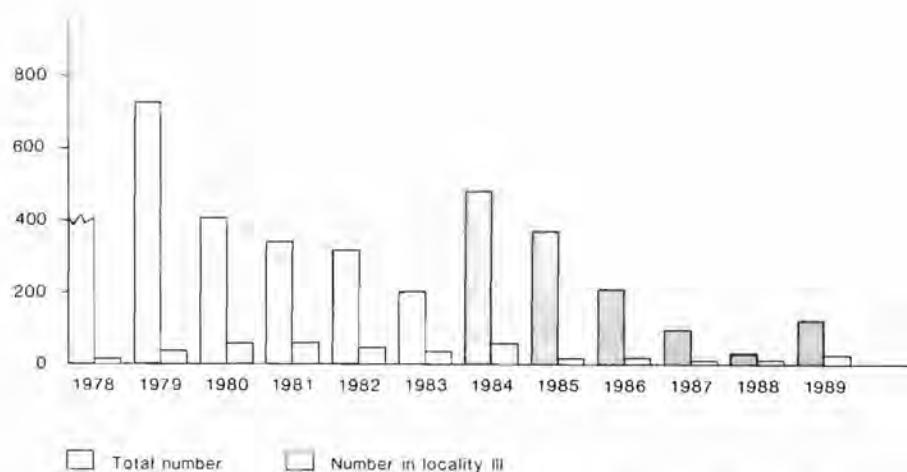


Fig. 11.4.1 Numbers of flowering specimens of *Nigritella nigra* recorded annually at Sølendet during the period 1978-1989. The "total number" value includes localities I-IV of table 11.4.1; locality III represents the present-day nature reserve.

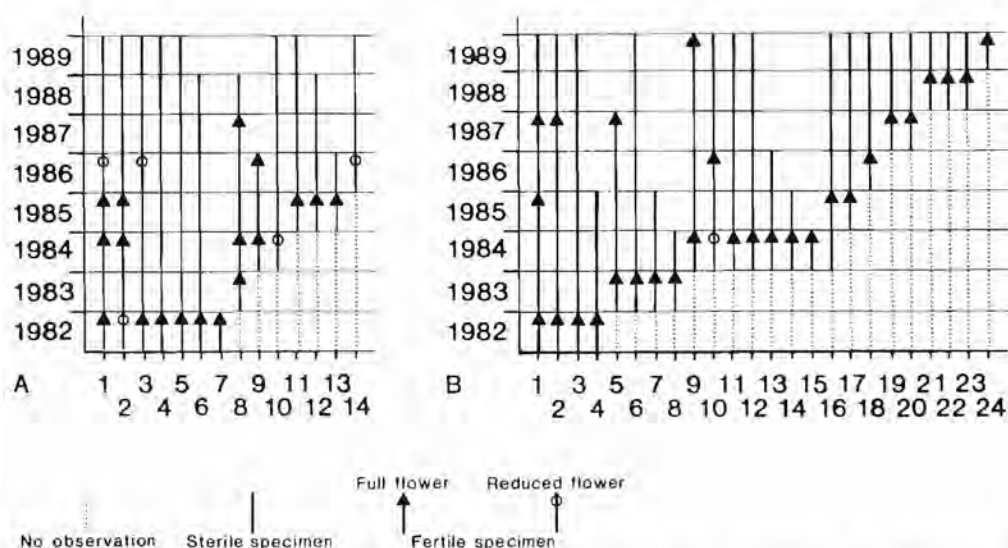


Fig. 11.4.2 The fertility of *Nigritella nigra* in two quadrats at Sølendet. A: One 1 m<sup>2</sup> quadrat of stand no. 77 of cluster O1. B: A 20 m<sup>2</sup> quadrat at locality no. 88, representing cluster O2. Each vertical line represents one specimen, starting with flowering individuals.

#### 11.4.4.2 Analyses of the *Nigritella nigra* syndria

Table 11.4.2 presents a summary of the phytosociological analyses of 21 quadrats (0.25–1 m<sup>2</sup> in size), all including *Nigritella nigra*, from different localities in Norway. The table includes only 37 species, amongst which are the most frequent ones. The plant communities in which *Nigritella* occurs are always very species-rich, usually 25–50 species in a 1 m<sup>2</sup>-quadrat, (even more than 60 species occur in some of the quadrats analysed). The quadrats from Sølendet are separated into a dry type A (included in cluster O1: *Achillea millefolium*-*Tortula ruralis*-type) and a damp type B, (O2: *Nardus stricta*-*Thalictrum alpinum*-*Sphagnum warnstorffii*-type). The four quadrats from Innerdalen also represent different types, two quadrats are rich *Calluna* heathlands (*Calluna vulgaris*, *Cladonia arbuscula* coll., and other lichens that are not included in the table), the other two quadrats represent more typical grassland types. The quadrats from Nordreisa (Engelskjøn & Skifte 1984) resemble the A type quadrats of Sølendet, but they lack *Geranium sylvaticum* and *Nardus stricta* and include additionally a number of *Kobresio-Dryadion* species, e.g. *Dryas* and *Carex rupestris*. Sætra (1987) has also published a 25 m<sup>2</sup> quadrat from the Nordreisa locality, in which *Dryas*, *Betula nana*, *Vaccinium uliginosum* and *Silene acaulis* are the most abundant species.



Table 11.4.2 Phytosociological analyses of *Nigritella nigra* from Sælendet (A&B), Innerdalen in Tynset (C), Balgesoaivve in Nordreisa (D), Olbu in Oppdal (E). Frequency values and characteristic degree of cover (Hult-Sernander-Du Rietz scale) are shown for 0.25-1 m<sup>2</sup> quadrats. Only a selection of species is shown.

Locality no. No. of quadrats	A 5	B 5	C 4	D 6	E 1
<i>Nigritella nigra</i>	100-1	100-1	100-1	100-1	1
<i>Betula nana</i>	-	80-1	50-2	-	-
<i>Dryas octopetala</i>	-	-	-	50-1	-
<i>Salix phylicifolia</i>	80-1	60-1	-	-	-
<i>Vaccinium vitis-idaea</i>	80-1	40-1	25-1	17-1	-
<i>Achillea millefolium</i>	80-3	-	-	-	2
<i>Antennaria dioica</i>	100-1	60-1	50-1	83-1	1
<i>Bartsia alpina</i>	-	30-1	100-1	33-1	-
<i>Botrychium lunaria</i>	80-1	-	-	67-1	-
<i>Campanula rotundifolia</i>	100-1	-	25-1	83-1	1
<i>Erigeron boreale</i>	100-1	-	50-1	17-1	-
<i>Gentiana nivalis</i>	80-1	-	-	83-1	-
<i>Geranium sylvaticum</i>	100-2	100-1	50-2	-	1
<i>Parnassia palustris</i>	20-1	60-1	25-1	50-1	-
<i>Pedicularis oederi</i>	20-2	100-1	75-1	-	-
<i>Polygonum viviparum</i>	100-2	100-1	25-1	100-2	2
<i>Potentilla crantzii</i>	80-1	-	50-1	100-1	1
<i>Saussurea alpina</i>	100-2	100-2	75-1	83-1	1
<i>Selaginella selaginoides</i>	100-2	80-1	25-1	-	-
<i>Solidago virgaurea</i>	80-2	60-1	-	100-2	-
<i>Succisa pratensis</i>	80-2	100-3	-	-	-
<i>Thalictrum alpinum</i>	100-3	60-4	75-4	100-2	3
<i>Viola biflora</i>	-	-	25-1	100-1	-
<i>Agrostis capillaris</i>	80-1	60-1	-	67-2	3
<i>Anthoxanthum odoratum</i>	100-1	100-1	50-1	33-1	2
<i>Carex capillaris</i>	80-1	60-2	100-1	33-1	1
<i>Carex rupestris</i>	-	-	25-1	83-3	-
<i>Carex vaginata</i>	100-1	100-1	100-1	50-2	1
<i>Deschampsia cespitosa</i>	60-2	60-1	50-2	67-1	2
<i>Festuca ovina</i>	100-1	100-2	25-1	17-1	1
<i>Nardus stricta</i>	80-2	100-3	75-2	-	3
<i>Aulacomnium palustre</i>	60-1	100-3	25-2	-	-
<i>Homalothecium nitens</i>	-	80-2	-	-	-
<i>Hylocomium splendens</i>	100-2	100-2	75-4	-	-
<i>Pleurozium schreberi</i>	80-2	60-3	50-2	-	-
<i>Sphagnum warnstorffii</i>	-	80-3	-	-	-
<i>Tortula ruralis</i>	100-3	-	-	-	-

The localities A-C are situated in areas transitional between the middle and the northern boreal regions, D is in the low alpine and E in the middle boreal region. Nearly all the quadrats have a number of calcicolous species in common, e.g. *Saussurea alpina*, *Thalictrum alpinum* and *Carex capillaris*. Species typical of an open vegetation with a low-growing field layer are also common, e.g. *Antennaria dioica*, *Botrychium* spp., *Campanula rotundifolia*, *Gentiana nivalis* and *Gentianella* spp.

The single quadrat for locality E represents a fenced pasture (artificial fertiliser used and heavily grazed by cattle) in the middle boreal region. Additional species, with cover values 3-4, are: *Leucanthemum vulgare*, *Trifolium pratense*, *Veronica officinalis*, *Deschampsia flexuosa*, *Calliergonella cuspidata*, *Climacium dendroides*, *Plagiomnium elatum* and *Rhytidiadelphus squarrosus*. The species composition listed is one typical of rich pastures, and in this community, with a dense field layer, there were (in 1985) a large number of flowering specimens of *Nigritella* (ca. 200 in an area of ca. 2 daa). Small shrubs (*Betula pubescens*, *Alnus incana*, *Populus tremula*) were also present, and *Nigritella* would have no chance of survival in this community without the heavy grazing pressure.

The last-mentioned quadrat bears a great resemblance to a number of analyses recorded from Sweden by Stenar (1947) and by Björkback & Lundqvist (1982), similarly situated in pastures in the middle boreal region. A number of "lowland pasture species" are among the most frequent ones in these "lowland" quadrats, species which are either not found or are very rare in the northern boreal/alpine *Nigritella* communities, e.g.: *Carum carvi*, *Hypochoeris maculata*, *Pimpinella saxifraga*, *Plantago media*, *Trifolium* spp. and *Vicia cracca*.

It seems obvious that localities A-D represent much more stable communities than that of E and of most of the Swedish quadrats referred to. Even in the first-mentioned types, however, changes are occurring (*Salix* scrub is invading the habitat, etc.) and some grazing and/or scything would seem to be necessary if *Nigritella* is to survive in most of the above-mentioned types of vegetation.

In the phytosociological system (cf. the previous section) it seems logical to place most of the samples of localities A-D in the *Potentillo-Polygonion* alliance; however, that at locality D and the Gjevilvasskammene community are also closely related to the *Kobresio-Dryadion* alliance. The samples from locality E (and a number of the Swedish samples previously referred to) represent heavily anthropogenically-influenced vegetation which has to be classified as belonging to the order *Arrhenatheretalia*.

## 12 THE VEGETATION MAP OF SØLENDET NATURE RESERVE; SURVEY AND ADDITIONAL DATA ON THE VEGETATIONAL UNITS

### 12.1 INTRODUCTION

The large-scale vegetation map of Sølendet (enclosed) is helpful for an understanding of the spatial relationships of the plant communities of the area. The next subsection of section 12, therefore, gives an English summary of the Norwegian text of the map. In this section, too, the areal distribution of the vegetational units of the map are tabulated. The subsequent sections describe the separate vegetational units represented.

### 12.2 EXPLANATION OF THE VEGETATION MAP

The methods that were used in mapping the vegetation have already been summarized in section 4.2 (cf. also Fig. 12.2.1).

The major aim in making the vegetation map was to provide a basis for the management plan (cf. sect. 3.5.3) for the nature reserve. The prior experience gained in mapping the vegetation of the upland areas of Central Norway (e.g. Moen & Moen 1975; cf. subsection 2.2.2) was of fundamental importance for the work done at Sølendet. The map units were defined using Gaare's (1963) data and those derived from the phytosociological analyses and species lists for the different vegetational types at Sølendet, obtained during the field work carried out in 1974-1976. Because of the intended use of the map, it was necessary to use a larger scale (i.e. 1:5000) than that previously adopted (i.e. 1:10 000), and also to diversify the number of units used in mapping the most important types of vegetation. The lawn communities of the rich fens, in particular, were split up into a number of subunits, and also the woodlands. The 25 units recognised and mapped at Sølendet are schematically presented in figure 12.2.2, arranged along the two main ecological gradients (rich to poor and dry to wet).

The vegetational units shown on the map coincide in the main with the phytosociological types described in sections 5, 6 and 9. Some units shown on the map, however, are only poorly separated phytosociologically, e.g. 2g and 2h (viz. *Carex rostrata*-*C. lasiocarpa* carpet-lawn and *Scirpus cespitosus*-*Eriophorum latifolium* lawn). Table 12.2.1 provides a survey of the vegetational units of the map.

The 25 vegetational units were defined and mapped without taking the tree and shrub layers into account, the hachurings indicating woodland and scrub were then added to the completed map; they therefore indicate the woodland and scrub situation as it was in 1976, i.e. before clearance started and scything recommenced. The minimum area covered by any unit shown on the map is

## SWAMP AND SPRING VEGETATION



Reedsvamp



Calcareous spring

## MIRE VEGETATION



2a Open bog. Hummocks dominant



2b Poor fen. Lawns dominant



2c Intermediate fen. Lawns dominant

2e *Scorpidium scorpioides* mud bottom-carpet2i *Carex heleonastes*-*Cinclidium stygium* carpet2g *Carex rostrata*-*C. lasiocarpa* carpet-lawn2h *Scirpus cespitosus*-*Eriophorum latifolium* lawn2i *Kobresia simpliciuscula* lawn2j *Sphagnum warnstorffii* lawn-hummock2k *Crepis paludosa*-*Molinia caerulea* lawn

## DAMP HEATH AND GRASSLAND VEGETATION



3a Damp dwarf-shrub heath

3b Damp *Nardus stricta* heath3c Damp *Deschampsia flexuosa* heath3e Damp *Nardus stricta* grassland

3k Damp herb-rich grassland



3m Damp tall-herb grassland

## DRY HEATH AND GRASSLAND VEGETATION

4a *Empetrum* heath4b *Nardus stricta* heath4c *Deschampsia flexuosa*-*Vaccinium myrtillus* heath4d *Gymnocarpium dryopteris* heath

4f Dry low-herb grassland

4k *Geranium sylvaticum*-*Alchemilla* grassland

4m Tall-herb grassland

Woodland species	Scrub species
	p <i>Betula pubescens</i>
A <i>Alnus incana</i>	u <i>Juniperus communis</i>
v <i>Salix petandra</i>	v <i>Salix petandra</i>
s <i>Salix</i> spp.	s <i>Salix</i> spp.

⚡ Strongly anthropogenically influenced vegetation

⚡ Boulders lying on the ground surface

† Hummock

• Lawn and carpet

⬇ Mud bottom

Fig. 12.2.1

Key to the vegetational units and the black symbols used on the enclosed, multi-coloured, vegetation map of Sølendet nature reserve.

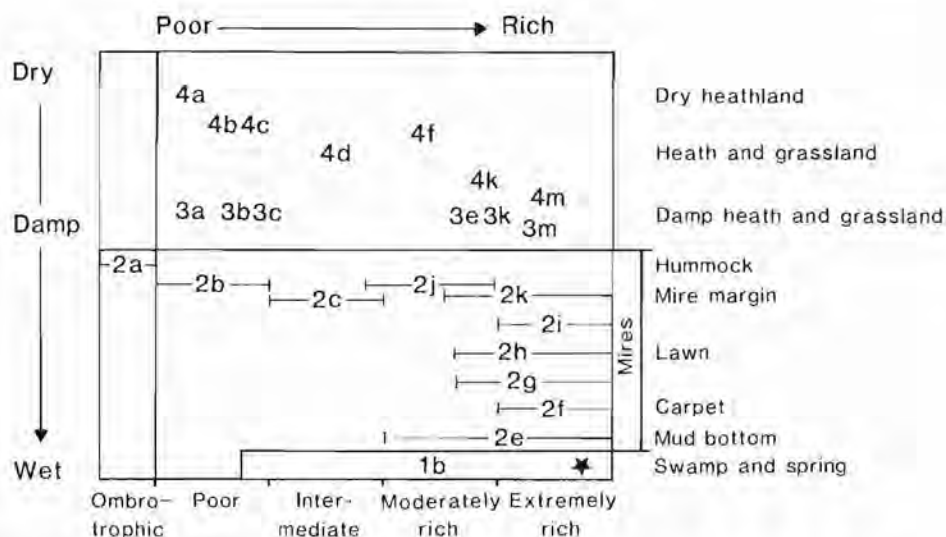


Fig. 12.2.2 Schematic presentation of the vegetational units shown on the Sølendet map, arranged along the poor-rich and dry-wet gradients. Names of the 25 units (1b - 4m) are listed in figure 12.2.1. The main occurrences, along the poor to rich gradient, of the mire units (2a - 2k) are shown by solid lines.

250 m<sup>2</sup>, except for the springs, which are marked by spot symbols. Each main vegetational unit has its own colour and number, subunits are indicated by small letters. **Mires** are coloured blue, **heathlands** are brown and **grasslands** are green. The darker the shade of colour used in each case, the richer the vegetation.

Where the mapped vegetation has a mosaic character, the colour assigned is that of the predominant unit. The percentual proportions of the vegetation cover in such mosaic areas (e.g. between the units 2a, 3a, 4a) are: 2a/3a = 50-60/40-50; 2a·3a = 60-80/20-40; 2a/3a·4a = 45/35/20; 2a·3a·4a = 50/30/20.

Definitions of the different layers of vegetation are given in section 4.3. Some additional definitions are given here. **Woodland**: Crown projection of the tree layer greater than 10%. **Scrub**: Shrub layer coverage greater than 20%. Species of trees and/or shrubs contributing more than 20% to the overall coverage of the tree/shrub layers are given their own symbols.

The mires are divided into 10 units. Additional symbols, in black, are used to indicate mire features, e.g. hummocks.



Table 12.2.1 The total area covered by each of the vegetational units shown on the vegetation map of the Sølendet nature reserve. The units (cf. Fig. 12.2.1) are tabulated in the same order as in the descriptions given in sections 12.3-6 (shown in the first column). The (phytosociological) vegetational types (= clusters) are listed in the last column: M = mire type (section 5.4); W = woodland type (section 9.5-6); O = open grassland type (section 9.7)

Contents of sections 12.3-6	Units on the vegetation map		Area		Veget. types (= clusters) sect. 5&9
	No.	Name	daa	%	
12.3 SWAMPS AND SPRINGS					
12.3.1 Swamp vegetation	1b	Reedswamp	0	0.0	-
12.3.2 Calcareous spring	1d	Calcareous spring	0	0.0	M16, M17
12.4 MIRE VEGETATION					
12.4.2 Bog hummock, <i>Sph. fusc. comm.</i>	2a	Open bog	14	0.5	M18
12.4.3 Poor and intermediate fens	2b	Poor fen	7	0.2	-
	2c	Intermediate fen	8	0.3	-
12.4.4 Rich fen, <i>Scorpidium comm.</i>	2e	<i>Scorpidium scorp. mud bottom-carpet</i>	26	0.9	M1, M2
12.4.5 Rich fen, <i>Drep.-Meesia comm.</i>	2f	<i>Carex hel.-Cincl. stygium carpet</i>	11	0.4	M11, M12 (M13)
12.4.6 Rich fen expanse, <i>Campyllum comm.</i>	2g	<i>Carex rostr.-C. las. carpet-lawn</i>	230	8.1	M4 (M2, M3)
	2h	<i>Scirpus cesp.-Eriophorum lat. lawn</i>	300	11	M3, M5 (M4)
12.4.7 Rich fen margin, <i>Campyllum, Sph. warnstorffii, Salix spp. comm.</i>	2i	<i>Kobresia simpliciuscula lawn</i>	440	16	M7 (M6)
	2j	<i>Sphagnum warnstorffii lawn-hummock</i>	6	0.2	M9, M10
	2k	<i>Crepis paludosa-Molinia caer. lawn</i>	250	8.8	M6 (M8, M14)
12.5 HEATHLAND VEGETATION					
12.5.2 Wiry grass heaths	4b	<i>Nardus stricta</i> heath	270	9.3	W1, W2
	3b/c	Damp <i>Nardus/Deschamps. flex.</i> heath	14	0.5	W2
12.5.3 Dwarf shrub/grass heaths	3a	Damp dwarf-shrub heath	60	2.1	-
	4a	<i>Empetrum</i> heath	30	1.1	W3
	4c	<i>Deschampsia flex.-Vacc. myrt.</i> heath	450	16	W4
12.5.4 Small-fern heaths	4d	<i>Gymnocarpium dryopteris</i> heath	160	5.4	W5
12.6 GRASSLAND VEGETATION					
12.6.2 Damp grassland communities	3e	Damp <i>Nardus stricta</i> grassland	13	0.5	O2 (W8)
	3k	Damp herb-rich grassland	273	9.6	W8, W9
	3m	Damp tall-herb grassland	21	0.7	W11 (O5, M15)
12.6.3 Dry/moist grassland communities	4f	Dry low-herb grassland	19	0.7	W6
	4g	Open low-herb grassland	-	-	O1
	4k	<i>Geranium syl.-Alchemilla</i> grassl.	190	6.6	W7 (O4)
	4m	Tall-herb grassland	62	2.2	W10
	Total area		2853	100.0	

## 12.3 SWAMPS AND SPRINGS

### 12.3.1 Swamp vegetation

Mapped unit: 1b. Reedswamp. Only one, very small area (ca. 250 m<sup>2</sup>) shown on the map. No phytosociological analyses.

The only area of reedswamp large enough to be shown on the map is in the eastern part of the reserve, near Nyvollvegen; it lies in a shallow depression

which fills with water at some times of year but is liable to dry out for long periods during the summertime. The margins of this small, shallow, impermanent tarn (Norw. "grubbe") are occupied by willow scrub (*Salix* spp.) with a scattering of vascular plants in the central depression itself, partly dense stands of a single or of a few species. *Veronica scutellata* is the predominant species. In addition, *Caltha palustris*, *Petasites frigidus*, *Potentilla palustris*, *Ranunculus reptans*, *Sparganium minimum*, *Carex vesicaria* and *Juncus filiformis* occur. *Dichylema falcatum* is dominant in some places in the sparse bottom layer.

"Loken på Storesmoen", on the northern border of the reserve, is another tarn liable to a lowering of its water-level during dry periods. Woodland vegetation, with willow scrub, predominates marginally, with tall-growing sedges in the field layer, e.g. dense stands of *Carex vesicaria* and large tussocks of *Carex juncea*. Swamp species, such as *Petasites frigidus* and *Potentilla palustris*, are common and *Cardamine pratensis* var. *palustris* and *Galium trifidum* also occur. On the clay-dominated bottom of the tarn, a number of aquatic/swamp plants occur: viz. *Potamogeton filiformis*, *P. gramineus*, *Ranunculus confervoides*, *R. reptans*, *Sparganium angustifolium*, *Subularia aquatica*, *Veronica scutellata* and *Alopecurus aequalis*. The only known sites at Sølendet for most of the species mentioned above are at this tarn at Storesmoen (cf. species list, Appendix B-Table 1).

A number of small, ephemeral pools (less than 1 m<sup>2</sup> in extent and drying out in summertime) also occur on the surface of the Sølendet mires, usually near large surface boulders. Some of these "pool hollows" are on former peat-cutting sites (the peat being used as pole-peat for the haystacks, cf. section 3.4.2). Sedges, such as *Carex lasiocarpa* and *C. rostrata* are dominant on the margins, but the vegetation cover is usually very sparse, and *Calliergon richardsonii* is a typical species in the bottom layer, growing together with scattered occurrences of other rich fen carpet species.

### 12.3.2 Spring vegetation

Mapped unit: 1d Calcareous spring.

Vegetational types (= clusters) of section 5: M16 *Saxifraga aizoides*-*Cratoneuron* spp. type; M17 *Epilobium alsinifolium*-*Cratoneuron* spp. type.

Phytosociological data for the small quadrats: Appendix C-table 12.

Phytosociological alliance: *Cratoneurion commutati*.

Photos in figures 3.2.5, 3.3.4, 7.2.2-3.

A large number of eustatic, strongly-flowing and weaker springs occur at Sølendet (altogether more than 50 springs are mapped in Fig. 3.2.4), but the total area occupied by such vegetation is still small, and it proved impossible to indicate the separate areas on the vegetation map (springs are marked as black, spot symbols). A survey of the spring vegetation and the vegetation of spring-fed streams has been given in section 7.2.

## 12.4 MIRE VEGETATION

### 12.4.1 Introduction

Mire vegetation (**mire series**) is defined as plant communities occurring in damp habitats, in which the plant litter does not wholly decompose, but accumulates to form a peat deposit of appreciable thickness. Gradual transitions are found between mire vegetation and those of heathlands, grasslands, swamps and springs.

In the system of vegetational units adopted in mapping Norwegian vegetation, and in the classification system adopted for mire nature reserves (cf. section 8.2) the mires are divided into 5 major units, on a basis of their trophic status (poor to rich), namely ombrotrophic mires, poor fen, intermediate fen, rich fen and extremely rich fen. Each is further subdivided according to their basic physiognomy, as open or wooded/scrub-covered, respectively. Further differentiation within these 10 primary units is achieved by use of symbols, so chosen as to allow several to be used in combination where necessary. The open mires are further categorised, on their type of detailed surface physiognomy, as hummocks, lawns/carpets and mud bottoms. The wooded and scrub-covered mires are given symbols to indicate the tree/shrub-species concerned.

At Sølendet the system described above was only adopted for certain units: bog (2a), poor fen (2b) and intermediate fen (2c). Taken together, these units cover only 1% of the total area of the reserve, the rest of the mire area (44% of the reserve) is covered by rich fen vegetation. Moderately rich fen vegetation also covers only very small areas (mainly parts of unit 2j *Sphagnum warnstorffii* lawn-hummock, accounting for only 0.2% of the area covered by the vegetation map). On the Sølendet map, therefore, **rich fen in reality means extremely rich fen**.

The mire vegetational types (plus two types of spring vegetation) are more fully described in section 5 (cf. survey in section 5.1), whilst here mainly their relationship to the units of the vegetation map will be considered. In addition are given a description of vegetational types that are not phytosociologically analysed, e.g. the poor and intermediate fens. References to the literature, the synsystematic survey etc. were dealt with in section 8 (Tables 8.2.5 and 8.3.1 list the phytosociological alliances).

### 12.4.2 Bog hummock, *Sphagnum fuscum* communities

Mapped unit: 2a Open bog.

Vegetational type (= cluster) of section 5: M18 *Betula nana*-*Sphagnum fuscum* type.

Phytosociological data for the small quadrats: Appendix C-table 13.

Phytosociological alliance: *Oxycocco-Empetrion*.

Photos in figures 3.2.9-10.

The five areas of bog (= ombrotrophic) vegetation mapped in the northwestern part of the reserve together account for only 0.5% of the total area covered by the vegetation map. These "plane bogs" are described in section 3.2.5. In addition, small patches of ombrotrophic vegetation are present on the tops of "island hummocks". Such hummocks are found on flat or gently sloping fens, often as a few close together; the hummock areas are designated by a T as an additional symbol on the rich fen areas on the vegetation map.

Stand 71 represents a typical bog hummock area in the northwestern part of Sølendet, and stand 89 represents a typical "island" hummock.

In general, the ombrotrophic vegetation of Sølendet is dominated by *Sphagnum fuscum*. In addition to the species listed for stands 71 and 89, some other bryophytes commonly occur on the hummocks, e.g. *Dicranum majus*, *Barbilophozia lycopodioides*, *Riccardia latifrons* and *Sphagnum capillifolium*. Some of the ombrotrophic bogs include wetter patches between small elevations occupied by dry hummocks. *Sphagnum balticum* is dominant in these "semi-hollows" and *Gymnocolea inflata* also occurs.

#### 12.4.3 Poor and intermediate fens

Mapped units: 2b Poor fen; 2c Intermediate fen.  
No phytosociological analyses.

The poor and intermediate fens of Sølendet, taken together, cover only 0.5% of the total area of the vegetation map. In the course of mapping the vegetation of Central Norway (cf. subsection 12.4.1), these units have usually been split into a number of subunits, some of which cover very large areas in the middle and northern boreal regions in Norway. In Øvre Forradal in Nord-Trøndelag, for example, the poor and intermediate fens together cover more than 50% of the entire area mapped (cf. Table 2.2.1). At Sølendet the areas of poor fen and intermediate fen mainly occur as transitional zones, a few metres broad, on the margins of the ombrotrophic bogs and between the rich fens and heath vegetation. There are no areas of typical open poor fen, or intermediate fen, at Sølendet.

Most of the areas of poor and intermediate fens are mire margin communities with scattered occurrences of birch (*Betula pubescens*) in the tree layer, and of *Betula nana*, *Salix glauca* and *S. lapponum* in the shrub layer. *Rubus chamaemorus*, *Juncus filiformis* and a large number of indifferent species occur in the field layer, e.g. dwarf-shrubs, *Potentilla erecta*, *Carex nigra*, *C. rostrata*, *Eriophorum angustifolium*, *E. vaginatum*, *Molinia caerulea*, *Nardus stricta* and *Scirpus cespitosus*. In the intermediate fens, *Selaginella selaginoides*, *Viola* spp. and *Carex dioica* are additional species. In both the poor and the intermediate fens the bottom layer is dominated by *Sphagna*, e.g. *Sphagnum angustifolium*, *S. capillifolium*, *S. centrale* and *S. russowii*; in a few localities with a carpet

vegetation, *Sphagnum balticum*, *S. jensenii* and *S. lindbergii* are also present. The intermediate fen lawns and low hummocks are dominated by *Sphagnum warnstorffii*.

Poor, intermediate and moderately rich fen vegetation of the mire expanses cover large areas on the mires just to the north of the Sølendet nature reserve. In these communities (800 m above s.l.) some mire species absent from the reserve occur as common species: *Drosera rotundifolia*, *Pinguicula villosa*, *Scheuchzeria palustris*, *Sphagnum compactum*, *S. magellanicum*, *S. papillosum* and *S. tenellum* on the poor fens, and *Sphagnum subfulvum* and *S. subsecundum* on the intermediate and moderately rich fens. Some of the rare mire species of the reserve, e.g. *Carex livida* and *Drosera anglica*, are also common species in this area. However, the mire vegetation N of Sølendet represents trivial types, with a wide distribution in the northern boreal region of the Røros area.

#### 12.4.4 Rich fen, *Scorpidium* communities

Mapped unit: 2e *Scorpidium scorpioides* mud bottom-carpet.

Vegetational types (= clusters) of section 5: M1 *Carex rostrata-Scorpidium scorpioides* type; M2 *Eleocharis quinqueflora-Scorpidium scorpioides-Drepanocladus revolvens* type.

Phytosociological data for the small quadrats: Appendix C-table 8.

Phytosociological alliance: *Stygio-Caricion limosae*.

Photo in figure 5.4.1.

*Scorpidium scorpioides* mud bottom-carpet (unit 2e) covers ca. 1% of the vegetation map area. It is dominant on some larger areas of the flat fens, e.g. at Floen, (see Figure 5.4.1), and also occurs as small, often well-separated, areas on minor level features (flarks) on the slightly sloping fens. The composition of the vegetation of this mud bottom unit is described under cluster M1 of the mire types.

The stands forming cluster M2, mainly belong to this unit, but it represents a transition to unit 2g *Carex rostrata-C. lasiocarpa* fen.

#### 12.4.5 Rich fen, *Drepanocladus-Meesia* communities

Mapped unit: 2f *Carex heleonastes-Cinclidium stygium* carpet.

Vegetational types (= clusters) of section 5: M11 *Menyanthes trifoliata-Carex heleonastes-Cinclidium stygium* type; M12 *Carex heleonastes-Drepanocladus revolvens-Meesia triquetra* type; M13 *Salix* spp. -*Equisetum palustre-Drepanocladus revolvens* type.

Phytosociological data for the small quadrats: Appendix C-table 11; plus the transect, figure 7.3.1.

Phytosociological alliance: *Caricion lasiocarpae*.

Photos in figures 7.3.2-3, 5.4.10.



**Carex heleonastes-Cinclidium stygium carpet** (unit 2f) covers ca. 0.5% of the mapped area. It occurs in five areas on the vegetation map, the majority of which include *Salix* spp. in the shrub or tree layers. Gråmyra is the only large area covered by the unit (see Fig. 5.4.10); in addition there is the long and narrow area in the centre of Vassdalen. Some smaller areas of this unit were overlooked during the mapping, e.g. at Rymyra, including locality 99; even so, the unit covers only very small areas at Sølendet.

Clusters 11-13 of the multivariate analyses of the mire samples represent this unit. Clusters 11 and 12 include stands of open carpet vegetation with swollen cushions of bryophytes, cluster 13 designates a fen community of more marginal character and includes some *Salix* spp. in its different layers. The stands of cluster 13, and some of no. 12, are all from Vassdalen; they are included in the presentation of the Vassdalen transect.

#### 12.4.6 Rich fen expanse, *Campyllum* communities

Mapped units: 2g *Carex rostrata*-*C. lasiocarpa* carpet-lawn;

2h *Scirpus cespitosus*-*Eriophorum latifolium* lawn.

Vegetational types (= clusters) of section 5: M3 *Carex lasiocarpa*-*Campyllum stellatum*-*Drepanocladus revolvens* type; M4 *Carex lasiocarpa*-*Potentilla erecta*-*Campyllum stellatum* type; M5 *Scirpus cespitosus*-*Carex hostiana*-*Campyllum stellatum* type. Residual sample no. 66.

Phytosociological data for the small quadrats of the clusters: Appendix C-tables 5, 6 & 9.

Phytosociological alliance: *Caricion atrofuscae*.

Photos in figures 1.1.1, 5.4.2-4.

**Carex rostrata-C. lasiocarpa carpet-lawn** (unit 2g). During the work on the vegetation map, unit 2g was defined as a community dominated by tall-growing sedges (mainly *Carex lasiocarpa* and *C. rostrata*); it forms a transition between the vegetation of mire lawns and carpets and that of the *Magnocaricetum*. *Drepanocladus revolvens* and *Scorpidium scorpioides* were used as important indicator species in the bottom layer. *Campyllum stellatum* should not be considered the sole dominant species.

The unit covers 8% of the vegetation map, the largest areas in the upper part of the fen area, on slightly sloping fens (e.g. Floen); in the central fen area, in western parts of the reserve, the unit covers large areas influenced by the spring-fed streams.

The changes in the vegetation from the *Scorpidium scorpioides* mud bottoms to carpets, and further to the units 2g and 2h (the typical lawn communities of the fen expanse) are gradual ones. During the vegetational mapping (in 1976) greater stress was laid on the dominant (physiognomically important) species

than was done during the phytosociological classification. There are therefore certain discordances between the mapping units and the clustering of the samples given by the multivariate analyses.

Some of the samples of cluster 2 represent a transition between the vegetation of units 2e and 2g. Cluster 3 represents a main type of unit 2g, but two of the five samples in this cluster (viz. nos. 7 and 65) lack the dominance of the tall-growing sedges. Cluster 4, in contrast, includes some samples (e.g. those from locality 1, i.e. nos. 1 and 110-117) that are dominated by *Carex lasiocarpa*; these are areas which were mapped as unit 2g.

**Stand 66** (*Carex rostrata*-*Cratoneuron* spp. community, cf. the phytosociological table of the small quadrats in Appendix C-table 11) represents a community that was mapped as "*Carex rostrata*-*C. lasiocarpa* carpet-lawn", but which, in the multivariate analyses, separated out as an outlier.

**Scirpus cespitosus-Eriophorum latifolium** lawn (unit 2h) covers just over 10% of the mapped area. This unit was defined as the typical sloping fen expanse unit of lawns, without exhibiting any of the characters of the *Magnocariceta* (i.e. a dominance of tall-growing sedges) and without any of the dry-lawn/marginal species which are important in the subsequent units (i.e. units 2i, j, k).

Clusters 4 and 5 mainly represent this unit.

#### 12.4.7 Rich fen margin, *Campylium*, *Sphagnum warnstorffii*, *Salix* spp. communities

Mapped units: 2i *Kobresia simpliciuscula* lawn; 2j *Sphagnum warnstorffii* lawn-hummock; 2k *Crepis paludosa*-*Molinia caerulea* lawn.

Vegetational types (= clusters) of section 5: M6 *Molinia caerulea*-*Succisa pratensis*-*Campylium stellatum* type; M7 *Molinia caerulea*-*Kobresia simpliciuscula*-*Campylium stellatum* type; M8 *Betula nana*-*Molinia caerulea*-*Campylium stellatum* type; M9 *Saussurea alpina*-*Carex vaginata*-*Sphagnum warnstorffii* type; M10 *Carex rostrata*-*Sphagnum warnstorffii* type; M14 *Salix* spp.-*Filipendula ulmaria*-*Plagiomnium ellipticum* type.

Phytosociological data for the small quadrats of the clusters: Appendix C-tables 6, 7, 10; plus the transect, figure 7.3.1.

Phytosociological alliances: *Caricion atrofuscae* (= M6-7), *Sphagno-Tomenthypnion* (M9-10, 14).

Photos in figures 3.4.6-7, 5.4.5-9, 5.4.11.

**Kobresia simpliciuscula** lawn (unit 2i) covers more than 15% of the mapped area and is the most common of all the fen units. This unit was defined as a "dry lawn" community with a low field layer of graminoids, such as *Kobresia simpliciuscula*, *Molinia caerulea* and *Scirpus cespitosus*, and including a number

of low-growing herbs, such as *Leontodon autumnalis*, *Pedicularis oederi* and *Succisa pratensis*. *Betula nana* occurs commonly and, after regular scything ceased, this species, together with low-growing *Salix* species, has become even more common.

Cluster M7 represents the typical community of this unit, although in addition, some of the samples of cluster M6 (viz. nos. 6, 13, 16 & 201) represent stands of a vegetation cover that was mapped as *Kobresia simpliciuscula* lawn. Clusters k and l of section 6 (altogether 21 samples) represent the type. Cluster M8 (stands 74 and 192) represents a dry, *Betula nana*-dominated type of vegetation transitional between *Kobresia simpliciuscula* lawn and the types of damp woodland.

**Sphagnum warnstorffii** lawn-hummock (unit 2j) covers only 0.2% of the total area of the vegetation map. This is an underestimate, however, since this unit occurs as patches which are often only 1-10 m<sup>2</sup> in extent, which were too small to appear on the map. Such patches are found all over the reserve, on the borders between rich fens and heathlands/grasslands (cf. the Vassdalen transect) and along stream margins (cf. the transect described in section 7.2.2). The cushions of *Sphagnum warnstorffii* have spread on the marginal areas of the mires and on low hummocks in the lawns etc. after scything ceased. They produce a type of vegetation transitional to the typically lawn communities. Cluster M10 includes the samples from one of the few larger areas covered by this unit. Three of the four stands of cluster M9 are from the Vassdalen transect.

**Crepis paludosa-Molinia caerulea** lawn (unit 2k) covers ca. 9% of the mapped area. The unit is common all over the reserve, most typically occurring as a narrow belt of vegetation between open fens and wooded grasslands. The unit is rather heterogeneous and could be further sub-divided.

The largest area of the unit has a vegetation of the type represented by a majority of the stands of cluster M6. A rather distinct type is the *Salix pentandra*-dominated fen community, represented by stands 82 and 83 (cluster M14). This type occurs as *Salix* spp. woodland, (*S. pentandra* and *S. nigricans*), especially on the margins of mires influenced by spring water. This type has been delineated on the vegetation map by the addition of the symbol for *Salix pentandra* to the mire signature. It covers less than 1% of the mapped area.

## 12.5 HEATHLAND VEGETATION

### 12.5.1 Introduction

In the heathland vegetation (= **heath series**) the field layer is dominated by ericaceous dwarf-shrubs, wiry graminoids and a scattering of herbs. The communities are usually poor in species. Mosses and lichens form the bottom layer. The soils are most often dry and impoverished podsols.

The concept of heathland includes wooded, scrub-covered and open areas (cf. section 4.2); it is not restricted to "true heathland", i.e. areas without trees or tall shrubs (Specht 1979).

Heathland covers ca. 35% of the nature reserve and dominates on large areas in the northwest, i.e. the areas above ca. 775 m above s.l. Heathland is also common on low ridges etc. in the eastern part of Sølendet and it dominates the flat sandy areas in the southeast (Fig. 3.1.4).

Most of the heathland area at Sølendet is covered by birch forest. Some of the heathlands are open communities without a tree or shrub layer, e.g. the *Nardus stricta*-dominated depressions in the north and some parts of the damp dwarf-shrub heaths. South of Sølendet, extensive areas of open heathland are dominant on the flat sandy areas near Aursunden. It seems reasonable to assume that the open heathlands in the Sølendet area are a result of deforestation following the start of mining at Røros in 1644 (cf. section 2.5). The assumption also seems justified that pine (*Pinus sylvestris*) would still be dominant over a large part of the lower-lying heathlands at Sølendet if this deforestation had not taken place. That even birch has difficulty in recolonising is shown by the events on an area of about 10 daa. at Storesmoen. This area was clear-felled in 1956, the old stumps are still visible, yet after more than 30 years only a few shrub-sized birches are present. This area, with a vegetation of *Deschampsia flexuosa*-*Vaccinium myrtillus* heath is still "open" heathland, as shown on the vegetation map. The lack of forest can at least partly be due to seed germination problems in the compact cover made by wiry grasses, litter and mosses.

Only a few of the phytosociological analyses (23 stands) are from heathland vegetation. Full phytosociological tables of all the stands are given in Appendix D-table 1, where the samples have been classified into 6 types of heathland. Details of the heathland stands are given in table 9.2.1, a synoptic phytosociological survey in table 9.2.2. The six heathland vegetation types (clusters W1-6 in the above-mentioned tables) are more fully described in section 9.5, whilst here only their relationships to the units recognised for the vegetation map will be considered. References to literature, synsystematic survey etc. were given in section 11.2; table 11.1.1 gives survey of the phytosociological units.

#### 12.5.2 Wiry grass heaths

Mapped units: 4b *Nardus stricta* heath; 3b & 3c Damp *Nardus stricta* and *Deschampsia flexuosa* heath.

Vegetational types (= clusters) of section 9.5: W1 Open *Nardus stricta*-*Polytrichum juniperinum* type; W2 *Betula pubescens*-*Nardus stricta*-*Rubus chamaemorus*-*Polytrichum commune* type.

Phytosociological associations: W1 *Carici bigelowii*-*Nardetum*; W2 *Nardo-Betuletum*.

Photos in figures 9.5.1-2.



The *Nardus stricta* heath (unit 4b) altogether covers 9% of the vegetation map. This area includes the open *Nardus* grass heath in shallow depressions (covering ca. 2% of the map) and the *Nardus*-dominated wooded heathlands. The vegetational units **Damp *Nardus stricta* heath (3b)** and **Damp *Deschampsia flexuosa* heath (3c)** together cover less than 1% of the vegetation map; during the mapping these units were restricted to areas with typical damp heathland vegetation; transitional types were mapped as 4b.

Phytosociological analyses exist for the two most common types of wiry grass heaths of Sølendet: 1. The open *Nardus stricta* heath (type W1; 2 stands) occurs mainly as long and narrow open areas in the upper part of the reserve (called "finnskjeggye", see Fig. 9.5.1). Throughout the summer these areas are pale-coloured from the cover (live and dead) of the wiry grasses, and they are surrounded by darker coloured patches on which *Juniperus communis* and dwarf-shrubs are present. 2. The wooded *Nardus stricta-Deschampsia flexuosa* damp heaths are represented in the phytosociological tables by the type W2. The cluster can be separated into two subtypes, i.e. stands dominated by *Nardus* (nos. 44 and 47) and those dominated by *Deschampsia flexuosa* (stands 45 and 46). The subtypes represent transitional types between the mapped units 4b-3b; and 4b-3c, respectively. Figure 9.5.2 gives a typical picture of this latter type.

### 12.5.3 Dwarf-shrub/grass heaths

Mapped units: 3a Damp dwarf-shrub heath; 4a *Empetrum* heath; 4c *Deschampsia flexuosa-Vaccinium myrtillus* heath.

Vegetational types (= clusters) of section 9.5: W3 *Betula pubescens-Empetrum hermaphroditum-Pleurozium schreberi* type; W4 *Betula pubescens-Vaccinium myrtillus*-wiry grass type.

Phytosociological associations: W3 *Empetro-Betuletum*; W4 *Myrtillo-Betuletum myrtilletosum*.

Photos in figures 9.5.3-4.

**Damp dwarf-shrub heath (unit 3a)** covers ca 2% of the mapped area, and no phytosociological analyses exist. Most of the area is open heathland, but scattered low birches occur. The unit is characterized by species such as *Betula nana*, *Calluna vulgaris* (often absent), *Empetrum hermaphroditum*, *Vaccinium* spp., *Equisetum sylvaticum* (scattered), *Rubus chamaemorus*, *Eriophorum vaginatum*, *Juncus filiformis* (scattered), *Pleurozium schreberi*, *Polytrichum commune*, *P. juniperinum*, *P. strictum*, *Sphagnum capillifolium*, *S. girgensohnii* and *S. russowii*. Some areas, e.g. to the west of Floen, are level and uniform and the vegetation cover is transitional to a mire vegetation, other areas (e.g. east of Starrmyra) have a very broken topography, with boulders lying on, or near, the ground surface.



**Empetrum heath** (unit 4a) covers ca. 1% of the nature reserve. This unit was adopted for the driest heathland types of Sølendet, dominated by dwarf-shrubs. Low birches form an open birch forest, with a dense shrub layer of *Juniperus communis* on most of the area. Samples of cluster W3 represent the unit, and stand no. 57 is the most representative. Some of the other stands (e.g. nos. 80 and 271) represent a transition to the next unit, i.e. 4c *Deschampsia flexuosa-Vaccinium myrtillus* heath. Stand 270 typifies the dry heathland, with scattered birches, found on the flat, sandy areas in the southeast (cf. the description of the Vassdalen transect; section 7.3). In this part of Sølendet (and further to the south and east) large areas of dry heathland occur; within the reserve these were mapped mainly as *Deschampsia flexuosa-Vaccinium myrtillus* heath.

**Deschampsia flexuosa-Vaccinium myrtillus heath** (unit 4c) covers 16% of the nature reserve, more than any other of the units mapped. Birch forest covers the whole area (excepting the clear-felled area of Storesmoen, cf. general description of section 12.5); *Juniperus communis* is dominant in the shrub layer on large areas. The unit covers large, continuous areas in the northern part of the reserve though at times somewhat split up by the *Nardus stricta*-dominated open heathlands in shallow depressions. Vegetation type W4 represents this unit, with stands 41-43 being typical of the vegetation cover, with a predominance of wiry grasses. Stand 28 represents a more species-rich, *Nardus stricta*-dominated, subtype that covers only small areas. The mapped unit has a somewhat wider scope than the quadrats composing cluster W4; for example, stand 80 of cluster W3 represents a vegetation mapped as unit 4c.

#### 12.5.4 Small-fern heaths

Mapped units: 4d *Gymnocarpium dryopteris* heath; (4f Dry low-herb grassland).

Vegetational types (=clusters) of section 9.5: W5 *Betula pubescens-Gymnocarpium dryopteris-Deschampsia flexuosa* type; W6 *Betula pubescens-Gymnocarpium dryopteris-Convallaria majalis* type.

Phytosociological association: W5-6 *Myrtillo-Betuletum dryopteridetosum*.

Photos in figures 9.5.5-6.

**Gymnocarpium dryopteris heath** (unit 4d) covers ca. 5% of the nature reserve, most typically on more steeply sloping areas than those occupied by the previously described vegetation types, and often forming a mosaic pattern with grassland types. Birch forest covers the whole area; *Juniperus communis* occurs as a dominant in the shrub layer in most of the area. Cluster W5 represents the typical composition of the vegetation of this unit. In addition, cluster W6 represents a dry, richer, subtype of small-fern heath, that forms a transition to the grassland types. Some small areas occupied by this subtype were mapped as low-herb grassland (i.e. unit 4f).

## 12.6 GRASSLAND VEGETATION

### 12.6.1 Introduction

In the grassland vegetation (= **grassland series**), herbs and broad-leaved grasses are the dominants. These are species-rich communities and dwarf-shrubs and lichens are either absent or only sparsely present. The soils are brown earths, with an improved moisture content and a better supply of nutrients compared to those of the heath series.

Most of the grassland area of Sølendet is wooded; smaller areas are scrub-covered or open grasslands.

The grasslands cover 20% of the nature reserve, the largest areas lying on the gentle slopes in the south and east, extending up to 775 m above s.l. Grassland is the dominant vegetation in these areas wherever the slope exceeds ca. 7°. Grasslands also become established in other areas not subject to paludification and where calcium-rich, phyllitic moraine forms the soil, or in areas that become regularly flooded during the snowmelt period (Fig. 3.1.4).

The vegetation map includes six vegetational units of grassland vegetation. Unit 4f "Dry low-herb grassland" is transitional to heathland vegetation. A seventh unit, the 4g "Open low-herb grassland", is not used on the vegetation map, but occurs mainly in the southeastern part of Sølendet (described in cluster O1).

During the vegetational mapping, the grassland vegetation was divided into damp grassland (units 3e, 3k, 3m, with blue stippled symbols additional to the basic green colour) and drier types of grasslands (units 4f, 4g, 4k, 4m). The first-mentioned units are ecologically transitional between the drier grassland types and the rich fen vegetation (cf. also Fig. 12.2.2). The damp grassland vegetational units include a number of species indicative of moist/damp habitats (e.g. *Luzula sudetica*, *Molinia caerulea*, *Petasites frigidus*, *Succisa pratensis*).

In addition to the dry-damp differentiation of the grasslands at Sølendet, the vegetation map reveals some other main differences:

- \* Wiry grass - low-herb - medium-sized herb - tall-herb grasslands. The vegetational units of the grasslands are based on this differentiation (e,f,g,k,m), shown by different colour shades.
- \* Open - scrub-covered - wooded grasslands are shown by hachuring and other symbols indicating the actual vegetational situation in 1976.
- \* Strongly anthropogenically influenced grasslands (in 1976) are shown by a separate symbol (⌵), and include clear-felled, manured and heavily scythed/grazed areas, where anthropochorous plants such as *Achillea millefolium*, *Leucanthemum vulgare* and *Trifolium* spp. were dominants.

The grassland areas were all formerly mown for hay, and the absence, or at least scarcity, of a shrub layer and the general composition of the present-day vegetation is very much due to such human activity in the past.

A number of stands of all the main grassland types have been analysed. Their species composition and the results of the multivariate analyses, the habitat conditions and field layer production of the quadrats, are described in section 9.

#### 12.6.2 Damp grassland communities

Mapped units: 3e Damp *Nardus stricta* grassland; 3k Damp herb-rich grassland; 3m Damp tall-herb grassland.

Vegetational types (= clusters) of section 9: W8 *Betula pubescens-Agrostis capillaris-Succisa pratensis* type; W9 *Betula pubescens-Crepis paludosa-Campylium stellatum* type; W11 *Salix* spp.-*Filipendula ulmaria-Sphagnum warnstorffii* type; O2 *Nardus stricta-Thalictrum alpinum-Sphagnum warnstorffii* type.

Phytosociological units: W8+9 *Deschampsio-Salicetum*; W11 *Filipendulo-Salicetum*; O2 (*Potentillo-Polygonion vivipari*).

Photos in figures 9.6.3-6, 9.6.8.

**Damp *Nardus stricta* grassland** (unit 3e) covers less than 1% of the mapped area. This unit includes some areas with a very scattered tree cover, mapped in the eastern part of the reserve. The wooded stands, nos. 26 and 56 (both in cluster W8) represent this *Nardus*-dominated, rich, low-herb, damp grassland community (transitional to the fen communities).

Another subtype is represented by the stands from Vassdalen, forming cluster O2 of the open grasslands. This type represents a narrow transitional zone between rich fen vegetation and drier wooded areas (Fig. 7.3.1). In the area from which stand 54 in Vassdalen is derived, the unit covers a large enough area for it to have also been shown on the vegetation map.

**Damp herb-rich grassland** (unit 3k) covers nearly 10% of the mapped area. This unit is common all over the reserve, except on the predominantly heathland area in the northwest and on the central fen area. Very often this unit forms a transition from fen vegetation to drier woodland areas, as is also clear from the vegetation map. In the field, in fact, this is even more commonly the case, because the damp grassland often forms quite a narrow belt (often only 1-5 m wide which it was not possible to show on a map of the scale 1:5000).

This damp grassland unit may be divided into several subunits. In the multivariate analyses of the woodland types, the samples representing this unit separated out into two types: W8 and W9. The former represents a poorer type than the latter, and two of the stands (i.e. nos. 26 & 56) are *Nardus* dominated, cf. unit 3e.

**Damp tall-herb grassland** (unit 3m) covers less than 1% of the mapped area. The typical damp grassland types are the *Salix*-dominated vegetation, represented by stands 84 & 85, which fall within the clusters W11, O5 and M15. This unit occurs as narrow belts along the margins of small streams and soaks; it includes species such as *Caltha palustris*, *Filipendula ulmaria* and *Petasites frigidus*.

### 12.6.3 Dry/moist grassland communities

Mapped units: 4f Dry low-herb grassland; 4k *Geranium sylvaticum*-*Alchemilla* grassland; 4m Tall-herb grassland. Additional unit: 4g Open low-herb grassland.

Vegetational types (=clusters) of section 9: W6 *Betula pubescens*-*Gymnocarpium dryopteris*-*Convallaria majalis* type; W7 *Betula pubescens*-*Geranium sylvaticum*-*Rubus saxatilis* type; W10 *Betula pubescens*-*Aconitum septentrionale*-*Angelica archangelica* type; O1 *Achillea millefolium*-*Tortula ruralis* type.

Phytosociological units: W6 *Myrtillo-Betuletum dryopteridetosum*; W7 *Geranietum sylvatici deschampsietosum*; W10 *Geranietum sylvatici aconitetosum*; O1 (*Potentillo-Polygonion vivipari*).

Photos in figures: 9.5.6, 9.6.1-2, 9.6.7, 9.7.1-2.

**Dry low-herb grassland** (unit 4f) covers less than 1% of the mapped area. It is present in areas of scattered birch forest in the northeastern parts of the reserve, near Dalbua. The unit was defined as a dry and rich type of low herb grassland, transitional to a heathland type, since it includes species such as *Convallaria majalis* and *Ranunculus platanifolius* (it may be regarded as a parallel to the *Melico-Piceetum* of the lowlands, cf. the comments on cluster U1 in section 11.2.3.4). During the field work in 1976, stands 31 and 33 (i.e. cluster W6) were regarded as representing this type of vegetation. The multivariate analyses also show that these two stands are transitional between the heathland and the grassland series, but with a greater resemblance to the communities of the heathland series. Consequently, some of the areas mapped as "Dry low-herb grassland" might have been better included in the "*Gymnocarpium dryopteris* heath" type.

The **Open low-herb grassland** (unit 4g) was not used for any area on the vegetation map. It is most common outside the present boundaries of the nature reserve, where it dominates the "grassland vegetation" area in the soaks (Fig. 3.2.4) that are flooded during the snowmelt period. In addition, this unit includes areas on old (abandoned), cultivated ground and on some intensively scythed areas. The 8 quadrats of cluster O1, all from the southeastern part of Sølendet, represent the typical low-herb grassland vegetation of this unit.

Some of the areas mapped as 4k ✕ (*Geranium sylvaticum*-*Alchemilla* grassland, strongly anthropogenically influenced) are transitional to the low-herb grassland

unit. By the processes of clearance and intensive scything during the past decade, the character of some of these areas within the nature reserve itself have changed, resulting in a decline of tall-herbs and an increase of low-herb communities. During this regression, low-herb species that are favoured by scything have spread, e.g. *Achillea millefolium*, *Gentiana nivalis* and *Gentianella* spp. As a consequence of management, the open low-herb grassland vegetation today covers a larger area than at the time of mapping (i.e. 1976).

**Geranium sylvaticum-Alchemilla grassland** (unit 4k) covers nearly 7% of the vegetation map. This is the main dry grassland unit at Sølendet, and is dominant in some of the larger wooded groves.

Cluster W7 of the woodland communities is representative of this unit, which includes types transitional to the richest types of heathland vegetation (small fern types) and to the tall-herb vegetation.

**Tall-herb grassland** (unit 4m) covers ca. 2% of the mapped area. The vegetation is described under cluster W10.

### 13 PRODUCTION AND POPULATION ECOLOGY OF SØLENDET

#### 13.1 INTRODUCTION

##### 13.1.1 General

The plant (=primary) production is traditionally considered by agronomists to be equal to the yield of a single growing season, i.e. the plant production equals the maximum biomass obtained from a single harvest. At Sølendet, as on most of the former outlying farmland cut for hay, these areas were only scythed every second year, because a larger yield was obtained than that given by annual scything. In addition to such cropping periodicity, in the scientific studies, the time of harvesting and the methods used (e.g. scything, cutting with scissors), will influence the yield. However, the estimates of plant production given by harvesting the field layer usually represent a considerable underestimate of the true annual primary production, since e.g. dry-matter accumulation in below-ground parts of the plants are not included. In the next subsection (13.1.2), therefore, the terminology and some results of the intensive studies of primary production and estimated total biomass, will be dealt with.

The hay crop (=yield) from the different vegetational types at Sølendet, together with estimates for the nature reserve as a whole, are dealt with in section 13.2. Comparisons with the hay yields and various productivity estimates for other similar areas, mainly in Fennoscandia, are cited in section 13.3.



Studies of the effects of scything (annually, biennially, or with an even longer rotation) on the different vegetation types and plant species have in the past few years formed an important part of the Sølendet investigations. However, only a summary of some results obtained so far will be given in the present monograph, in section 13.4. The effect of scything varies much at the species level from community to community, and there are also appreciable differences from year to year. The plant population studies at Sølendet will be further dealt with in a separate publication (in prep.).

### 13.1.2 Production ecology terminology, comments on the IBP results

In the field of production ecology, ideas, methods, and results all developed rapidly during the course of the various IBP (International Biological Programme) projects in the 1970s. Different ecosystems were being studied, e.g. forests, open grasslands, mires and the so-called "tundras", a number of different techniques were used, and important definitions and concepts were standardized, cf. Newbould (1967), and Milner & Hughes (1968). The results obtained from the "IBP tundra studies" made in Fennoscandia have been published in a variety of publications, by amongst others Rossvall & Heal (1975), Wielgolaski (1975a), Sonesson (1980), and Bliss et al. (1981).

The **net primary production** is usually considered to be the amount of organic matter incorporated by a plant, or an area of vegetation (gross primary production minus the loss due to respiration), over a given period of time. The net primary production of a community represents the change in **biomass** (= live material) plus the losses due to death, shedding and grazing etc. of parts of the plant during the given time period. Estimation of the **standing crop** (live + dead material) at the peak of the growing season often gives an overestimation of the net primary production, because part of the plant litter will have been derived from the previous years production (e.g. the estimation of hay yield (= above-ground standing crop) at Sølendet by scything, cf. section 4.5.3).

The IBP projects have helped to clarify the complex nature of reliable calculation of net primary production. Such estimates were shown to be very time-consuming and laborious to obtain, with great variations involved for estimates of communities and of species, even in areas regarded as homogeneous, and also subject to great annual differences (e.g. Wielgolaski & Kjelson 1975 and Sonesson & Bergman 1980).

The plant biomass and production data for Hardangervidda (e.g. Sonesson et al. 1975, Wielgolaski 1975b, Wielgolaski & Kjelson 1975, Østbye et al. 1975, S. Kjelson 1978, Wielgolaski et al. 1981). were obtained by harvesting in different types of vegetation, of which the results for the "Rich fen" (= Wet meadow), and "Willow grassland" (= Willow thicket) types are those that most resemble the vegetational types that have been scythed at Sølendet.

The Hardangervidda rich fen community was assigned to the *Caricion canescenti-nigrae* alliance (Sonesson et al. 1975); it is transitional, however, to the *Sphagno-Tomenthypnion* alliance (phytosociological analyses in Lye 1972). The community is rather different from those of the Sølendet fens and is closest related to the rich fen, *Sphagnum warnstorffii* communities (section 5.4.4). At the Hardangervidda site the total standing crop was estimated to be 3200 g (dry weight) per m<sup>2</sup>, and the total plant biomass to be 1600 g/m<sup>2</sup>. The biomass value included 150 g for the above-ground parts of the vascular plants (115 g when woody material was omitted; i.e. about the same as for equivalent types at Sølendet), the bryophytes accounted for 175 g, and the below-ground biomass accounted for as much as 1300 g (i.e. the ratio of the above- to the below-ground biomasses of the vascular plants was 1:9).

The Hardangervidda willow grassland community was assigned to the *Lactucion alpinae* alliance (Sonesson et al. 1975); it seems to be most closely related to the Sølendet type W11 (*Salix-Filipendula ulmaria-Sphagnum warnstorffii* type, section 9.6.2). The standing crop was estimated to be 2900 g/m<sup>2</sup> and the total plant biomass as 2400 g/m<sup>2</sup> (above-ground vascular plants: 775 g, bryophytes: 310 g, below-ground vascular plants: 1300 g). The vascular plants, *Salix* excepted, accounted for 72 g/m<sup>2</sup> of the total above-ground biomass. For the field layer species (vascular plants except *Salix*), the ratio between the above-ground and below-ground biomass values was ca. 1:9 (cf. Kjølvik & Kärenlampi 1975). Compared with the equivalent types at Sølendet, the biomass value for the field layer at the Hardangervidda site was low, i.e. the vascular plants would seem to occur rather scattered. This difference is typical for that found between alpine (viz. Hardangervidda) and more lowland types of vegetation (viz. Sølendet). In addition, communities dominated by *Salix* scrub very often have a relatively sparse field layer; when such scrub is cleared, the field layer becomes much denser, as the experience at Sølendet has shown.

In general, the conclusions from the IBP tundra project were that the type of vegetation and the species composition are both very important for the "shoot to root" biomass ratio. For similar vegetational types, this ratio was found to increase with decreasing northerly latitude and with lower altitude, and also usually to increase throughout the habitat gradient for "wet-damp-moist-dry" communities. Further comments on these aspects will be made in section 13.3.5.2.

## 13.2 THE PRODUCTIVITY AT SØLENDET

### 13.2.1 The hay-crop, based on interviews with farmers

The number of loads of hay harvested annually by each of the nine holdings at Sølendet and the calculated annual yields of hay from the nature reserve area have already been dealt with in section 3.4.2. These calculations apply to the final decades of haymaking activity at Sølendet, i.e. mainly to the 1930s-

1940s. About 70 tons of hay (water content ca. 20%, cf. section 4.5.3.2) was harvested on average every year from the area of the nature reserve.

### 13.2.2 Dry matter yields with different scything intervals

The methods that were used for studying the field layer production were described in section 4.5.3. Scything of permanent quadrats represents an inaccurate method of estimating the total standing crop of the field layer at the peak of the growing season (ca. August 1). Scything the sward leaves a stubble ca. 2-4 cm in height, i.e. for most communities this represents 10-20% of the total standing crop of the field layer. The stubble accounts for an even greater proportion in the case of the low-growing, low-production communities. Estimates of this stubble residue have been made for several of the vegetational types found at Sølendet (Moen, unpubl.), and at Nordmarka (cf. Moen 1976b).

The scythed herbage includes a proportion of plant litter that differs from community to community, and which also changes in relation to the scything frequency (annually, biennially, etc.). For the commonest communities mown for hay at Sølendet, the proportion of litter for areas scythed every other year is about 10-20%.

The mean values (with standard deviations, etc.) for the dry matter yields of the field layer of the different communities of the fen vegetation and of the vegetational types growing on mineral soils have been dealt with in sections 5.3-4 and 9.4-6 (cf. Tables 5.3.2 and 9.4.3), respectively. Table 1 of Appendix E includes all the dry matter yield data, for the period 1974-1988, obtained by scything the permanent quadrats. Figures 13.2.1-2 show the changes recorded over a single decade in the standing crop, litter proportion and biomass values for the field layer on the permanent quadrats of a rich fen and a wooded grassland site, respectively, scythed either annually or biennially. The figures show the typical situation as regards the dry matter yields for most communities after the recommencement of scything on the former haymaking areas at Sølendet. However, for the fen community, the litter fraction is somewhat greater than the usual value obtained for the low-growing fen communities. In the first year after the recommencement of scything, litter accounted for 35% of the total standing crop (see photo of the actual locality in Fig. 5.4.2).

One feature that is typical for the dry matter yield, and which is also visible in the courses of the curves in figures 13.2.1-2, is that annual scything only yields about a half of the biomass (usually a little more) obtained by scything every other year. Longer intervals between scything (every 3<sup>rd</sup> or 4<sup>th</sup> year) produced only minor increases in biomass, but the litter proportion (which has a very low fodder value) increased substantially. For the majority of the vegetational types, the most rational and economic method of utilizing the plant production, by scything for hay, is to take a harvest every second year, i.e. precisely that of traditional haymaking (cf. section 3.4.2.2, and for further explanation section 13.3.5.2).

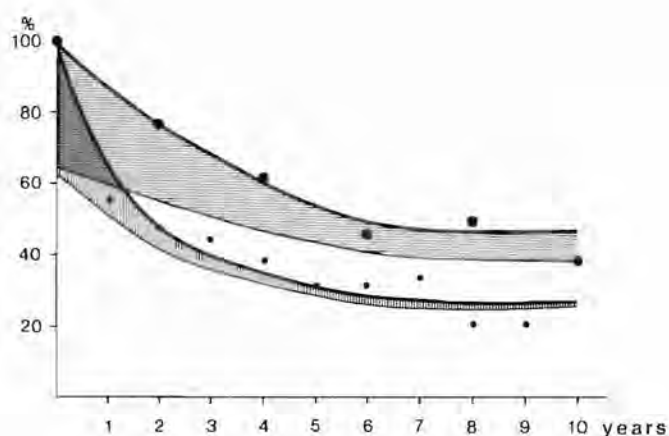


Fig. 13.2.1

Schematic representation of the changes in the productivity of the field layer induced by scything of the permanent quadrats, annually (lower curves) or biennially (upper curves), over a period of 10 years at Sølendet. Standing crop shown by thick lines (dots represent exact values, after Fig. 5.3.1 A), litter fraction hatched, and biomass shown by thin lines. Data for the rich fen of locality no. 1 (cluster M4 = *Carex lasiocarpa*-*Potentilla erecta*-*Campylum stellatum* type, included in the *Caricion atrofuscae* alliance).

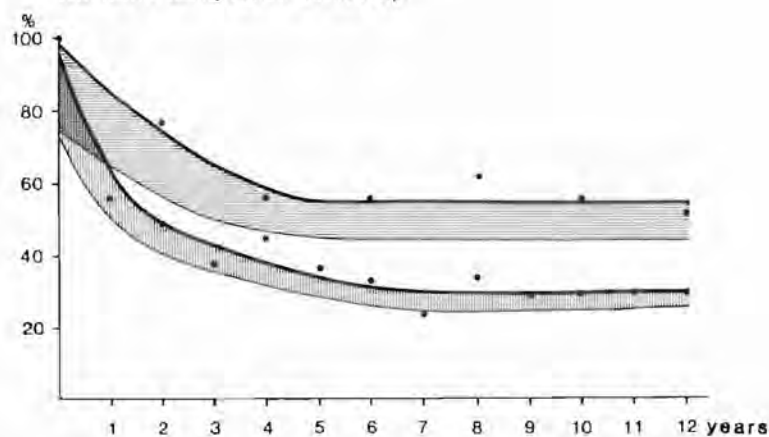


Fig. 13.2.2

Schematic representation of the changes in standing crop (cf. Fig. 9.4.1 A), litter and biomass induced by scything annually or biennially over a period of 12 years at Sølendet. Further details in figure 13.2.1. Data for the tall-herb, wooded grassland type of locality no. 40. (cluster W9 = *Betula pubescens*-*Aconitum septentrionale*-*Angelica archangelica* type, included in the *Geranietum sylvatici aconitetosum* subassociation).

Table 13.2.1 The potential dry weight yield of the vegetation at Sølendet. The areas considered suitable for scything (altogether 1976 daa) have been calculated from the vegetation map; for 13 of the vegetational units, the whole area they cover is tabulated; for unit 4b (*Nardus stricta* heath) only a half of the area covered (i.e. 135 daa) is regarded as utilisable. The remaining areas of the reserve (mainly heathland vegetation) are not regarded as potential haymaking land. The field layer production values (second column) are expressed as kg/daa (=g/m<sup>2</sup> = ton/km<sup>2</sup>) of dry matter (dried at 80°C) from quadrats scythed every second year. The values for 12 of the units are identical with the mean values for the quadrats of the clusters described in section 5.3 (M= mire clusters) and 9.4 (W= woodland cluster), cf. also table 1 of Appendix E. The values shown for two of the units, (nos. 2e and 3m), represent more subjective estimates.

Units on the vegetation map No Name	Area in daa	Field layer yield in kg d.w./daa	Yield in in kg dry weight	Reference to clusters
2e <i>Scorpidium scorpioides</i> mud bottom-carpet	26	ca.40	1040	M2
2f <i>Carex heleonastes</i> - <i>Cinclidium stygium</i> carpet	11	90	990	M11
2g <i>Carex rostrata</i> - <i>C. lasiocarpa</i> carpet-lawn	230	115	60950	M3-5
2h <i>Scirpus cespitosus</i> - <i>Eriophorum</i> <i>latifolium</i> lawn	300			
2i <i>Kobresia simpliciuscula</i> lawn	440			
2j <i>Sphagnum warnstorffii</i> lawn-hummock	6	103	618	M7(+M6pp) M10
2k <i>Crepis paludosa</i> - <i>Molinia caerulea</i> lawn	250	133	33250	M6pp+M8
4b <i>Nardus stricta</i> heath	135	63	8505	W1
4f Dry low-herb grassland	19	70	1330	W6
3e Damp <i>Nardus stricta</i> grassland	13	122	1586	W8
3k Damp herb-rich grassland	273	141	38493	W9
4k <i>Geranium sylvaticum</i> - <i>Alchemilla</i> grassland	190	127	24130	W7
3m Damp tall-herb grassland	21	ca.140	2940	(W9pp)
4m Tall-herb grassland	62	156	9672	W10
Total	1976		215184	

### 13.2.3 Dry matter yields of different vegetational units

Those areas of the nature reserve regarded as suitable for haymaking, together with their dry matter yields, are set out in table 13.2.1. The yields per unit area show the values obtained by harvesting every other year. Fourteen of the vegetational units that were mapped are included in the table, the remainder either cover only small areas (e.g. unit 1h Reedswamp), or are regarded as being unsuitable for hay cropping by scything (e.g. 2a Open bog). Comments on some of the units are as follows:

The poor and intermediate fens (units 2b and 2c) include some patches of vegetation that might be suitable for scything, although no estimates of the potential production have been made for these heterogeneous vegetational types



at Sølendet, which altogether cover only 15 daa. These areas, therefore, would nevertheless have little importance in increasing the overall hay yield even if they were included.

The whole area covered by rich fen vegetation is included (1263 daa); this has been split into six separate parts in table 13.2.1. The units that account for the greatest area are represented by a large number of scythed quadrats; these estimated values are therefore reliable. Unit 2e (the *Scorpidium scorpioides* communities), however, is represented by only one stand (no. 67) with a mean yield value of 70 g/m<sup>2</sup>, one which is not representative for the mud bottom-carpet communities of the entire unit. Tall sedges contribute a high proportion of the yield shown for this stand (cf. section 5.4.1.2). Judging from the production values obtained for the same type of vegetation at Nordmarka (cf. Moen 1976b), I consider that 40 g/m<sup>2</sup> would be a fair estimate for the hay yield for this unit (2e) at Sølendet.

The mapped vegetational units 2g-2h were defined in a somewhat different manner from the delimitation procedure adopted for clusters M3-5 (cf. section 12.4.6). The yield for the typical quadrats of tall-growing sedges (unit 2g; e.g. localities nos. 1, 63, 64) are ca. 130-150 g/m<sup>2</sup>, compared to values for typical quadrats of unit 2h (e.g. localities nos. 2, 61, 65) of ca. 80-100 g/m<sup>2</sup>. Since the production values for the quadrats of equivalent vegetation types vary rather much, I am inclined to consider the 12 localities representing clusters M3-5, chosen for the productivity studies, to be representative for the entire area (530 daa) covered by both units (2g and 2h), which results in a mean value of 115 g/m<sup>2</sup>.

When mapping the vegetation, the unit 2i (440 daa) was defined in a rather broader fashion than that adopted for the stands included in cluster M7. The yield value shown for unit 2i (72 g/m<sup>2</sup>), is therefore the mean value for localities nos. 3, 6, 13 and 16. The mean yield shown for the area covered by unit 2k (250 daa) is based on the data for 4 localities (nos. 4, 11, 14 and 87) representing cluster M6 and the single value for cluster M8.

Most of the heathland vegetation is considered to be either wholly unsuitable, or at least little suitable, for haymaking. The open *Nardus*-dominated areas, however, have been so used in former times. Some areas covered by other types of heathland (e.g. the *Gymnocarpium dryopteris* heathland, unit 4d) could perhaps be utilized, however, though the hay yields would be low and would include a high proportion of litter (cf. section 9.5.3.2). It should be noted that half the mapped area of unit 4b (i.e. 135 daa) has been included in the calculation of the yield value shown for cluster W1 (63 g/m<sup>2</sup>) in table 13.2.1.

The wooded grassland units that were mapped, agree for the most part with the cluster types recognised. The areas covered by these units were therefore adopted when the estimated dry-weight yields for these clusters were calculated. However, for one of the five units (3m Damp tall-herb grassland), because no production data were available, the approximate value obtained for cluster W9 (140 g/m<sup>2</sup>) has been used.

#### 13.2.4 The potential hay-crop of the reserve

Altogether 1976 daa are regarded as potential hayland on the Sølendet nature reserve (Table 13.2.1), i.e. about the same as the gross area that was formerly scythed. The calculated total dry weight yield of hay from this area is 215 tons, when harvested every other year. If a half of the above area was to be scythed annually, as was the common practise in former times, this would give a yield of ca. 107 tons of hay every year for the nature reserve.

When this estimated annual yield is compared with the actual yield of hay, two important factors need to be taken into consideration.

1. The area available for scything, as calculated from the vegetation map (i.e. 1976 daa), includes many small areas covered by boulders, small hummocks, tree trunks, bushes, small streams etc. that cannot be scythed, i.e. the net area available for scything for hay has to be reduced by ca. 10-20%.

2. The hay crop harvested by the farmers has a water content of 15-20%. The dry-weight yield values for the experimental plots were obtained by drying the samples at 80° C, a resultant water content of only 1-2% (section 4.5.3.2).

Both these factors involve errors of about the same magnitude, but, because they are opposite in sign, they eliminate each other. The conclusion to be drawn is that the production values for the permanent quadrats, taken together with the areas covered by the respective units, as estimated from the vegetation map, mean that the potential (maximum) annual yield of hay from the Sølendet nature reserve is ca. 107 tons, compared to the estimate of 70 tons of hay harvested by the farmers during the final decades of haymaking there. (Further comments on this discrepancy will be made in subsection 13.3.5.1).

### 13.3 HAY-CROPS AND PRODUCTIVITY STUDIES IN OTHER COMPARABLE AREAS

#### 13.3.1 Yield statistics for Sør-Trøndelag, Røros and Brekken

According to the official statistics for 1907, the total area of upland cut for hay in Sør-Trøndelag county was 363 km<sup>2</sup>, of which the Røros administrative district accounted for 41 km<sup>2</sup> (cf. sections 2.1 and 3.4). This total includes not only the areas scythed in 1907, but also areas scythed biennially or at longer intervals in the years before 1907. Annual statistics for the areas that were actually scythed in any particular year exist for 1917, 1929, 1939 and 1949 (Table 13.3.1). The tabulated data include only the uncultivated outlying land cut for hay, any hay crop taken from the enclosed meadows around the summer farms ("seterløkke") being omitted. In 1917 the scythed area in Sør-Trøndelag amounted to 83 km<sup>2</sup>. The hay yield in that year was also recorded,

Table 13.3.1 The total area (in km<sup>2</sup>) of outlying land mown for hay in different years during 1907-1958, in Norway as a whole, in Sør-Trøndelag county and in the Røros and Brekken districts; excluding the hay meadows of the summer farms ("setertøkker").

\* Values including all areas utilized during the period around 1907. The values for all other years refer to the areas actually scythed in that year.

Data from Statistisk Sentralbyrå (1910-11, 1921, 1931, 1940, 1950, 1963).

	Norway	Sør-Trøndelag	Røros	Brekken
1907	2681*	363*	41*	-
1917	886	83	12	-
1929	886	84	12	4,6
1939	549	40	4,8	2,5
1949	225	15	2,7	1,7
1958	ca. 50	-	-	-

viz. 6905 tons of hay were harvested in Sør-Trøndelag (Statistisk Sentralbyrå 1921), which represents a mean hay yield of 83 kg/daa.

For 1929, the values given for the whole of Norway, for Sør-Trøndelag county and for Røros are the same, or nearly so, as those for 1917. During that decade there was obviously no decline in the utilization of the outlying haymaking areas. However, the general impression has been that such utilization was most intensive during the last few decades of the 19<sup>th</sup> century, gradually declining thenceforward, (e.g. Reinton 1957, Kjelland 1982).

From 1929 to 1939 the statistics show a dramatic decline by about 50% in the upland area cut for hay, for all parts of Norway. The same is recorded from 1939 to 1949, with a further decline of about 50% in general, although the decline in the Røros area and in Brekken parish in particular, was not so marked as over the rest of Norway, or in Sør-Trøndelag county as a whole. After 1929 separate statistics were collected for Brekken parish (as a part of the Røros district). In 1929, Brekken accounted for 38% of the total upland area cut for hay in Røros district. In both 1939 and 1949 the Brekken proportions were greater, 52% and 63%, respectively.

The conclusion is that between 1929 and the 1950s the upland area scythed for hay fell steadily every decade, and thereafter had virtually ceased. In the Brekken area there was still, in 1939 and 1949, an appreciable area of outlying hay land, compared to the whole of Norway, Sør-Trøndelag and Røros.

### 13.3.2 Hay-crops in some other parts of C. Norway

Moen (1989) gave estimates of the hay-crop taken in former times from five different areas in Central Norway, viz. Sølendet, Nerskogen, Nordmarka, Rindal and Hollamarka. The data for all these areas, except Sølendet, will be summarized here and compared with the data for Sølendet. The estimates for the hay-crop of Nerskogen is based on archival data and on interviews, for the three other areas it is based on the former number of hay-barns.

### 13.3.2.1 The Nerskogen area

Moen & Moen (1975) described the vegetation of the Nerskogen area of Sør-Trøndelag, including a vegetation map on a scale of 1:10 000. Only a relatively small area of this map (6.8 km<sup>2</sup>) will be considered here; that covering the proposed (and later built) reservoir for hydroelectric power. This area, based on calculations made from the vegetation map, included 30% of grassland (mainly wooded types of the *Lactucion alpinae*) and ca. 25% of rich fen (mainly extremely rich lawn communities). Assuming that in former times a half of the Nerskogen area was used as hayland, and that a half of that area was scythed every other year for hay, would mean that ca. 1.7 km<sup>2</sup> was used as hayland every year.

Kjelland (s.a.) calculated the former hay yield, based on data in a land register (matrikkel) for 1860, to have been 134 tons in that year. In addition to hay-making in 1860, quite extensive areas of upland were also grazed by farm stock at that time. Assuming that 134 tons of hay were harvested from this area of ca. 1.7 km<sup>2</sup> would give a yield per unit area of ca. 80 kg/daa. Since, however, some of this area was used for summer farming and for grazing, I consider that a value of 100 kg/daa is a reasonable estimate for the actual hay yield at Nerskogen, i.e. about the same as that at Sølendet. The vegetation at Sølendet and at Nerskogen bear close similarities (cf. e.g. sections 10 and 11.3.6 for a description of the *Lactucion alpinae* vegetation of the two areas). Compared to other areas of Central Norway, the vegetation types at Sølendet and Nerskogen have quite a high productivity and in both areas a high proportion of the area was utilized for haymaking, (ca. 60% at Sølendet and ca. 50% at Nerskogen). The total hay yields per unit area there, were certainly among the highest for any of the outlying farm lands in Norway (ca. 20-30 tons/km<sup>2</sup> for each area).

At Nerskogen such haymaking continued as late as 1957, compared to 1950 at Sølendet. Kjelland's (s.a.) estimates for the annual hay yields for the Nerskogen area were as follows: 1860: 134 tons; 1935: 65 tons; 1939: 50 tons; 1950: 25 tons (the values for 1935-1950 were based on interviews with the local farmers).

### 13.3.2.2 Nordmarka, Rindal and Hollamarka

At Nordmarka, which lies in the districts of Rindal and Surnadal, in Nordmøre province, the former hay-crop obtained from an area of ca. 13 km<sup>2</sup> was calculated by counting the numbers of hay-barns and stack poles that were still in use during the period 1930-1940 (Moen 1969). Forty hay-barns were found within an area of 13 km<sup>2</sup> (each capable of holding ca. 2100 kg of hay) in addition to ca. 80 stack poles (each one capable of holding ca. 500 kg of hay). This gives a total of ca. 130 tons of hay in a "normal" year; i.e. a mean yield of ca. 10 tons/km<sup>2</sup>. Less than a half of this area, however, was suitable for scything, and, in addition, much of the area was also grazed by farm stock.



In the Rindal administrative district as a whole, Moen (1989) mapped a total of 233 hay barns. Assuming that 300 barns were used yearly, in addition to ca. 600 stack poles, a potential total of 950 tons of hay would have been harvested annually from a total area of 592 km<sup>2</sup>, about a half of which lies in the alpine or in the lowland region, in which there were no hay barns or haymaking on outlying lands. For the altitudinal belt in the Rindal district available for haymaking, there used to be ca. 1 hay-barn and 2 stack poles in use per km<sup>2</sup>, i.e. a yield of ca. 3 tons of hay per km<sup>2</sup>.

At Hollamarka, in Hemne district, O.A. Aune (1973) mapped 100 hay-barns and 25 stack poles within an area of ca. 60 km<sup>2</sup>. Almost a half of this area, however, lies in the alpine or in the lowland region, where there were no hay-barns and no outlying haylands. This gives an estimate of ca. 3 barns and one stack pole per km<sup>2</sup> for the upland area available for haymaking.

On a basis of the above estimates and on a general knowledge of the outlying farm lands of Central Norway, the conclusion is that, in the boreal uplands on average, at least one hay-barn and one stack pole existed per km<sup>2</sup>, in former times. Over wide areas of Norway the annual hay yield was ca. 3-10 tons/km<sup>2</sup> (as in Rindal, Nordmarka and Hollamarka) and for some of the most productive, smaller areas (e.g. Sølendet and Nerskogen) yields of up to 20-30 tons/km<sup>2</sup> were obtained from these upland areas.

### 13.3.3 The hay yields at Grangärde in Sweden

Sjörs (1954) described the wooded grasslands of the southern boreal region at Grangärde in Dalarna, Sweden. At the time of his investigations (ca. 1949) the area was scythed annually in the traditional manner. Sjörs, himself, studied hay yields by scything quadrats in different vegetational types. In the *Geranium sylvaticum*-dominated woodlands, the average yield over a wide area was estimated to be ca. 100 g/m<sup>2</sup> of air-dried hay. The yield for 17 different quadrats, representing four separate associations, varied from 87 g/m<sup>2</sup> to 195 g/m<sup>2</sup>, with a mean of 135 g/m<sup>2</sup>.

The above yields for Grangärde are rather high when compared to the values for Sølendet, taking into consideration that the typical soil profile for most of the scythed areas at Grangärde were podsoles, and that the areas were scythed annually and were grazed in the autumn, otherwise receiving no manure. However, the weather conditions at Grangärde would seem to be somewhat more favourable for plant production, since the growing season is longer than at Sølendet, and the precipitation about the same or a little higher (740 mm per yr. at Grangärde).

Sjörs (1954) also calculated the amounts of total nitrogen (Kjeldahl), calcium and phosphorus removed annually with the hay crop from the outlying lands at Grangärde (estimated values of ca. 1.5, 0.7 and 0.1 g/m<sup>2</sup>, respectively). The supply of leaf litter (from the trees) was found to be insufficient to account



for the losses due to haymaking on the grassland. Sjörs concluded, in regard to the nutrient balance of the wooded grasslands, that the lack of nitrogen was the most decisive factor influencing the plant production. In addition, production was also found to be regulated by the water supply. He also suggested that phosphorus might be a limiting factor, though the amounts of Ca and K seemed to be sufficient.

### 13.3.4 Other productivity records in the literature

#### 13.3.4.1 Tall-herb communities

Holmen (1965) calculated the above-ground biomass values for communities of the *Lactucion alpinae* alliance in Jämtland. The values represent the first-year yields for grasslands that had not been scythed for decades past, perhaps even never been scythed? Holmen found a mean value of 360 g/m<sup>2</sup> dry weight for the *Cicerbita alpina*-*Aconitum septentrionale*-dominated communities (maximum value 620 g/m<sup>2</sup>, minimum 150 g/m<sup>2</sup>).

The highest values for Holmen are higher than any of the values for Sølendet, and also higher than all other records for boreal uplands found in the literature. However, Holmen's quadrats were dominated by *Cicerbita*, a species that only occurs scattered at Sølendet and at Nerskogen. Dense stands of *Cicerbita* are never found in areas that were scythed up to a few years ago; it is certainly a species that is favoured by cessation of haymaking, like *Aconitum* (cf. also Nordhagen 1943).

At Sølendet, the highest biomass value recorded for a quadrat of tall-herb vegetation, harvested with scissors, has so far been 374 g/m<sup>2</sup> (unpubl. data). The highest value for the standing crop for the same community when scythed has been 356 g/m<sup>2</sup> (at locality no. 5 in cluster W9, cf. Table 1 of Appendix E). At Sølendet, however, both *Aconitum* and *Cicerbita* are absent from this community (*Geranium sylvaticum* and *Alchemilla* spp. were the dominants). The maximum values for the standing crop from the *Aconitum*-communities at Sølendet, when scythed, were 250–350 g/m<sup>2</sup>.

Harvesting (by scissors) of *Aconitum*-*Geranium sylvaticum*-dominated communities at Dovre and Nerskogen yielded mean biomass values of 270 g/m<sup>2</sup> (Baadsvik s.a.) and 300 g/m<sup>2</sup> (Moen & Moen 1975), respectively.

Holmen's (1965) cited maximum herbaceous biomass value for the *Lactucion alpinae* communities is certainly extremely high, perhaps due to favourable summer conditions, and even the cited mean value (360 g/m<sup>2</sup>) is rarely exceeded in the investigated communities at Sølendet and Nerskogen.

## 13.3.4.2 Wetland and fen communities

Pearsall & Newbould (1957) estimated the biomass in the field layer at 6 woodland sites, 4 grassland sites and 7 wetland sites (including the lawn communities of rich fens) in the northern boreal/low alpine regions of northern Scandinavia. The mean biomass values were about 200-300 g dry weight/m<sup>2</sup> for the samples from each of the three main types. The values for the wetland (fen) types varied from 125 g/m<sup>2</sup> for a *Scirpus cespitosus*-dominated type, to 373 g/m<sup>2</sup> for a *Carex rostrata*-dominated *Magnocariceta* type. Pearsall & Newbould concluded that the mean value (250 g/m<sup>2</sup>) for all the 17 types investigated was "less than half of the corresponding figure for northern Britain (ca. 690 g/m<sup>2</sup>).<sup>2</sup>" They correlated this difference with the different durations of the growing seasons, that in N. Scandinavia being only half as long as in Britain.

Bernard (1973) studied the standing crop and primary production of the *Carex*-dominated wetlands of N. America and of Europe in relation to latitudinal and altitudinal gradients. He found that both values decreased with increasing northerly latitude and altitude (cf. also the comments on the IBP results in section 13.1.2). In the nemoral zone, the above-ground, standing crop values for the *Carex*-dominated sites varied from 300 to 1000 g/m<sup>2</sup>, whereas in the upper boreal region values below 300 g/m<sup>2</sup> were found.

Mörnsjö (1970), who studied the *Magnocariceta* communities of southern Sweden, found standing crop values of ca. 300-400 g/m<sup>2</sup> (air-dried material, with a water content of 10%) for the *Carex lasiocarpa*-*C. rostrata*-dominated communities. For the communities dominated by *Cladium mariscus*, *Carex acuta*, *C. elata* and other tall-growing sedges, the standing crop values were as high as ca. 500-900 g/m<sup>2</sup>. The calculated standing crop values for the field layer of *Carex lasiocarpa*-dominated communities of the *Mediocariceta* were 120-170 g/m<sup>2</sup> (260 g/m<sup>2</sup> for one community). The calculated standing crop for a *Molinia caerulea*-dominated vegetation was 160 g/m<sup>2</sup>, with an above- to below-ground biomass ratio of 1:4.3, compared to ratios of 1:3 and 1:4 for the *Carex lasiocarpa* and *C. elata*-communities, respectively.

Elveland, in his studies of the ecology and environmental management of wetlands in North Sweden (full references in section 2.3.3), only made a few calculations of the hay yields for his scythed study plots. For a formerly mown, long abandoned, tall-growing sedge community (including *Carex lasiocarpa*, *C. rostrata*, *Equisetum fluxiatile*), the calculated field layer yield (oven-dried at 40° C) was ca. 200-280 g/m<sup>2</sup> (cf. Elveland 1983a, 1984c, 1985; Elveland & Sjöberg 1982). Elveland also found that annual scything of some irrigated wetlands did not lead to a decline in the herbage yield, although for most of his localities annual scything did result in an obvious fall in the weight of the standing crop. Shoot density, frequency of fertile shoots and seed production of *Carex lasiocarpa* and *C. rostrata* also decreased when scything recommenced. Annual scything over a period of four years of a *Carex lasiocarpa* community, reduced the standing crop to only 6-7% of the initial value, and this sedge suffered severely for several years after scything ceased. *Equisetum fluviatile*, growing

in the same community, reacted in the opposite manner and indeed increased (Elveland 1984c).

Moen (1976b) has published data from Nordmarka, in Nordmøre, for the above-ground biomass of 11 fen communities (documented by phytosociological tables); the herbage was cut with scissors and sorted into the different plant types (graminoids, herbs, wooded species and litter). For areas of rich fen lawns that had not been scythed for ca. 25 years, the above-ground biomass values were 146-278 g dry weight per m<sup>2</sup>. The graminoids accounted for ca. 90% of the biomass in most of the communities, but in the fen margin communities herbs were more common.

The calculated biomass values for four fen communities, all sampled at about the same seasonal developmental stage (ca. August 1) over a 4-year period (1972-75), varied quite appreciably from year to year. Even larger differences were found in the biomass values for samples taken on different dates in the growing season (July 14, August 8 and 22 in 1974). The above-ground biomass of all four communities, sampled by cutting with scissors, also distinctly increased in 1975, in the following ascending order: 1: scythed in 1973-74, 2: scythed in 1974 (i.e. the previous year), 3: scythed in 1973 (i.e. two years previously), 4: Not scythed for ca. 25 years.

### 13.3.5 Conclusions

#### 13.3.5.1 The hay-crop from the Sølendet nature reserve

Based on the interviews with farmers, ca. 70 tons of hay had previously been harvested from the nature reserve area every year. Based on the yield estimates given by scything permanent quadrats and from the estimated areal extents of the different vegetational types obtained from the vegetation map, the calculated potential hay-crop was 107 tons. At Nerskogen, the amount of hay harvested seemed to have declined steadily during the 20<sup>th</sup> century. In general, a marked decline in the area mown for hay, during the years 1929-1958, is documented by the statistics for all districts, regions and for the whole of Norway. In the Brekken district, the area mown for hay in 1939 was only about one half of that mown in 1929. Even at Sølendet it is reasonable to assume that a general decline in the utilization of the upland for haymaking occurred during the 20<sup>th</sup> century, and certainly did during the last few decades prior to 1950.

The volume of the hay-crop harvested during the last few decades of upland utilization (1930-1940, from interviews held in 1976), was submaximal for most of the holdings. In other words, the calculated value of 107 tons for the potential hay crop at Sølendet may well be a realistic assessment of that which was harvested annually more than 6 decades ago.

### 13.3.5.2 Total biomass in relation to annual or biennial scything

On Hardangervidda (cf. section 13.1.2), in both a rich fen and a willow grass-land community, the ratio between the above- and below-ground biomass values for the vascular plants in the field layer was ca. 1:9. For the "wet-damp" communities studied under the IBP programme for arctic/alpine areas, in general, the shoot to root ratio was found to be as low as about 1:21 (Wielgolaski 1986). Based on these IBP results and from other references in the literature (cf. section 13.3.4.2) it seems reasonable to predict that the total biomass of the field layer species (trees and shrubs excluded) on the scythed areas at Sølendet amounts to at least twice the value for the scythed crop, for the fen communities about 5-10 times that of the scythed crop. For the typical haylands at Sølendet, a rough estimate of the total biomass of the field layer species would be ca. 500-3000 g/m<sup>2</sup>.

To explain the differences found in the yields from upland areas scythed at different time intervals, the whole biomass of the community ought to be taken into consideration. However, no data for the value of root biomass at Sølendet are available. In the first year of scything (after its cessation for decades past) it is obvious that only part of the aerial shoot biomass had originated from that year's production, the rest having been stored in hibernating buds, rhizomes and roots. In general, defoliation of the sward by scything (and grazing) is followed by a decrease in food reserves in the below-ground storage organs, e.g. a fall in carbohydrate levels (cf. Duffey et al. 1974). In the fen carpet communities, the effect of harvesting is reflected in a lowering of the resistance of the carpet to trampling (especially well documented at Nordmarka Moen unpubl.; cf. also Elveland 1978). For an annually scythed hay land which retains its productivity balance, the harvested material provides a measure of the annual production. Annual scything was the common practice at Grangårde (cf. section 13.3.3) and also on the irrigated fens of N. Sweden (cf. Elveland & Sjöberg 1982), but not at Sølendet or on the other outlying, upland areas in Norway. At Sølendet, annual scything of typical communities yielded less than a half of the biomass obtained in the first year after scything recommenced, and about half that yielded by scything biennially (Figs. 13.2.1-2).

It seems obvious that the accumulation of underground biomass will be greatest in years when the field layer is not harvested. In areas where biennial scything is the norm, therefore, the hay yield will reflect the productivity achieved during two years. The results of the Sølendet experiments in scything permanent quadrats have shown that biennial scything is the most economic method of utilizing the main types of hay land at Sølendet, when the aim is to obtain the highest possible yield with the lowest possible amount of effort. The farmers, too, usually scythed biennially in the past.

The nutrient balance of the plant communities mown for hay, has not been studied at Sølendet, however. From studies made elsewhere (e.g. Sjörs 1954) the lack of certain nutrients (e.g. available N, P, K) do seem to be the most decisive factors limiting plant production.



### 13.4 NOTES ON THE VEGETATIONAL CHANGES INDUCED BY SCYTHING

Section 3.4.2 summarized our knowledge of the former utilization of Sølendet and mentioned some general effects of haymaking on the vegetation. The effect of scything on plant production has been dealt with in section 13.3. In the present section the population changes induced by scything of the wooded grasslands and rich fens will be dealt with.

The phytosociological method of analysis of the quadrat data, using the Hult-Sernander-Du Rietz cover scale, is a rather rough and ready one and is also subjective. Minor quantitative changes may be missed. The cover scale was therefore somewhat modified by subdividing both the traditional classes 1 and 5 (cf. section 4.3.2). However, even the more detailed scale requires to be supplemented by further quadrat data so as to gain a better quantification of the plant cover and any changes induced. Different methods have been used at Sølendet, e.g. by making counts of shoot density and of fertile shoots, measurements of shoot heights, calculation of plant biomass, etc. In addition to the phytosociological analyses, the present section also includes the results of some more detailed analyses. However, the population changes in the different types of communities of Sølendet induced by scything will be dealt with in more detail in future publications.

#### 13.4.1 The wooded grasslands of Sølendet

Four of the wooded grassland localities are represented by 3-4 sample stands in the multivariate analyses described in sections 9.2 and 9.6. (Locality no. 5 is represented by samples 255-258 in cluster W9; locality 8 by samples 259-261 in cluster W10; locality 35 by samples 35, 250-251 in cluster W7; locality 40 by samples 40, 252-254 in cluster W10). One or two stands from each of these localities represent the vegetation cover as it existed 25-30 years after regular scything ceased; 2 stands from each of the localities represent reanalyses of the initial sample quadrat after clearance and recommencement of scything. The reanalyses were all done in 1983, 7-8 years after the initial ones; the quadrats reanalysed had been scythed 3-8 times during the intervening period. Fuller information and site descriptions can be found in section 9.6. On a basis of the reanalyses, and from additional notes, the changes in the wooded grasslands of Sølendet can be summarized as follows.

Clearance and scything reduce the density of the birch stands (e.g. the photos in Figs. 3.4.4-5 and 9.6.1-2 for locality no. 35, taken before and after clearance) and of the willow stands, *Salix* spp. (e.g. photos in Figs. 9.6.5-6 for locality no. 5). The litter layer is heavily reduced. No plant species have with certainty been found to disappear, but a number of species show reductions in cover degree, biomass, number of shoots and fertility. Among those showing the greatest reduction in degree of cover and biomass (decrease relative to total cover/biomass; those showing more uncertain, or only weak tendencies in paren-



theses) are the following: *Aconitum septentrionale*, *Cicerbita alpina*, *Filipendula ulmaria*, (*Geranium sylvaticum*), *Geum urbanum*, *Oxalis acetocella*, *Trientalis europaea*, *Milium effusum*, (*Poa nemoralis*) and *Rhodobryum roseum*. The general scarcity of *Cicerbita* in the tall-herb communities at Sølendet can be explained by haymaking in the past. The absence of *Stellaria nemorum* from the analysed quadrats (the species has only been found in two localities, both of which had not been scythed for 4-5 decades and where it is at present spreading) can also be explained in the same way.

Scything has induced increases (relative to total cover/biomass) at Sølendet of the following common species: *Ranunculus acris*, (*Viola biflora*), *Agrostis capillaris*, *Anthoxanthum odoratum*, *Deschampsia cespitosa* and *Festuca rubra*. A large number of species, all with more scattered occurrences, have become more common in the intensively scythed grassland areas, e.g. *Achillea millefolium*, *Botrychium* spp., *Corallorhiza trifida*, *Gentiana nivalis*, *Gentianella* spp., *Leucanthemum vulgare*, *Ranunculus auricomus*, *Sagina procumbens*, *Taraxacum* spp., *Hierochloa odorata*, *Phleum alpinum*, *Poa alpina* and *Poa pratensis*.

The cover values for the bryophytes have usually increased in the scythed areas, a natural consequence of the reduction in the amount of litter and the change to a more open field-layer. *Rhytidiadelphus squarrosus* has shown the greatest increase in the quadrats mentioned above, but a large number of other species benefit from such scything: *Brachythecium reflexum*, *B. salebrosum*, *B. velutinum*, *Campylium stellatum*, (*Mnium spinosum*), (*M. stellare*), *Rhytidiadelphus subpinnatus*, *Chiloscyphus pallescens*, *Lophocolea bidentata*, *Scapania* spp.

Clearance and scything have led to typical quantitative changes in the vegetation cover, although, as shown by the results of the multivariate analyses (section 9.2 and 9.6), samples originating from the same locality have shown great similarities, since they belonged to the same cluster (further comments in section 9.6.1.2).

#### 13.4.2 The fen lawns of Sølendet

##### 13.4.2.1 The analyses

In the multivariate analyses of the mire vegetation (section 5), only the data from unscythed quadrats and quadrats that had been scythed once during the past decades were dealt with.

The results of the analyses of all the small quadrats for the fen localities nos. 1-4, are presented in tables 5-7 of Appendix C. Some of the stand samples (e.g. those for the small quadrats nos. 31-36 of table 5 of App. C) are for permanent quadrats that had been scythed annually for 10 consecutive years, some others are for quadrats scythed biennially for about one decade (the headings of Tables 5-7 of App. C and Table 1 of App. A provide details).

Table 13.4.1 Observations of degree of cover, number of shoots, shoot height and yields of the field layer species in two parallel quadrats (each 0,25 m<sup>2</sup>) at locality no. 1, made in 1981. Quadrat A had been scythed annually 1974-1980, quadrat B had not been scythed for 30 years. Cover scale: s, u, 1, 2, 3, 4, 5, 6 (cf. section 4.3.2). After Moen (1985d).

	A					B				
	Degree of cover	No. of shoots per m <sup>2</sup>		Mean height in cm	Dry m. yield g/m <sup>2</sup>	Degree of cover	No. of shoots per m <sup>2</sup>		Mean height in cm	Dry m. yield g/m <sup>2</sup>
		Total	Fert.				Total	Fert.		
<i>Dactylorhiza cruenta</i>	s	4	.	2	0,0	.	.	.	.	.
<i>Equisetum palustre</i>	s	8	.	10	0,6	u	16	.	5	0,1
<i>E. variegatum</i>	u	240	.	8	3,0	u	120	.	.	.
<i>Pedicularis palustris</i>	s	12	8	8	1,0	u	25	25	12	3,3
<i>Polygonum viviparum</i>	u	80	.	1	0,2	u	80	.	7	0,4
<i>Potentilla erecta</i>	u	40	.	2	0,4	u	60	.	32	1,9
<i>Selaginella selaginoides</i>	s	8	f	2	0,1	.	.	.	.	.
<i>Succisa pratensis</i>	.	.	.	.	.	2	12	.	4	9,2
<i>Thalictrum alpinum</i>	3	800	16	2	2,7	2	400	.	3	2,9
<i>Carex dioica</i>	2	1200	280	5	24	1	600	.	5	3,6
<i>C. flava</i>	1	36	.	10	1,6	2	120	12	10	5,8
<i>C. lasiocarpa</i>	2	320	.	40	37	4	600	4	35	59
<i>C. nigra</i>	.	.	.	.	.	1	120	60	30	9,0
<i>C. panicea</i>	2	160	20	12	12	2	240	.	15	24
<i>C. rostrata</i>	.	.	.	.	.	s	4	.	25	0,9
<i>Eriophorum angustifolium</i>	2	120	28	10	12	u	80	.	25	2,9
<i>E. latifolium</i>	s	4	.	5	0,2	.	.	.	.	.
<i>Molinia caerulea</i>	u	120	.	10	3,4	1	100	f	20	12
<i>Scirpus cespitosus</i>	2	1200	f	15	16	4	2000	f	25	42
Dry matter yield in g/m <sup>2</sup> :										
Herbs					7,9	21				
Graminoids					107	168				
Litter					10	120				
Above-ground standing crop					125	309				

#### 13.4.2.2 The effect of scything on *Carex dioica*, *C. lasiocarpa* and *Molinia caerulea*

In addition to *Scirpus cespitosus*, *Carex dioica* is the most numerous (based on shoot numbers) of all the vascular plant species forming the rich fen lawn communities at Sølendet. *Carex dioica* is usually sterile in areas that have not been scythed for a long period and it becomes progressively more scattered as the process of overgrowth (recovery) by other plants takes place. In the boreal region in Fennoscandia, however, it is a constant species in nearly all types of rich fen lawns, as in the drier parts of the carpets (cf. comments in section 8.4.3.2). At locality no. 1, *C. dioica* has been favoured by scything, as in all the other lawn communities investigated. The number of shoots has increased, both by new shoots from successfully germinated seedlings, and, first and foremost, by vegetative shoots. The number of fertile specimens (both male and female) has also increased. In lawns that have been intensively scythed, the mean number of fertile shoots of *C. dioica* is often as high as 200-300 pr. m<sup>2</sup>, whereas in the unscythed quadrats 0-2 is a "normal" value at Sølendet and at Nordmarka (Moen unpubl.).

*Carex lasiocarpa* is a species that suffers more than most of the other sedges from intensive scything. After a few years, the species becomes sterile, both the numbers of individual shoots and their height are reduced and the above-ground biomass decreases. However, the species was still common in the stands at locality no. 1 after ten years of regular scything. After cessation of scything the number of shoots (vegetative reproduction) increased, and a number of them became fertile 3-4 years later. No such drastic reduction in *Carex lasiocarpa* by scything has been recorded at Sølendet as that found by Elveland (1984c) in the wetlands of N. Sweden (cf. section 13.3.4.2). The stands of *Carex lasiocarpa* investigated at Sølendet are mainly fen lawns (and the drier parts of carpets), whereas Elveland's localities were much wetter. In such habitats, with a high groundwater-level, oxygen transport to the rhizomes and roots may be blocked after their destruction by trampling, or by subsequent flooding of the scythed stubble, which may explain the decrease described by Elveland (1984c). Elveland (1984a) also reported degeneration of a *Carex rostrata* stand caused by flooding of the stubble left after scything.

*Molinia caerulea* is a very common (often the dominant) species of the unscythed fen lawns (e.g. cluster M6 *Molinia caerulea*-*Succisa pratensis*-*Campyllum stellatum* type of section 5.4.3) and of the damp grasslands at Sølendet. *Molinia* has suffered from intensive scything of the above-mentioned communities. After being scythed annually on ca. August 1 for only about 3 years, it was often found to be drastically reduced. In the fen lawn community (cluster M6) the *Molinia* decline had a marked effect on the total biomass value (cf. the curve for the annual hay yield for locality no. 4 in Fig. 5.3.2); the increased yield after ca. 4-5 years was due to the increases in the amounts of *Carex atrofusca*, *C. dioica*, *C. flava* and other species which profited from the *Molinia* decline. The same trend was also found in the numbers of flowering shoots of *Molinia*,

e.g. the numbers of flowering shoots recorded in quadrat 4G: In 1986, before the recommencement of scything on that plot, the number of fertile shoots of *Molinia* was 40 per m<sup>2</sup>. This plot has been scythed annually since 1986, and the number of flowering shoots has decreased markedly, viz. to 3 per m<sup>2</sup> in 1988 and to 1 per m<sup>2</sup> in 1989.

The above-ground biomass and number of fertile shoots of *Molinia* have, however, increased in the formerly scrub-dominated communities of the damp grasslands and fens at Sølendet, after removal of the scrub, followed by extensive mowing (5 to 10-year rotation) by tractor (i.e. leaving a high stubble). The areas of *Betula nana*-*Molinia caerulea*-dominated vegetation described in section 5.4.4 (i.e. cluster M8) thereafter became dominated by dense "hummocks" of fertile *Molinia* after some years. The quadrats scythed intensively (i.e. biennially), however, became dominated by *Carex flava* after one decade, and *Molinia* decreased substantially (unpubl. data for locality 74).

The fall in *Molinia* biomass at Sølendet, as also at Nordmarka (Moen unpubl.) on the intensively scythed areas contrasts with the results found for wetlands of the nemoral region, e.g. Godwin (1941), who found that *Molinia* increased in two communities of tall-growing fen species at Wicken fen, Cambridge, that were scythed annually. *Molinia* has been found to be favoured by intensive scything, both in autumn (Godwin 1941) and in summer (Rowell et al. 1985), in England.

The explanation for this difference in the behaviour of *Molinia* may be as follows: In low-growing, intensively scythed fens, the club-shaped, food-storing, stem bases of *Molinia* are often destroyed, either by subsequent drying out or by decay (see photo in Fig. 13.4.1). These destructive results of scything account at least in part for the decline in the hay yields of the *Molinia*-dominated communities at Sølendet. In addition, even *Molinia* plants which are not adversely affected in that way by scything, will nevertheless suffer greatly from annual scything, due to the increased drain on their stored food-reserves. In more southern regions, the food-reserves may be more rapidly built up once more, because of the greater duration of the vegetational period. In these areas, as also in the extensively-mown, scrub-dominated areas at Sølendet, *Molinia* is favoured by the removal of competition from the taller-growing species.

It should also be noted that *Molinia caerulea* is a very variable species (Tutin et al. 1980), and the club-shaped stem bases of different taxa may be formed at different heights relative to ground-level.

#### 13.4.2.3 The effect of scything on fen species

The general effect of regular scything on fen species at Sølendet, based on the aforementioned analyses of the fen lawn communities (i.e. the *Campylium* communities of section 5.4), is presented in table 13.4.2 (mainly after Moen 1985b, d).





Fig. 13.4.1 The club-shaped, food-storage, stem bases of *Molinia caerulea* are visible in the foreground. Most of the *Molinia* ramets have been killed as a result of years of intensive scything. Locality 3. 19820802.

Shrub and dwarf-shrub species either disappear or are drastically reduced in frequency, likewise all the tall herbs. Some small-herbs, such as *Leontodon autumnalis*, *Pinguicula vulgaris* and *Thalictrum alpinum*, however, are favoured and form an increasing proportion of the total biomass. This is explained by the fact that most of their leaves lie close to the ground and are thus unharmed by scything. Even *Succisa pratensis*, in some communities, is favoured for the same reason, though elsewhere it suffers a decline. *Saxifraga aizoides* also becomes more abundant in some of the communities that are scythed only every other year. Intensive scything leads to a reduction, both in biomass and fertility, of *Dactylorhiza* spp. and of *Gymnadenia conopsea*, (cf. next subsection). Scything reduces the fertility not only of *Carex lasiocarpa* and *Molinia caerulea*, but also of *C. panicea* and *C. rostrata*, which, in addition to *Scirpus cespitosus*, do not show a greater reduction in cover/biomass values than the total cover/biomass value for the community as a whole.



Table 13.4.2 Schematic representation of the effect of intensive scything on the relative above-ground biomass (as a proportion of total biomass, - or +) and on flowering frequency (increased sterility or fertility) of certain plant species in the lawn communities of the rich fens at Sølendet. Weak, variable or uncertain tendencies are shown in parentheses; strong tendencies given double symbols.

	Decreases	Increases
Shrubs and dwarf-shrubs	--st	
<i>Bartsia alpina</i>	-	
<i>Dactylorhiza cruenta</i>	-st	
<i>D. pseudocordigera</i>	-st	
<i>Gymnadenia conopsea</i>	-st	
<i>Leontodon autumnalis</i>		++f
<i>Pedicularis oederi</i>	-st	
<i>P. palustris</i>		(+f)
<i>Pinguicula vulgaris</i>		+
<i>Potentilla erecta</i>	-st	
<i>Saussurea alpina</i>	-st	
<i>Saxifraga aizoides</i>		+f
<i>Succisa pratensis</i>	-st	
<i>Thalictrum alpinum</i>		+f
<i>Carex atrofusca</i>		+++f
<i>C. capillaris</i>		+f
<i>C. dioica</i>		+++f
<i>C. flava</i>		+++f
<i>C. lasiocarpa</i>	(-)st	
<i>C. nigra</i>		+++f
<i>C. panicea</i>	st	
<i>C. rostrata</i>	st	
<i>Eriophorum angustifolium</i>		++f
<i>E. latifolium</i>		+f
<i>Juncus</i> spp.		+++f
<i>Molinia caerulea</i>	--st	
<i>Scirpus cespitosus</i>	(-)	
<i>Campyllum stellatum</i>		++
<i>Homalothecium nitens</i>	--	
<i>Sphagnum</i> spp.	--	
<i>Aneura pinguis</i>		+
<i>Lophozia borealis</i>		+

In addition to *Carex dioica* (cf. the previous subsection), *Carex atrofusca*, *C. capillaris*, *C. flava*, *C. hostiana*, *C. flava* x *C. hostiana*, *C. nigra*, *Eriophorum angustifolium*, *E. latifolium*, *Juncus alpino-articulatus*, *J. castaneus* and *J. triglumis* all become more common on the scythed areas. All the above-mentioned taxa seem to be spreading, vegetatively the majority, and some from seeds. A number of these taxa which are favoured by scything are weakly-competitive, alpine species. The large number of alpine species (e.g. the three *Juncus* spp.) in the fen communities at Sølendet is certainly a result of the regular scything in the past.

*Kobresia simpliciuscula* is a dominant species in the dry, low-growing, fen carpet vegetation (cluster M6-7) at Sølendet. However, intensive scything reduces the fertility of this species, as is shown by the wide variety of plant species (e.g. the orchids) that seem to be most commonly present in the fen lawns some years after the cessation of scything. Under the undisturbed course of natural succession, however, these species would certainly be eliminated, as *Molinia*, *Betula nana*, *Salix* spp. and other tall-growing shrubs, graminoids and herbs become more abundant. Future management at Sølendet, however, will be so designed as to favour, in some areas, such weakly competitive species.

*Campylium stellatum* is the bottom layer species which profits most markedly from scything, though *Aneura pinguis* and *Lophozia borealis* are also favoured, at least in some communities (e.g. at locality no. 1). *Homalothecium nitens*, *Plagiomnium* spp., *Rhizomnium* spp., *Sphagnum* spp. (e.g. *S. warnstorffii*), and other acrocarpous and/or "hummock-building" moss species become replaced by pleurocarpous, prostrate ones (first and foremost *Campylium stellatum*).

#### 13.4.3 General considerations and comparisons with results in the literature

Both scything and grazing are followed by a decrease in the total biomass of the communities affected. When the vegetation is mown or grazed during the growing season, the position of the growing point of the plants is important. If this is situated apically, at the shoot, it is removed by scything, leading to a cessation of growth, followed either by death, or renewed growth from lateral shoots. Grasses and sedges, which have their growing points at ground-level, escape such damage and survive scything well, though the loss of herbage may weaken them. The food reserves remaining after defoliation, i.e. in the stubble and in the subterranean organs etc., are important for the potential renewal of growth from undamaged growing points (side-shoots), and thus in the competitive relationships. In general, the graminoids (grasses, sedges etc.) can tolerate scything better than herbs. Thus the proportion of graminoids in the vegetation cover usually increases on intensively scythed areas, compared to that of herbs. This holds true in general and at Sølendet in particular.

The effect of grazing on boreal communities has been dealt with in a number of publications, e.g. Baadshaug (1974), who summarizes the results of Norwegian agronomic studies in upland areas, Nordhagen (1943), Steen (1958) and Kielland-Lund (1976). The effect of scything differs from that of grazing in at least three respects (cf. Duffey et al. 1974):

1. Scything is nonselective, all vegetation situated above blade-level is cut off.
2. More nutrients are removed, in the form of hay, since no dung or urine are returned as is the case with grazing animals.
3. The mechanical (trampling) effect is different.

Some species gain an advantage when the vegetation is scythed, other species when it is grazed. Virtually no studies have been carried out on the reaction of the plant communities and species of the upper boreal, rich fens and wooded grasslands to different types of management, apart from those made by Elveland and myself (cf. section 13.3.4.2). Better descriptions exist for the vegetational changes brought about by different types of management of the grasslands mown for hay further south in Fennoscandia, e.g. those of Tamm (1956), Pettersson (1958), Persson (1980, 1984), Fogelfors (1982), Regnell (1982), Fogelfors & Steen (1983), Häggström (1983, 1987), Austad et al. (1985), Austad & Skogen (1988), Losvik (1988) and Ekstam et al. (1988). The effect of different management regimes on the vegetation of rich fens in S. Sweden were summarized by Tyler (1984), although no experimental studies were made. Regnell (1986) made a mowing experiment on an area of fen grassland 15 years after regular grazing had ceased. He concluded that restoration of the former species composition was difficult/impossible by scything; and suggested the use of more drastic measures, e.g. removal of the topsoil so as to initiate a near-primary succession, followed up by regular grazing or mowing.

In general, in areas situated further south, or at lower altitudes than Sølendet, where the growing conditions are more favourable, plant production is greater, and the successions occur faster than in the upper boreal region. A number of publications describe the successions observed on wetlands and fens in Britain after their utilization was abandoned, and the changes induced when scything recommenced, e.g. Godwin (1929, 1941), Wheeler (1980) and Rowell (1988). For the fen vegetation in Britain, Wheeler & Giller (1982) concluded that the reduction in standing crop and litter in summer was usually associated with an increase in (plant) species density. Fogelfors (1982) and Fogelfors & Steen (1983) also found a marked increase in species diversity in scythed quadrats of grasslands in C. Sweden, compared to abandoned and manured quadrats.

At Sølendet, however, scything has been found to produce mainly quantitative differences, the probable explanation being that the communities there had reached a state of equilibrium with scything as an ecological factor, operative for centuries, and the successions taking place after its cessation have progressed for only a short time so far. In some communities, however, the increases in the cover values of a few favoured species (e.g. *Betula nana*, *B. pubescens*, *Salix* spp., *Carex lasiocarpa* and *Molinia caerulea*) and in the amount of litter, leads to increased competition for many other species and, over a period of several decades certainly results in a decline in the number of species present. Scything of these communities then leads to an increase in species diversity. However, in some of the fen quadrats scythed annually, the reverse effect was found, with a further reduction in the number of species present (cf. the quadrats of localities 1-4 in Tables 5-7 of Appendix C).

#### 13.4.4 Comments on population ecology and flowering frequency

Few long-term, autecological studies have been made of any of the individual plant species in boreal communities. The studies made since 1943 by Tamm (1948, 1956, 1972) and Inghe & Tamm (1985, 1988) on some of the perennial herbs of open and wooded grasslands in Sweden form an exception.

Data for the annual flowering frequencies for *Dactylorhiza cruenta*, *D. pseudocordigera*, *Gymnadenia conopsea*, *Nigritella nigra* and *Pedicularis oederi* at Sølendet have been published by Moen (1985b, d). These data, taken together with those given in the present monograph (e.g. those for *Nigritella* in section 11.4.4) and the comments made earlier in section 13.4, lead to the conclusion that the flowering frequency of most species varies very much from one year to another. Flowering frequency also varies very much under different management regimes. The orchids, mentioned previously, and *Pedicularis oederi*, did not tolerate intensive scything when carried out around August 1. These species do not, in general, produce flowers every year, more often every other year under natural conditions. Furthermore, these species behave differently when growing in different communities.

In short, there is an urgent need for further knowledge of the population ecology of the individual species forming the plant communities at Sølendet.

## 14 SUMMARY

### 1. The Sølendet area, geology and climate

The Sølendet nature reserve was established in 1974, covering an area of 2850 daa. The area investigated, included in addition a planned extension of the reserve to the SE. Sølendet is situated in Brekken parish, in the administrative district of Røros, in Sør-Trøndelag county.

In the Sølendet area the predominant bedrock is a grey-green phyllite. Most of the nature reserve is covered by a bottom moraine composed of base-rich phyllite, with a high proportion of clay particles, yielding a nutrient-rich soil which readily becomes waterlogged. Fine-grained, nutrient-poor sand is predominant on the flatter parts of Sølendet (below 706 m). Within the nature reserve there are more than 50 marked springs, a majority of which occurs as spring-lines at an altitude of 770-780 m above s.l., together with a large number of more diffuse groundwater outflows. These springs carry calcareous, mineral-rich water (pH: 7.8, specific conductivity value: 180  $\mu\text{S}/\text{cm}$ ) to the fen surface throughout the year.

Figure 3.2.4 shows the terrain and the various hydrological structures; the hydrology well explains the extensive occurrence of extremely rich fens on the gently sloping morainic areas. After permeating through the peat, the seepage water collects on the lower-lying, flat, sandy parts of Sølendet, to drain away along small valleys. They are all flooded by calcareous water in springtime. During most of the year, however, the groundwater-level in these valleys lies below the surface. The fen and grassland vegetational types of these drainage valleys are of particular interest, because they include rare species (e.g. *Nigritella nigra*); a profile and transect of the main drainage valley is shown in figure 7.3.1.

The annual mean temperature at Sølendet is about  $+0.6^{\circ}\text{C}$ , the January and July means are  $-9.0^{\circ}\text{C}$  and  $+11.7^{\circ}\text{C}$ , respectively. The mean annual precipitation is about 600 mm, more than half of which falls during June-September.

The snow-cover in most years lasts from late October to late May, usually 210-220 days; the snow depth in wintertime is ca. 1 m. In some years during periods of low temperatures, when there is little or no snow-cover, frost penetration into the soil/peat may be of considerable depth and lasts until the summer.

The humidity indices (values of 57 and 360 for the Martonne aridity and Tamm indexes, respectively) indicate a humid climate in the area.

### 2. The flora

The vascular flora of Sølendet (including the proposed extension to the SE of the reserve) includes 294 taxa, 25 of which are hybrids, the bryophyte flora includes 256 species, cf. Appendix B.



*Carex hostiana* is the most typical of the suboceanic species, *C. appropinquata* has a southeastern distribution in Fennoscandia; both are "lowland species" that occur at Sølendet at or close to their upper distributional limits in Fennoscandia. A large number of species with an alpine and upper boreal distribution in Fennoscandia occur, e.g. *Carex atrofusca*, *Kobresia simpliciuscula*, *Juncus castaneus* and *Pedicularis oederi*. 25 taxa of orchids, (including 12 hybrids) are found at Sølendet, a number of them are very numerous, e.g. *Dactylorhiza cruenta*, *D. fuchsii*, *D. pseudocordigera*, *Gymnadenia conopsea* and *Listera ovata*.

### 3. Human impact, management

The traditional haymaking at Sølendet ceased ca. 1950, after a gradual decrease in intensity throughout the preceding decades. Most of the hay swards were formerly cut every second year; the full history of haymaking is not known, but this activity was certainly practised at Sølendet for hundreds of years. The main tools used have been the scythe, the hay-rake and horse-drawn, summer hay-sledges. The work involved scything, drying the herbage and transporting the hay to the hay-barns or haystacks. Calculations based on the data for the last decades of haymaking indicate that, in the nature reserve in summertime, haymaking activities involved about 1000 man-days annually. The hay was transported down to the farms during the wintertime.

A vegetational succession commenced as soon as haymaking ceased, the most obvious change was the formation of scrub and a heavy litter layer in the tall-growing fen and swamp communities. The restoration of the earlier haymaking lands at Sølendet started in 1976. The large-scale clearance (by axe) was mostly complete by 1983, by which time ca. 560 daa of scrub-covered land had been cleared. Altogether 1600 daa of former haymaking lands have been restored and most of these areas have been mown (with a scythe or a motor mower) two to five times during the years 1976-1989.

The main aims of the management plan for the nature reserve is to reconstitute and preserve the former type of cultural landscape, to maintain a wide variety of vegetation types and to further the thrift of rare species. Some areas of the reserve are managed intensively, some areas are more extensively managed and some areas are left untouched.

### 4. Methods

The analyses of the plant communities, the ecological investigations, the productivity and population studies, etc., have been made in homogeneous, permanent quadrats of 12.5-25 m<sup>2</sup>, at ca. 100 localities. Each locality represented a homogeneous area (stand s.lat.) at the start of the study. A number of permanent quadrats were established in some localities, the clearing and scything involved differed from quadrat to quadrat. In subsequent years the phytosociological reanalyses have been treated as stand samples in their own right. In the mire and spring communities, 3-5 small quadrats (0.25 m<sup>2</sup>) were analysed within each permanent quadrat. The stand samples used in the multivariate analyses were synthesis samples made up of the cover degrees of these small

quadrats. In wooded areas, the permanent quadrats (12.5-25 m<sup>2</sup>) were analysed as single quadrats, which represented the stand sample.

An expanded Hult-Sernander-Du Rietz scale was used for the degree of cover of each species, transformed to a 9-degree scale for use in the multivariate analyses (Table 4.3.1).

The phytosociology of the plant communities has been studied using both classification (TABORD and TWINSpan) and DCA-ordination (DECORANA) techniques; figure 4.4.1 shows a flow diagram of the computer programs.

The ecological studies involved conventional methods; soil profile and peat depth investigation, soil and peat pH, pH and specific conductivity of water, ground-water-level in peat pits, etc. The harvesting method used for estimating the hay yield was to cut the sward of the permanent quadrats (ca. Aug. 1), with a scythe. Dry weight was estimated at 80°C. (Appendix E gives details of 624 such harvestings).

### 5. The mire and spring vegetation

Mires cover 45% of the nature reserve. The bog, poor fen and intermediate fen vegetation altogether cover only 1%, the rest represents extremely rich fen vegetation. The mire vegetation at Sølendet is dealt with in four sections: 5, 6, 8 and 12.4; the spring vegetation in sections 5 and 7.

Section 5 deals with the different types of mire and spring vegetation; the multivariate analyses included 80 samples collected by myself; 18 clusters (M1-18) were defined, which were amalgamated to yield 7 mire cluster groups and one spring group. The group names are also used as the headings for the same type of mire vegetation in all sections, viz:

1. Rich fen, *Scorpidium* communities
2. Rich fen expanse, *Campylium* communities
3. Rich fen margin, *Campylium* communities
4. Rich fen, *Sphagnum warnstorffii* communities
5. Rich fen, *Drepanocladus-Meesia* communities
6. Rich fen, *Salix* communities
7. Bog hummock, *Sphagnum fuscum* communities
8. Rich spring, *Cratoneuron* communities (only in section 5).

The ecological data for the mire and spring communities are summarized in table 5.3.1. The pH of the peat and water samples from the bog stands was ca. 4.0.

The mean pH values of the peat in the stands of the fen clusters varied between 5.9 and 6.7, the pH in water between (6.1)6.7 and 7.3, and the specific conductivity between 74 and 162 µS/cm. The minor variation in the pH values in fen communities is explained by the nature of the vegetation, only rich fen communities were investigated.

The surface inclination of the mire stands varied between 0° and 6°. The *Scorpidium*, *Drepanocladus-Meesia* and *Sphagnum fuscum* communities occur on flat mires. The *Campylium* communities occur on sloping fens, the highest inclination values were recorded for the fen margin communities.

The peat depth of the stands on flat areas mostly exceeded 0.6 m; the sloping fens usually had a peat depth of 0.2-0.4 m, the mire margin types had even lower values. The groundwater-level during dry periods varied very much, from rather high levels of the *Scorpidium* and *Drepanocladus-Meesia* communities, to the low levels of the *Campylium* communities. As found in general (by e.g. Havas 1961, Persson 1962), also applied at Sølendet: the greater the surface slope of the fen, the deeper the groundwater-level lay in dry periods, and the thinner the peat layer. Figure 8.4.1 well illustrates the increasing values for the groundwater-level along the vegetational gradient: mud bottom - carpet-lawn expanse - lawn margin.

Section 6 concerns the *Scorpidium*, *Campylium*, *Sphagnum warnstorffii* and *Drepanocladus-Meesia* cluster groups. For this analysis, 59 of the samples used in section 5 were combined with 38 samples taken by Gaare at Sølendet ca. 1960. Fifteen clusters (a-o) altogether were defined, 6 of which included Gaare's samples. The marginal types of *Campylium* communities, including a large number of Gaare's samples, are presented in greatest detail in section 6. Because the data set included analyses made by two different observers, a noise factor was introduced, which made direct comparisons and their use in successional studies difficult. However, the rather low cover-degree values recorded by Gaare for *Betula nana*, dwarf-shrubs (e.g. *Vaccinium* spp.) and *Molinia caerulea* growing in the marginal communities is explained by the fact that Gaare made his analyses only a few years after regular scything had ceased; all the above-mentioned species certainly increase when scything ceases.

A hierarchical, classification system is proposed for the mire and spring vegetation in Norway (Table 8.2.5), that comprises 3 classes, 5 orders and 14 alliances. Table 8.3.1 gives a survey of the mire and spring clusters described at Sølendet, together with a comparison with a number of other Fennoscandian classification systems. In the proposed hierarchical system, the Sølendet rich fen communities are included in the following alliances: *Stygio-Caricion limosae*, *Caricion atrofuscae*, *Sphagno-Tomenthypnion* and *Caricion lasiocarpae*. The hummock vegetation belongs to the *Oxycocco-Empetrion* alliance, the spring vegetation to the *Cratoneurion commutati* alliance.

## 6. Heathland vegetation

The heathland series altogether cover 35% of the nature reserve (section 12.5). The results of the multivariate analyses of a data set of the heathland and wooded grassland samples of Sølendet are presented in section 9. The 23 heathland samples were well separated from the 32 grassland samples, both by the TABORD and TWINSpan classifications, and the DCA-ordination. The heathland samples, classified as 6 clusters (W1-6), were amalgamated to form the 3 cluster groups used as main headings for sections nos. 9.5, 11.2 and 12.5. Synsystematic surveys of the heathland (and the grassland) types are given in table 11.1.1 (cf. also Fig. 11.1.1).

1. Wiry grass heaths include the open *Nardus stricta* type (cluster W1), belonging to the *Carici bigelowii-Nardetum* association. The *Nardus*-dominated birch woodland community (cluster W2) is described as a new association: *Nardo strictae-Betuletum pubescentis*, placed in the *Vaccinio-Piceion* alliance.

2. Dwarf-shrub/grass heaths include two clusters, one (W4) of which is placed in the *Myrtillo-Betuletum myrtilletosum* (subass. nov.) of the *Vaccinio-Piceion* alliance.

3. Small-fern heaths comprise two clusters, both of which are placed in the *Myrtillo-Betuletum dryopteridetosum* (subass. nov.). One of the clusters (W6) represents a type transitional to the wooded grasslands.

The soil profiles of all the heathland stands are podzols, the pH of the humus layer varying from 3.8 (the wiry grass heath types) to 4.8 (the W6 type).

#### 7. Wooded grasslands of Sølendet and C. Norway

The samples of the wooded grasslands from Sølendet separated out into 5 clusters (W7-11, section 9). The pH of the humus/mull layer varied from 5.3 to 6.2; i.e. significantly higher than the values for the heathland types. The wooded grasslands cover 20% of the nature reserve (section 12.6). A full comparison of the Sølendet wooded grassland stands with similar types from three other districts in C. Norway (Nedalen in Sylane, Nerskogen and Innerdalen) are dealt with in section 10. The multivariate analyses included 101 samples; 7 clusters (U1-7) are defined and described, the Sølendet samples are included in 6 of them.

A majority of the wooded grassland samples dealt with in sections 9.6 and 10 are assigned to the *Lactucion alpinae* alliance, which is defined as an alliance of rich grassland communities, including tall-herbs and broad-leaved grasses, of the upper boreal and low alpine regions. *Lactucion alpinae* has been split up into 3 associations:

1. *Geranietum sylvatici*, further separated into two subassociations: *deschampsietosum* subass. nov. and *aconitetosum* subass. nov.
2. *Filipendulo-Salicetum phylicifoliae*
3. *Deschampsio cespitosae-Salicetum lapponae*

Surveys of the phytosociological types, characteristic species, etc., are given in the tables 11.3.1-2.

#### 8. The *Nigritella nigra* communities

Synedria analyses of *Nigritella nigra* and some further analyses of small quadrats from the low-herb grasslands are dealt with in sections 9.3 & 9.7. Two clusters that included *Nigritella nigra* are defined: the *Achillea millefolium-Tortula ruralis* type (cluster O1) includes a number of calcicolous species of dry habitats, e.g. the four species of *Botrychium*. The *Nardus stricta-Thalictrum alpinum-Sphagnum warnstorffii* type (cluster O2) represents a grassland type



transitional to fens and heathlands. The described communities occur on the flat, sandy areas in the SE of Sølendet, and are subject to flooding by calcareous water in the snowmelt period. The soil profiles are gleyed brown earths, transitional to podzols; in the stands of cluster O2 the humus layer was peaty. The humus pH mean values were 5.4 and 5.6, respectively. Both communities show some similarities with the communities of the *Potentillo-Polygonion vivipari* and *Nardo-Agrostion* alliances, the cluster O2 also with the *Sphagno-Tomenthypnion* alliance. However, the clusters are provisionally assigned to the first-mentioned alliance, which is included in the *Seslerietea* class, where also the C. European *Nigritella nigra* communities belong.

The main localities for *Nigritella nigra* at Sølendet are situated outside the nature reserve itself, the number of flowering specimens of *Nigritella* has been declining drastically during the past decade (Fig. 11.4.1), probably mainly due to overgrowth when haymaking and grazing ceased.

#### 9. The vegetation map of Sølendet

The large-scale (1:5000) vegetation map of Sølendet depicts 25 vegetational units (English text given in Fig. 12.2.1), which largely coincide with the phytosociological types. Table 12.2.1 provides a survey, together with the areal extents of the different units.

#### 10. Productivity and hay crops

Details of the dry matter yields of the field layer in the quadrats scythed either annually or biennially at Sølendet are given in sections 5 and 9; further surveys in section 13.2. (cf. also Figs. 13.2.1-2 and Appendix E). The main conclusions are:

1. In the quadrats scythed every other year the standing crop was a little more than half of that recorded in the first year after the recommencement of scything. The litter fraction for the first harvesting was ca. 1/3, thereafter, in the regularly scythed areas it formed 10-20% of the standing crop. With a regular scything interval the biomass was reduced to about 2/3 of the value recorded in the first year.
2. In quadrats scythed annually, the standing crop was reduced to about 1/3 of that from the first harvesting, with a litter fraction of 5-10%.
3. Annual scything yielded about half of the biomass obtained by scything every other year.
4. The most economic method of utilizing the plant production, by scything for hay was to take a harvest biennially; i.e. just that of traditional haymaking.

For the rich fen expanse, *Campylium* communities at Sølendet, that cover an area of more than 0.5 km<sup>2</sup>, the calculated mean dry weight yield by scything biennially was 115 kg/daa. The values for the wooded grasslands are higher, and the highest values were recorded for the tall-herb grasslands (156 kg/daa).



Based on the yield estimates and from the estimated areal extents of the different vegetational types, taken from the vegetation map, the calculated potential hay-crop at Sølendet is 107 tons. Based on the interviews with the farmers, ca. 70 tons of hay had previously (in the 1930s-1940s) been harvested from the nature reserve every year. It is assumed that a general decline in the utilization of Sølendet for haymaking occurred in the decades before 1950. The calculated value of 107 tons for the potential hay crop is regarded as a realistic assessment of the maximum value for the annual hay crop more than six decades ago.

#### 11. Vegetational changes following scything

Regular scything of fen and grassland communities leads to an overall reduction in the shrubs (e.g. *Betula nana*, *B. pubescens*, *Salix* spp.), dwarf-shrubs and in the litter layer; the proportion of herbs is generally reduced, whereas that of the graminoides is increased. The pleurocarpous, prostrate bryophytes (e.g. *Campylium stellatum* and *Rhytidiadelphus squarrosus*) are favoured, whereas the acrocarpous and/or "hummock-building" bryophytes (e.g. *Sphagnum* spp.) are reduced by scything and trampling. The common occurrence in the fen lawn communities at Sølendet of a number of alpine, weakly-competitive species (e.g. *Carex atrofusca*, *Juncus alpino-articulatus*, *J. castaneus*, *J. triglumis* and *Saxifraga aizoides*) is regarded as a result of the regular scything of these areas in past decades. Both the numbers of shoots and the fertility of the above-mentioned species, as also of *Carex dioica*, *C. capillaris*, *C. flava*, *C. nigra*, *Eriophorum angustifolium* and *E. latifolium* increase as a consequence of scything (Table 13.4.2). *Molinia caerulea*, however, was found to be drastically reduced by intensive scything. The orchid species (e.g. *Dactylorhiza cruenta*, *D. pseudocordigera*, *Gymnadenia conopsea*) and *Pedicularis oederi* did not tolerate intensive scything, but they are favoured in the lawn communities by extensive scything, which reduces competition from shrubs, *Molinia caerulea*, etc.

Intensive scything of the tall-herb grasslands reduces the proportion of tall-herbs (e.g. *Aconitum septentrionale*, *Cicerbita alpina*), and increases that of grasses, such as *Agrostis capillaris*, and of low-herbs such as *Botrychium* spp., *Gentiana nivalis*, *Gentianella* spp. and *Leucanthemum vulgare*. Some of the last-mentioned species have spread to new localities at Sølendet, but in general, the qualitative changes in the plant communities induced by scything have so far been small. The explanation is that, with regular scything as a prime ecological factor, these communities had reached a state of equilibrium over past centuries and the time elapsing since its cessation has been too short for any major changes to occur.

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## 16 APPENDICES

## APPENDIX A. TABLES FOR THE DETAILS OF SAMPLE STANDS AND LOCALITIES AT SØLENDET

Table 1 Details of the stands and localities at Sølendet where phytosociological analyses were made. Second column: Number indicates the individual locality (see Fig. 4.3.1); small letters (a,b etc.) represent different ("small") localities; capital letters (A,B etc.) refer to the 12.5 m<sup>2</sup> quadrats analyzed at the locality; q = quadrat no.; prf1 = profile (transect) of Vassdalen (Fig. 7.3.1).  
The persons responsible for the analyses were: AM: Asbjørn Moen; BFM: Berit F. Moen; SB: Simen Bretten. The final column shows the years in which the stand had been scythed (R: only cleared) before the vegetation analysis were made.

Stand sample no.	Locality & stand quadrat	No. x size in m <sup>2</sup> of small quadrats	Person	Date of analysis	m above s.l.	UTM grid system, zone 32V,PQ	Inclination		Year(s) scythed before anal.
							Aspect	Slope in g	
001	1A+B	5x0.25	AM	740805	713	4593,5382	S	3.0	-
002	2A+B	5x0.25	AM	740805	724	4563,5382	S	5.0	-
003	3A+B	5x0.25	AM	740805	727	4561,5384	S	5.0	-
004	4A+B	5x0.25	AM	740806	753	4531,5397	SSE	5.0	-
005	5A+B	4x0.25	AM	740806	755	4529,5399	SE	6.0	-
006	6A+B	5x0.25	AM	750722	775	4493,5397	S	2.0	-
007	7A+B	5x0.25	AM	750722	775	4492,5395	S	2.0	-
008	8A+B	1x25	SB	750812	760	4525,5403	SE	5.0	-
009	9A+B	5x0.25	AM	760728	731	4587,5407	SE	7.0	-
010	10A+B	5x0.25	AM	760729	731	4589,5410	SSE	5.0	-
011	11A+B	5x0.25	AM	760729	735	4582,5409	SSE	5.0	-
012	12A+B	5x0.25	AM	760730	728	4591,5407	SSE	5.0	-
013	13A+B	5x0.25	AM	760803	742	4579,5423	SE	3.0	-
014	14A+B	5x0.25	AM	760803	742	4580,5422	E	3.0	-
015	15A+B	5x0.25	AM	760731	748	4474,5334	S	3.0	-
016	16A+B	5x0.25	AM	760731	748	4470,5333	S	3.0	-
017	17A+B	5x0.25	AM	760802	760	4552,5467	SW	0.5	-
018	18A+B	5x0.25	AM	760802	760	4551,5469	S	0.5	-
019	19	5x0.25	AM	770802	700	4610,5363	ESE	0.5	-
020	20A+B	1x25	BFM	760728	737	4575,5406	SE	6.0	-
021	21A+B	1x25	BFM	760729	738	4573,5407	SE	7.0	-
022	22A+B	1x25	BFM	760729	738	4588,5419	ESE	4.0	-
023	23A+B	1x25	BFM	760730	735	4589,5414	SSE	7.0	-
024	24	1x25	BFM	760729	735	4587,5413	SSW	5.0	-
025	25A+B	1x25	BFM	760729	742	4583,5418	-	0.0	-
026	26	1x25	BFM	760730	740	4565,5407	S	4.0	-
027	27A+B	1x25	BFM	760730	730	4583,5402	SSE	9.0	-
028	28A+B	1x25	BFM	760730	741	4568,5408	SSE	4.0	-
029	29A+B	1x25	BFM	760731	728	4578,5398	S	7.0	-
030	30A+B	1x25	BFM	760731	737	4567,5403	S	7.0	-
031	31A+B	1x25	BFM	760731	763	4545,5461	E	12.0	-
032	32A+B	1x25	BFM	760731	767	4542,5461	SE	1.0	-
033	33A+B	1x25	BFM	760802	763	4548,5459	ESE	12.0	-
034	34A+B	1x25	BFM	760802	760	4545,5456	ESE	6.0	-
035	35A+B	1x25	BFM	760802	755	4548,5453	SSE	8.0	-
036	36A+B	1x25	BFM	760802	755	4547,5452	SSE	5.0	-
037	37A+B	1x25	BFM	760803	758	4545,5449	ENE	18.0	-
038	38A+B	1x25	BFM	760803	762	4543,5450	SE	10.0	-
039	39A+B	1x25	BFM	760803	765	4540,5455	SSE	6.0	-
040	40A+B	1x25	BFM	760804	760	4539,5432	E	6.0	-
041	41A+B	1x25	BFM	760804	782	4481,5417	-	0.0	-
042	42A+B	1x25	BFM	760804	782	4480,5415	-	0.0	-
043	43A+B	1x25	BFM	760804	782	4482,5414	-	0.0	-
044	44A+B	1x25	BFM	760805	788	4453,5413	S	3.0	-
045	45	1x25	BFM	760805	787	4454,5412	S	3.0	-
046	46A+B	1x25	BFM	760805	788	4451,5413	S	3.0	-
047	47	1x25	BFM	760805	789	4451,5417	S	4.0	-
048	48	1x25	BFM	760805	790	4448,5418	S	3.0	-
049	49A+B	1x25	BFM	760806	795	4448,5433	SE	0.0	-
050	50A+B	1x25	SB	760804	757	4543,5431	E	5.0	-
054	54	2x1	AM	770801	700	4618,5358	E	0.5	-
055	55A+B	1x25	BFM	760806	795	4445,5433	ESE	0.0	-
056	56A+B	1x25	BFM	760806	784	4482,5420	SE	0.0	-
057	57	1x25	BFM	760806	733	4592,5411	SE	12.0	-
060	60	5x0.25	AM	760804	760	4551,5469	S	0.0	-
061	61A+B	5x0.25	AM	770802	750	4550,5442	E	5.0	-
062	62	5x0.25	AM	770802	700	4612,5362	ESE	0.5	-
063	63A+B	5x0.25	AM	770806	738	4501,5331	ESE	5.0	-

App. A Table 1 continued

Stand sample no.	Locality & stand quadrat	No. x size in m <sup>2</sup> of small quadrats	Per-son	Date of analysis	m above s.l.	UTM grid system, zone 32V, Pq	Inclination		Year(s) scythed before anal.
							Aspect	Slope in g	
064	64A+B	5x0.25	AM	770806	738	4500, 5330	ESE	5.0	-
065	65A+B	5x0.25	AM	770806	736	4501, 5327	SE	4.0	-
066	66A+B	5x0.25	AM	770806	760	4485, 5359	SE	3.0	-
067	67A+B	5x0.25	AM	770807	777	4520, 5447	E	0.5	-
068	68	5x0.25	AM	770807	777	4520, 5447	E	0.0	-
069	69A+B	5x0.25	AM	780807	780	4512, 5457	ESE	3.0	-
070	70A+B	5x0.25	AM	780807	782	4508, 5459	E	1.0	-
071	71	5x0.25	AM	780810	796	4429, 5442	-	0.0	-
072	72	2x0.25	AM	800805	758	4542, 5432	E	8.0	-
073	73a	5x0.25	AM	800805	748	4556, 5425	SE	1.0	78
074	74A+B	5x0.25	AM	800806	751	4537, 5403	SE	6.0	-
075	75	1x1	AM	750722	705	4608, 5378	S	1.0	-
076	76	1x0.25	AM	810805	700	4634, 5367	SE	1.0	-
077	77	1x1	AM	810805	700	4638, 5366	SE	1.0	-
078	78	1x1	AM	810805	700	4632, 5367	-	0.0	-
079	79	1x1	AM	810805	706	4609, 5389	S	4.0	-
080	80	1x25	BFM	780801	750	4569, 5444	S	1.0	-
081	81	3x1	AM	780802	700	4636, 5368	SE	1.0	-
082	82	4x4	AM	780809	770	4461, 5372	S	1.0	-
083	83	2x4	AM	780809	769	4448, 5371	S	3.0	-
084	84	1x4	AM	780810	788	4486, 5469	S	2.0	-
085	85	1x4	AM	780810	788	4485, 5468	S	2.0	-
086	86	2x0.25	AM	810808	763	4536, 5433	S	6.0	79
087	87	5x0.25	AM	810809	722	4583, 5395	S	5.0	-
088	88	1x1	AM	750722	700	461, 536	S	5.0	-
089	89	1x4	AM	760807	722	4443, 5278	S	0.0	-
091	91	4x0.25	AM	820806	700	463, 535	S	0.0	-
092	92a	2x0.25	AM	820804	750	455, 544	S	-	-
093	93a+b	3x1	AM	820804	783	450, 545	SE	0.0	-
094	94a-c	3x0.1	AM	820804	777	450, 541	SE	-	-
095	95	3x0.25	AM	820805	770	447, 537	S	-	-
096	96	5x0.25	AM	820803	748	455, 542	S	1.0	78
098	98	2x1	AM	830803	785	4430, 5413	-	0.0	-
099	99	2:0.5 1.0	AM	830803	795	4428, 5458	-	0.0	-
101	101	3x0.25	AM	860801	725	4565, 5384	S	5.0	-
102	102+101	3x0.25	AM	860801	725	4566, 5384	S	5.0	-
103	103	1x4	AM	860805	733	4593, 5414	S	3.0	-
104	104	1x1	AM	860805	733	4593, 5414	S	3.0	-
110	10+C	3x0.25	AM	750812	713	459, 538	S	3.0	-
111	1A+B	3x0.25	AM	750811	713	459, 538	S	3.0	74
112	10+U	3x0.25	AM	770802	713	459, 538	S	3.0	-
113	1A+B	3x0.25	AM	770802	713	459, 538	S	3.0	74-76
114	1A	3x0.25	AM	790804	713	459, 538	S	3.0	74-78
115	1C	3x0.25	AM	790804	713	459, 538	S	3.0	77
116	1D	3x0.25	AM	790804	713	459, 538	S	3.0	-
117	1U	2x0.25	AM	810808	713	459, 538	S	3.0	-
118	1A	2x0.25	AM	810808	713	459, 538	S	3.0	74-80
119	1A	2x0.25	AM	840816	713	459, 538	S	3.0	74-83
120	2A	3x0.25	AM	790806	724	456, 538	S	5.0	74-78
121	2C	3x0.25	AM	790806	724	456, 538	S	5.0	77
122	2F	3x0.25	AM	790806	725	456, 538	S	5.0	-
123	2J+U	2x0.25	AM	810805	724	456, 538	S	5.0	-
124	2A	2x0.25	AM	810804	724	456, 538	S	5.0	74-80
125	2A	1x0.25	AM	840817	724	456, 538	S	5.0	74-83
126	2A	1x0.25	AM	850804	724	456, 538	S	5.0	74-83
127	2A	1x0.25	AM	860911	724	456, 538	S	5.0	74-83
130	3A	3x0.25	AM	790807	727	456, 538	S	5.0	74-78
131	3F	2x0.25	AM	790807	727	456, 538	S	5.0	-
140	4A	3x0.25	AM	750812	753	453, 539	SSE	5.0	74
141	4C+D+E	3x0.25	AM	750812	753	453, 539	SSE	5.0	-
142	4A	3x0.25	AM	790807	753	453, 539	SSE	5.0	74-78
143	4A	2x0.25	AM	810805	753	453, 539	SSE	5.0	74-80
144	4D+G	2x0.25	AM	810805	753	453, 539	SSE	5.0	-
145	4A	3x0.25	AM	840802	753	453, 539	SSE	5.0	74-83
146	4C	2x0.25	AM	840803	753	453, 539	SSE	5.0	77+79+81+83
147	4G	2x0.25	AM	840801	753	453, 539	SSE	5.0	-
148	4A	1x0.25	AM	850805	753	453, 539	SSE	5.0	74-83
149	4A	1x0.25	AM	860912	753	453, 539	SSE	5.0	74-83
151	1A	2x0.25	AM	850803	713	459, 538	S	3.0	74-83
152	1A	2x0.25	AM	860910	713	459, 538	S	3.0	74-83
190	73b	5x0.25	AM	820803	748	455, 542	S	1.0	78
191	74b	2x0.25	AM	810807	748	455, 542	SE	6.0	R80
192	74c	2x0.25	AM	820801	748	455, 542	SE	6.0	-
193	92b	2x0.25	AM	820804	750	455, 544	S	-	-
194	92c	4x0.25	AM	820804	750	455, 544	S	-	-
195	93c	4x0.25	AM	820804	783	450, 545	SE	0.0	-
196	93d	4x0.25	AM	820804	783	450, 545	SE	3.0	-

App. A Table 1 continued

Stand sample no.	Locality & stand quadrat	No. x size in m <sup>2</sup> of small quadrats	Per- son	Date of analysis	m above s.l.	UTM grid system, zone 32V,PQ	Inclination		Year(s) scythed before anal.
							Aspect	Slope in g	
197	94b	2x0.25	AM	820804	777	450, 541	SE	-	-
198	61E	2x0.25	AM	820807	750	445, 544	E	5.0	78
199	70D	2x0.25	AM	820807	782	450, 546	E	1.0	-
200	69D	2x0.25	AM	820807	780	451, 545	ES	3.0	78
201	13C	2x0.25	AM	820807	742	457, 542	S	3.0	76+78+80
250	35A	1x12.5	AM	830730	755	4548, 5453	SS	8.0	77+79+81
251	35B	1x12.5	AM	830730	755	4548, 5453	SS	8.0	77+80+82
252	40A	1x12.5	AM	830731	760	4539, 5432	E	6.0	76-82
253	40B	1x12.5	AM	830731	760	4539, 5432	E	6.0	76+78+80+82
254	40C	1x12.5	AM	830731	760	4539, 5432	E	6.0	78
255	5A	1x12.5	AM	830801	755	4529, 5399	SE	6.0	74-82(-75)
256	5B	1x12.5	AM	830801	755	4529, 5399	SE	6.0	74-76+78+80+82
257	5D	1x12.5	AM	830801	755	4529, 5399	S	6.0	-
258	5A+B	1x25	AM	740806	755	4529, 5399	S	6.0	-
259	8C	1x12.5	AM	830802	760	4525, 5403	S	6.0	-
260	8A	1x12.5	AM	830802	760	4525, 5403	S	6.0	75+76+78+80+82
261	8B	1x12.5	AM	830803	760	4525, 5403	S	6.0	75+76+79+81
270	prf1 q1-2+	1x4	AM	770805	700	460, 536	S	1.0	-
271	prf1 q3+	1x4	AM	770805	700	460, 536	S	3.0	-
272	prf1 q21-22+	1x4	AM	770805	700	460, 536	N	2.0	-
273	prf1 q5-6	2x0.9	AM	770805	700	460, 536	S	3.0	-
274	prf1 q7-8	2:1.9, 1.0	AM	770805	700	460, 536	S	2.0	-
275	prf1 q9	1x2.5	AM	770805	700	460, 536	S	1.0	-
276	prf1 q11-12	2:2.5, 1.7	AM	770805	700	460, 536	S	1.0	-
277	prf1 q15	1x4	AM	770805	700	460, 536	ESE	0.5	-
278	prf1 q16-17	2:4.1, 2.1	AM	770805	700	460, 536	E	0.5	-
279	prf1 q18-20	3:1.8, 0.7, 0.7	AM	770805	700	460, 536	N	1.0	-
280	prf1 q13-14	2:3.7, 4.1	AM	770805	700	460, 536	ESE	0.5	-
281	82 q1	1x4	AM	780809	770	4461, 5372	S	1.0	-
282	82 q2	1x4	AM	780809	770	4461, 5372	S	1.0	-
283	82 q3	1x4	AM	780809	770	4461, 5372	S	1.0	-
284	82 q4	1x4	AM	780809	770	4461, 5372	S	1.0	-
285	83 q1	1x4	AM	780809	769	4448, 5371	S	3.0	-
286	83 q2	1x4	AM	780809	769	4448, 5371	S	3.0	-
287	81 q1	1x1	AM	780802	700	4636, 5368	S	1.0	-
288	81 q2	1x1	AM	780802	700	4636, 5368	S	1.0	-
289	81 q3	1x1	AM	780802	700	4636, 5368	S	1.0	-
290	prf1 q18	1x1.8	AM	770805	700	460, 536	N	1.0	-
291	prf1 q19	1x0.7	AM	770805	700	460, 536	N	1.0	-
292	prf1 q20	1x0.7	AM	770805	700	460, 536	N	1.0	-
293	prf1 q7	1x1.9	AM	770805	700	460, 536	S	2.0	-
294	prf1 q8	1x1	AM	770805	700	460, 536	S	2.0	-

## APPENDIX A

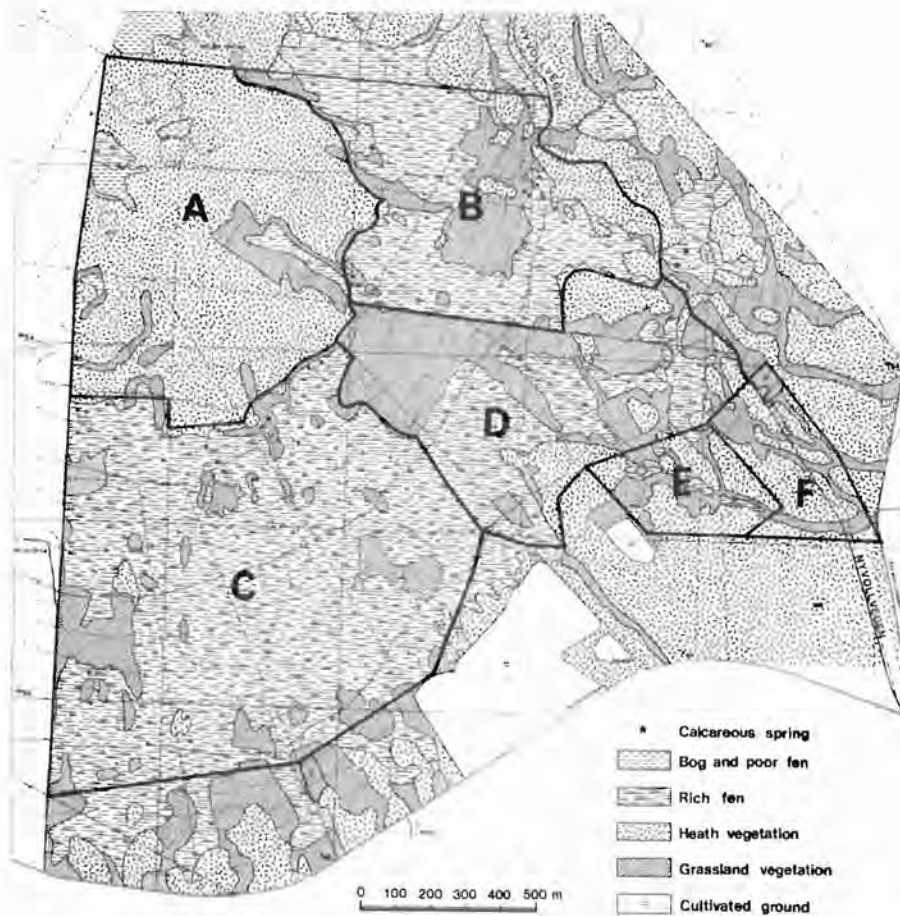
Table 2 Ecological details for the stand localities at Sølendet: depth of "soil", and pH in soil (3-5 cm below the surface) and water. The stand sample no. is the same as that in the foregoing table (giving exact position, number and size of quadrats etc). Localities including two or more sample stands (e.g. quadrats reanalysed after scything) are represented by one data set, tabulated for the lowest-numbered stand. Column no. 2: B: brown earth; P: podsol; T: peat. Mean values (minimum-maximum in parentheses) are listed for mull/humus/peat depth. The majority of the values refer to ca. Aug. 1 1981; those marked with a plus (+) were recorded in September (mainly 1981/0916).

Stand sample no.	Depth of soil/peat	pH in soil	pH in water
001	T:45(35-65)	6.0 6.2	6.7 6.9
002	T:35(25-40)	6.0 6.3	7.1 7.1
003	T:15(5-20)	6.3 6.3	6.7 6.6
004	T:15(5-25)	6.6 6.6	7.0 7.0
005	B:ca. 15	5.6 5.6	-
006	T:30(20-40)	6.7 6.9	7.1 7.4
007	T:60(50-80)	6.5 6.9	7.0 7.4
008	B:20(10-30)	5.5 5.8	-
009	T:60	6.5 6.7	7.3 7.4
010	T:50(35)	6.6 6.7	7.2 7.3
011	T:30(20-40)	6.3 6.7	6.8 7.4
012	T:60(50-70)	6.5 6.8	7.3 7.4
013	T:20(10-40)	6.2 6.2	6.8 6.8
014	T:15(10-25)	6.3 6.7	6.6 7.0
015	T:20	6.3 6.5	7.1 7.3
016	T:10(5-20)	6.2 6.5	6.8 6.9
017	T:75	6.5 6.5	7.2 7.1
018	T:80	6.4 6.6	7.3 7.2
019	T:70(50-80)	6.7 6.4	7.2 7.2
020	B(T):4	5.6 5.7	-
021	B:5	5.1+ 5.2+	-
022	B:5	5.6 5.8	-
023	P:2	4.4 4.8	-
024	P:4	4.6+ 4.4+	-
025	P:3	4.0+ 4.8+	-
026	B(P):7	5.6+ 5.4+	-
027	B(T):20	6.3+ 6.1+	-
028	P:6	4.3+ 4.1+	-
029	B:12	6.1+ 6.0+	-
030	P:6	3.7+ 4.1+	-
031	P:5	4.5 4.8	-
032	P	5.2 5.2	-
033	P	5.1 4.7	-
034	B	5.4 5.8	-
035	B	5.4 5.9	-
036	B	6.3 5.7	-
037	B	5.8 6.2	-
038	B	6.0 6.3	-
039	P	4.3 4.5	-
040	B	5.9 5.9	-
041	P:4	4.0+ 4.1+	-
042	P:4	3.9+ 4.0+	-
043	P:4-5	4.0+ 4.0+	-
044	P:9	3.8+ 4.0+	-
045	P:8(5-10)	3.7+ 3.8+	-
046	P:9(6-12)	3.6+ 3.8+	-
047	P:9(8-10)	3.8+ 3.8+	-
048	P:3	4.0+ 4.1+	-
049	(P):3	3.8+ 3.8+	-
050	B	5.5 5.7	-
054	T/B/:6	5.6 5.5	-
055	P:3	3.8+ 3.8+	-
056	T(P):5	5.1+ 5.1+	-
057	P:2	4.8 5.0	-
060	T:80	-	-
061	T:35(30-40)	6.8 6.6	7.4 7.4
062	T:100(60)	6.4 6.1	7.3 6.7

Stand sample no.	Depth of soil/peat	pH in soil	pH in water
063	T:15	6.7 6.7	7.6 7.4
064	T:30(20-40)	6.4 6.8	7.5 7.5
065	T:15(10-20)	6.6 6.7	7.6 7.5
066	T:25(20-30)	6.7 7.1	7.3 7.4
067	T:30(25-40)	6.0 6.1	6.7 7.2
068	T:20(10-30)	6.4 6.7	6.6 7.6
069	T:50(40-60)	6.6 6.7	7.3 7.3
070	T:50	6.4 6.4	6.3 5.7
071	T:140	4.0+ 3.9+	3.9+ 3.8+
072	B	-	-
073	T:50	7.0+ 6.4+	7.6+ 7.3+
074	T:16	6.1 5.9	-
075	P/B:4	4.7 4.6	-
076	B:3	5.5 5.6	-
077	B:3	5.8 5.7	-
078	P:2	5.1 5.7	-
079	B:4	5.8	-
080	P	-	-
081	B:4	5.6 5.0	-
082	T:100(80)	6.0 6.3	6.7 6.9
083	T:70(60-80)	6.0 6.3	6.8 6.3
084	T/B:5	5.2	5.8
085	T/B:3	5.4	-
086	B	-	-
087	T:35	5.9+ 6.4+	6.9+ 7.0+
088	T/P:12	-	-
089	T:100	-	-
091	(T)	-	-
092	T:45	-	7.3
093	T:80	-	7.8
094	T:3	-	-
095	T:8	-	7.9 8.0
096	T:50	-	-
098	T	-	-
099	T	-	-
101	T:15	6.7+	-
102	T:15	6.6+	-
103	T/B:10	6.3+	-
104	T:10	6.3+	-
190	T:50	-	-
191	T:16	-	-
192	T(B):5	-	-
193	T:30(20-40)	-	-
194	T:8(5-20)	-	7.7
195	T:95	-	-
196	T:100	-	-
197	T:10	-	-
270	P:5	4.6+	-
271	P:10	-	-
272	P/T/B:8	6.0+ 6.1+	-
273	P:13	4.7+	-
274	P(T):12	5.5+ 5.5+	-
275	T:20	5.8+	-
276	T:55	5.7+	7.0+
277	T:65	6.7+	7.1+
278	T:50	6.6+ 6.9+	6.8+
279	T:12	6.6+	-
280	T:70	6.1+ 6.9+	7.1+ 7.1+

## APPENDIX B. SPECIES LISTS FOR SØLENDET

Appendix B-table 1 lists the vascular plants and their occurrences in six areas at Sølendet (App. B-Fig. 1). Inside the Sølendet nature reserve is found 282 taxa (including 25 hybrids); 12 more species found in the planned extension of the reserve to the SE (area F in the figure), are also listed. Table 2 of Appendix B shows the list of the 256 bryophytes. Both lists indicate the frequencies of the taxa inside the nature reserve.



Appendix B-figure 1. The 6 smaller areas at Sølendet (A-F) used in App. B-table 1.



## APPENDIX B

Table 1 Vascular plants at Sølendet. A-E represent different parts of the nature reserve (cf. Fig. 1 of App. B), F is the area to the southeast of the reserve, which is planned to be included in the future. Freq. indicates the frequency with which the species occurs at Sølendet nature reserve (A-E). The following scale is used:

(x) : Very rare  
 x : Rare  
 xx : Fairly common  
 xxx : Very common  
 xxxx : Very common and often dominant  
 y : Only outside the reserve (in area F)

	A	B	C	D	E	F	Freq.
<b>Trees and shrubs</b>							
<i>Alnus incana</i>	+	+	+	+			xx
<i>Betula nana</i>	+	+	+	+	+	+	xxxx
<i>Betula pubescens</i>	+	+	+	+	+	+	xxxx
<i>Daphne mezereum</i>				+	+		(x)
<i>Juniperus communis</i>	+	+	+	+	+	+	xxxx
<i>Picea abies</i>		+		+			(x)
<i>Pinus sylvestris</i>	+	+	+	+	+	+	x
<i>Populus tremula</i>				+			(x)
<i>Prunus padus</i>			+	+			(x)
<i>Rosa majalis</i>						+	y
<i>Salix arbuscula</i>	+	+	+	+	+		xx
<i>Salix borealis</i>	+	+	+	+	+		x
<i>Salix coetanea</i>		+		+			(x)
<i>Salix glauca</i>	+	+	+	+	+	+	xxxx
<i>Salix hastata</i>	+	+	+	+	+	+	xx
<i>Salix lanata</i>		+		+	+	+	x
<i>Salix lapponum</i>	+	+	+	+	+	+	xxxx
<i>Salix myrsinites</i>	+	+	+	+	+		xx
<i>Salix nigricans</i>	+	+	+	+	+	+	xxx
<i>Salix pentandra</i>	+	+	+	+	+	+	xx
<i>Salix phylicifolia</i>	+	+	+	+	+	+	xxx
<i>Salix reticulata</i>	+	+	+	+			xx
<i>Salix starkeana</i>					+	+	x
<i>Sorbus aucuparia</i>	+	+	+	+	+	+	xxx
<b>Dwarf-shrubs</b>							
<i>Andromeda polifolia</i>	+	+	+	+	+		xxx
<i>Arctostaphylos alpina</i>	+	+	+	+	+	+	xx
<i>Calluna vulgaris</i>	+	+	+	+	+		xxxx
<i>Empetrum hermaphroditum</i>	+	+	+	+	+		xxxx
<i>Oxycoccus microcarpus</i>	+	+	+	+	+		xx
<i>Phyllocladus caerulea</i>		+				+	x
<i>Vaccinium myrtillus</i>	+	+	+	+	+	+	xxxx
<i>Vaccinium uliginosum</i>	+	+	+	+	+	+	xxxx
<i>Vaccinium vitis-idaea</i>	+	+	+	+	+	+	xxxx
<b>Herbs</b>							
<i>Achillea millefolium</i>	+	+	+	+	+	+	xx
<i>Aconitum septentrionale</i>	+	+	+	+	+	+	xxxx
<i>Alchemilla alpina</i>						+	y
<i>Alchemilla filicaulis</i>					+	+	x
<i>Alchemilla glabra</i>	+	+	+	+	+	+	xxxx
<i>Alchemilla glomerulans</i>	+	+	+	+	+	+	xxxx
<i>Alchemilla monticola</i>				+		+	x
<i>Alchemilla murbeckiana</i>		+			+		xx
<i>Alchemilla subcrenata</i>	+	+	+	+	+	+	xxxx
<i>Alchemilla wickstrae</i>		+		+	+	+	xx
<i>Anemone nemorosa</i>	+	+	+	+			x
<i>Angelica archangelica</i>	+	+	+	+	+		xxx
<i>Angelica sylvestris</i>	+	+	+	+	+	+	xxx
<i>Antennaria dioica</i>	+	+	+	+	+	+	xx
<i>Anthriscus sylvestris</i>	+	+	+	+	+	+	xx
<i>Bartsia alpina</i>	+	+	+	+	+	+	xxx
<i>Botrychium boreale</i>		+			+	+	x
<i>Botrychium lanceolatum</i>						+	(y)
<i>Botrychium lunaria</i>	+	+	+	+	+	+	xx
<i>Botrychium multifidum</i>						+	(y)
<i>Caltha palustris</i>	+	+	+	+	+	+	xx
<i>Campanula rotundifolia</i>	+	+	+	+	+	+	xx
<i>Cardamine pratensis</i> coll.	+	+		+	+	+	x
<i>Cerastium fontanum</i>	+	+	+	+	+	+	xx
<i>Cicerbita alpina</i>	+	+	+	+	+		xx
<i>Cirsium helenioides</i>	+	+	+	+	+	+	xx
<i>Cirsium palustre</i>	+	+	+	+	+	+	xx
<i>Coeloglossum viride</i>	+	+	+	+	+	+	xx

App. B Table 1 continued

	A	B	C	D	E	F	Freq.
<i>Convallaria majalis</i>	+	+	+	+			X
<i>Corallorhiza trifida</i>	+	+	+	+	+		X
<i>Cornus suecica</i>	+	+					X
<i>Crepis paludosa</i>	+	+	+	+	+		XXXX
<i>Dactylorhiza cruenta</i>	+	+	+	+	+		XXX
<i>Dactylorhiza fuchsii</i>	+	+	+	+	+		XXX
<i>Dactylorhiza incarnata</i>	+	+	+	+	+		XX
<i>Dactylorhiza maculata</i>	+	+	+	+	+		XXX
<i>Dactylorhiza pseudocordigera</i>	+	+	+	+	+		XXX
<i>Diphysium alpinum</i>	+					+	X
<i>Draba incana</i>						+	Y
<i>Drosera anglica</i>	+						(X)
<i>Dryopteris expansa</i>	+	+					(X)
<i>Epilobium alsinifolium</i>		+	+				X
<i>Epilobium angustifolium</i>	+	+	+	+	+	+	XX
<i>Epilobium davuricum</i>		+	+		+	+	X
<i>Epilobium hornemanii</i>	+	+	+	+			X
<i>Epilobium lactiflorum</i>	+	+	+	+			X
<i>Epilobium palustre</i>	+	+	+	+	+		XX
<i>Equisetum arvense</i>	+	+	+	+	+	+	X
<i>Equisetum fluviatile</i>	+						(X)
<i>Equisetum hyemale</i>	+	+	+	+	+	+	XX
<i>Equisetum palustre</i>	+	+	+	+	+	+	XXX
<i>Equisetum pratense</i>	+	+	+	+	+	+	XX
<i>Equisetum scirpoides</i>		+	+	+			X
<i>Equisetum sylvaticum</i>	+	+	+	+	+		XX
<i>Equisetum variegatum</i>	+	+	+	+	+	+	XXX
<i>Erigeron boreale</i>	+	+	+	+	+	+	XX
<i>Erigeron politus</i>						+	(Y)
<i>Euphrasia frigida</i>	+	+	+	+	+	+	XXX
<i>Euphrasia stricta</i>						+	Y
<i>Filipendula ulmaria</i>	+	+	+	+	+	+	XXX
<i>Galium boreale</i>	+	+	+	+	+	+	XXX
<i>Galium palustre</i>				+	+	+	X
<i>Galium trifidum</i>	+						X
<i>Galium uliginosum</i>				+	+	+	X
<i>Gentiana nivalis</i>		+		+	+	+	X
<i>Gentianella amarella</i>		+	+	+	+	+	X
<i>Gentianella campestris</i>	+	+	+	+	+	+	XX
<i>Geranium sylvaticum</i>	+	+	+	+	+	+	XXXX
<i>Geum rivale</i>	+	+	+	+	+	+	XXX
<i>Gnaphalium norvegicum</i>	+	+	+	+	+	+	XX
<i>Gymnadenia conopsea</i>	+	+	+	+	+	+	XXX
<i>Gymnocarpium dryopteris</i>	+	+	+	+	+		XXXX
<i>Hieracium spp.</i>	+	+	+	+	+	+	XXX
<i>Huperzia selago</i>	+	+	+	+	+		XX
<i>Knautia arvensis</i>						+	(Y)
<i>Leontodon autumnalis</i>	+	+	+	+	+	+	XXX
<i>Leucanthemum vulgare</i>	+	+	+	+		+	X
<i>Leucorchis albida</i>	+	+	+	+			X
<i>Linnaea borealis</i>	+	+	+	+	+	+	XX
<i>Listera cordata</i>	+	+	+	+	+		XX
<i>Listera ovata</i>	+	+	+	+	+		XXX
<i>Lycopodium annotinum</i>	+	+	+	+	+	+	XXX
<i>Lycopodium dubium</i>	+	+	+	+			X
<i>Maianthemum bifolium</i>	+	+	+	+	+		XX
<i>Melampyrum pratense</i>	+	+	+	+	+		XXX
<i>Melampyrum sylvaticum</i>	+	+	+	+	+	+	XXX
<i>Menyanthes trifoliata</i>	+	+	+	+	+		XX
<i>Montia fontana</i>				+			(X)
<i>Myosotis decumbens</i>	+	+	+	+	+	+	XXX
<i>Nigritella nigra</i>				+	+	+	X
<i>Orthilia secunda</i>	+	+	+	+			XX
<i>Oxalis acetosella</i>	+	+	+	+	+		XXX
<i>Paris quadrifolia</i>	+	+	+	+	+		XX
<i>Parnassia palustris</i>	+	+	+	+	+	+	XXX
<i>Pedicularis oederi</i>	+	+	+	+	+	+	XXX
<i>Pedicularis palustris</i>	+	+	+	+	+	+	XXX
<i>Pedicularis sceptrum-carolinum</i>				+	+		X
<i>Petasites frigidus</i>	+	+	+	+	+	+	XX
<i>Pinguicula vulgaris</i>	+	+	+	+	+		XXX
<i>Plantago major</i>		+				+	(X)
<i>Polygala amarella</i>			+	+	+		X
<i>Polygonatum verticillatum</i>	+	+	+	+	+		XX
<i>Polygonum viviparum</i>	+	+	+	+	+	+	XXX
<i>Potamogeton filiformis</i>	+						(X)
<i>Potamogeton gramineus</i>	+						(X)
<i>Potentilla crantzii</i>		+	+	+	+	+	X
<i>Potentilla erecta</i>	+	+	+	+	+	+	XXX
<i>Potentilla palustris</i>	+	+		+	+	+	X

App. B Table 1 continued

	A	B	C	D	E	F	Freq.
<i>Prunella vulgaris</i>		+		+			X
<i>Pyrola minor</i>	+	+	+	+	+	+	XX
<i>Pyrola rotundifolia</i>	+	+	+	+	+	+	XX
<i>Ranunculus acris</i>	+	+	+	+	+	+	XXX
<i>Ranunculus auricomus</i>		+		+	+	+	XX
<i>Ranunculus confervoides</i>	+						(X)
<i>Ranunculus platanifolius</i>	+	+	+	+	+		XXX
<i>Ranunculus repens</i>	+	+	+	+	+	+	XX
<i>Ranunculus reptans</i>	+	+	+		+	+	X
<i>Rhinanthus minor</i>	+	+	+	+	+	+	XX
<i>Rubus chamaemorus</i>	+	+	+	+	+		XXX
<i>Rubus idaeus</i>				+			(X)
<i>Rubus saxatilis</i>	+	+	+	+	+	+	XX
<i>Rumex acetosa</i>	+	+	+	+	+	+	XXX
<i>Rumex acetosella</i>		+	+	+	+	+	X
<i>Sagina procumbens</i>		+	+				X
<i>Sagina saginoides</i>	+		+			+	X
<i>Saussurea alpina</i>	+	+		+	+	+	XXX
<i>Saxifraga aizoides</i>	+	+	+	+	+	+	XXX
<i>Selaginella selaginoides</i>	+	+	+	+	+	+	XXX
<i>Silene dioica</i>	+	+	+	+	+	+	XXX
<i>Silene vulgaris</i>						+	(Y)
<i>Solidago virgaurea</i>	+	+	+	+	+	+	XXX
<i>Sparganium angustifolium</i>	+						(X)
<i>Sparganium minimum</i>		+					(X)
<i>Stellaria calycantha</i>	+	+	+	+	+	+	XX
<i>Stellaria graminea</i>	+			+		+	(X)
<i>Stellaria nemorum</i>				+		+	(X)
<i>Subularia aquatica</i>	+						(X)
<i>Succisa pratensis</i>	+	+	+	+	+	+	XXX
<i>Taraxacum sp.</i>	+	+	+	+	+	+	XX
<i>Thalictrum alpinum</i>	+	+	+	+	+	+	XXXX
<i>Thalictrum simplex</i>						+	(Y)
<i>Thelypteris phegopteris</i>	+						(X)
<i>Tofieldia pusilla</i>	+	+	+	+	+		XXX
<i>Trientalis europaea</i>	+	+	+	+	+	+	XXX
<i>Trifolium pratense</i>		+	+	+	+	+	X
<i>Trifolium repens</i>	+	+	+	+	+	+	XX
<i>Triglochin palustris</i>	+	+	+	+	+	+	XXX
<i>Trollius europaeus</i>	+	+	+	+		+	X
<i>Tussilago farfara</i>		+	+	+			(X)
<i>Urtica dioica</i>				+			(X)
<i>Utricularia minor</i>		+	+		+		XX
<i>Utricularia ochroleuca</i>					+	+	(X)
<i>Valeriana sambucifolia</i>	+	+	+	+	+	+	XXX
<i>Veronica alpina</i>		+		+			X
<i>Veronica scutellata</i>	+	+			+	+	X
<i>Veronica serpyllifolia</i>		+		+		+	X
<i>Viola biflora</i>	+	+	+	+	+	+	XXX
<i>Viola epipsila</i>	+	+	+	+	+	+	XXX
<i>Viola montana</i>					+	+	X
<i>Viola palustris</i>	+	+		+	+	+	XX
<b>Graminoids</b>							
<i>Agrostis canina</i>		+		+			X
<i>Agrostis capillaris</i>	+	+	+		+	+	XXX
<i>Agrostis mertensii</i>	+		+	+	+	+	XX
<i>Alopecurus aequalis</i>	+						(X)
<i>Anthoxanthum odoratum</i>	+	+	+	+	+	+	XXX
<i>Avenula pubescens</i>				+	+	+	(X)
<i>Calamagrostis purpurea</i>	+	+	+	+	+	+	XXX
<i>Calamagrostis stricta</i>		+	+	+	+	+	XX
<i>Carex appropinquata</i>		+					(X)
<i>Carex atrata</i>	+	+	+	+	+	+	X
<i>Carex atrofusca</i>	+	+	+	+	+		XXX
<i>Carex bigelowii</i>	+	+	+	+			X
<i>Carex brunnescens</i>	+	+		+	+	+	XX
<i>Carex buxbaumii</i>	+	+	+	+	+	+	XXX
<i>Carex canescens</i>	+	+	+	+	+	+	XX
<i>Carex capillaris</i>	+	+	+	+	+	+	XX
<i>Carex capitata</i>			+	+			X
<i>Carex chordorrhiza</i>	+	+	+	+			XX
<i>Carex dioica</i>	+	+	+	+	+	+	XXXX
<i>Carex echinata</i>	+	+	+	+	+		XX
<i>Carex flava</i>	+	+	+	+	+	+	XXXX
<i>Carex heleonastes</i>	+	+		+	+		X
<i>Carex hostiana</i>	+	+	+	+			XX
<i>Carex juncella</i>	+	+	+	+	+	+	XX
<i>Carex lasiocarpa</i>	+	+	+	+	+	+	XXXX
<i>Carex limosa</i>	+	+	+	+	+		XXXX

App. B Table 1 continued

	A	B	C	D	E	F	Freq.
<i>Carex livida</i>	+						(x)
<i>Carex magellanica</i>	+	+	+	+	+	+	xx
<i>Carex microglochin</i>		+	+			+	(x)
<i>Carex nigra</i>	+	+	+	+	+	+	xxxx
<i>Carex norvegica</i>	+	+	+	+	+	+	xx
<i>Carex ornithopoda</i>			+	+			(x)
<i>Carex pallens</i>	+	+	+	+	+		xxx
<i>Carex panicea</i>	+	+	+	+	+	+	xxx
<i>Carex pauciflora</i>	+	+	+	+	+		xx
<i>Carex rostrata</i>	+	+	+	+	+		xxxx
<i>Carex saxatilis</i>	+			+	+	+	x
<i>Carex stenolepis</i>	+						(x)
<i>Carex vaginata</i>	+	+	+	+	+	+	xxx
<i>Carex vesicaria</i>	+	+					x
<i>Deschampsia cespitosa</i>	+	+	+	+	+	+	xxxx
<i>Deschampsia flexuosa</i>	+	+	+	+	+	+	xxxx
<i>Eleocharis quinqueflora</i>	+	+	+	+	+		xx
<i>Eriophorum angustifolium</i>	+	+	+	+	+	+	xxx
<i>Eriophorum latifolium</i>	+	+	+	+	+	+	xxxx
<i>Eriophorum vaginatum</i>	+	+	+	+	+	+	xxxx
<i>Festuca ovina</i>	+	+	+	+	+	+	xxx
<i>Festuca rubra</i>	+	+	+	+	+	+	xxx
<i>Festuca vivipara</i>	+						(x)
<i>Hierochloa odorata</i>	+	+	+	+	+	+	xx
<i>Juncus alpino-articulatus</i>	+	+	+	+	+	+	xx
<i>Juncus bufonius</i>						+	(y)
<i>Juncus castaneus</i>	+	+	+	+	+	+	xx
<i>Juncus filiformis</i>	+	+	+	+	+	+	xx
<i>Juncus triglumis</i>	+	+	+	+	+	+	xxx
<i>Kobresia simpliciuscula</i>	+	+	+	+	+	+	xxxx
<i>Luzula multiflora</i> ssp. <i>frigida</i>	+	+	+	+	+	+	xxx
<i>Luzula mult.</i> ssp. <i>mult</i>						+	x
<i>Luzula pilosa</i>	+	+	+	+	+	+	xxx
<i>Luzula sudetica</i>	+	+	+	+	+	+	xxx
<i>Melica nutans</i>		+	+	+	+	+	xx
<i>Milium effusum</i>	+	+	+	+	+		xx
<i>Molinia caerulea</i>	+	+	+	+	+	+	xxxx
<i>Nardus stricta</i>	+	+	+	+	+	+	xxxx
<i>Phleum alpinum</i>	+	+	+	+	+	+	xx
<i>Phleum pratense</i>						+	(y)
<i>Poa alpigena</i>	+	+	+	+	+	+	xx
<i>Poa alpina</i>	+	+	+	+	+	+	x
<i>Poa annua</i>		+	+	+	+	+	xx
<i>Poa nemoralis</i>	+	+	+	+	+	+	xx
<i>Poa pratensis</i>	+	+	+	+	+	+	xx
<i>Poa remota</i>	+	+	+	+	+	+	xx
<i>Roegneria canina</i>		+	+	+	+	+	x
<i>Scirpus cespitosus</i>	+	+	+	+	+	+	xxxx
<i>Scirpus hudsonianus</i>	+	+	+	+	+	+	xx

Hybrides (and two taxa of *Dactylorhiza fuchsii*):

\*: The hybrid difficult to separate from the species.

<i>Betula nana</i> x <i>B. pubescens</i>	(x)
<i>Salix borealis</i> x <i>S. lapponum</i>	(?)
* <i>Salix borealis</i> x <i>S. nigricans</i>	xxx
<i>Salix borealis</i> x <i>S. phylicifolia</i>	x
<i>Salix glauca</i> x <i>S. myrsinitens</i>	xx
<i>Salix glauca</i> x <i>S. nigricans</i>	(x)
* <i>Salix nigricans</i> x <i>S. phylicifolia</i>	xx
<i>Coeloglossum viride</i> x <i>Dactylorhiza fuchsii</i> (pink)	(x)
<i>Coeloglossum viride</i> x <i>Dactylorhiza maculata</i>	(x)
* <i>Dactylorhiza cruenta</i> x <i>D. incarnata</i>	x
<i>Dactylorhiza cruenta</i> x <i>D. maculata</i> /D. <i>fuchsii</i>	x
<i>Dactylorhiza cruenta</i> x <i>D. pseudocordigera</i>	xxx
<i>Dactylorhiza cruenta</i> x <i>Gymnadenia conopsea</i>	(x)
<i>Dactylorhiza fuchsii</i> - (pale)	xxx
<i>Dactylorhiza fuchsii</i> - (pink + leaves with spots)	xxx
<i>Dactylorhiza fuchsii</i> (pale) x <i>D. incarnata</i>	(x)
* <i>Dactylorhiza fuchsii</i> x <i>D. maculata</i>	xx
<i>Dactylorhiza fuchsii</i> x <i>D. pseudocordigera</i>	x
<i>Dactylorhiza fuchsii</i> x <i>Gymnadenia conopsea</i>	(x)
<i>Dactylorhiza maculata</i> x <i>D. pseudocordigera</i>	xx
<i>Dactylorhiza maculata</i> x <i>Gymnadenia conopsea</i>	(x)
<i>Epilobium hybrides</i>	?
<i>Carex atrata</i> x <i>C. norvegica</i>	(x)
<i>Carex flava</i> x <i>C. hostiana</i>	xx
* <i>Carex panicea</i> x <i>C. vaginata</i>	xx
<i>Carex rostrata</i> x <i>C. saxatilis</i>	(x)
<i>Carex saxatilis</i> x <i>C. stenolepis</i>	(x)

## APPENDIX B

Table 2 Species list of the bryophytes found on the Sølendet nature reserve. Prepared by Anne A. Frisvoll &amp; Asbjørn Moen. Scale of frequency:

(x)	: Very rare
x	: Rare
xx	: Fairly common
xxx	: Very common
xxxx	: Very common and often dominant
y	: Only outside the reserve

Mosses	Freq.		Freq.
Amblyodon dealbatus	(x)	Dicranum scoparium	xxx
Amblystegium jungermannoides	x	Dicranum spadiceum	x
Amblystegium serpens	(x)	Didymodon fallax	(x)
Andreaea rupestris	x	Distichium capillaceum	xxx
Aongstroemia longipes	(x)	Ditrichum cylindricum	(x)
Aulacomnium palustre	xxx	Ditrichum flexicaule	xxx
Bartramia ithyphylla	x	Ditrichum pusillum	(x)
Bartramia pomiformis	(x)	Drepanocladus badius	x
Blindia acuta	x	Drepanocladus exannulatus	x
Brachythecium mildeanum	x	Drepanocladus fluitans	x
Brachythecium reflexum	xxxx	Drepanocladus revolvens s.l.	xxxx
Brachythecium rivulare	(x)	Drepanocladus sendtneri	(x)
Brachythecium salebrosum	xxx	Drepanocladus tundrae	(x)
Brachythecium starkei	x	Drepanocladus uncinatus	xxxx
Brachythecium turgidum	x	Dryptodon patens	(x)
Brachythecium velutinum	(x)	Fissidens adianthoides	xxx
Bryoerythrophyllum recurvirostrum	x	Fissidens bryoides	x
Bryum argenteum	(x)	Fissidens osmundoides	xxx
Bryum capillare s.l.	(x)	Funaria hygrometrica	xxx
Bryum creberrimum	x	Gymnostomum aeruginosum	(x)
Bryum inclinatum	x	Homalothecium nitens	xxxx
Bryum pallens	xx	Hypnophyllum luridum	x
Bryum pallescens	x	Hylocomium pyrenaicum	xxx
Bryum pseudotriquetrum	xxxx	Hylocomium splendens	xxxx
Bryum weigelii	xx	Hylocomium umbratum	x
Calliergon cordifolium	x	Hypnum bambergeri	x
Calliergon giganteum	xxx	Hypnum lindbergii	xx
Calliergon richardsonii	xx	Hypnum pratense	xx
Calliergon samentosum	xx	Isopterygium pulchellum	(x)
Calliergon stramineum	xxx	Klaeria blyttii	(x)
Calliergon trifarium	xxx	Leptobryum pyriforme	x
Calliergonella cuspidata	xx	Lescuraea incurvata	x
Campylium chrysophyllum	(y)	Lescuraea radicata	(x)
Campylium polygamum	(x)	Meesia triquetra	xx
Campylium sommerfeltii	x	Meesia uliginosa	xxx
Campylium stellatum	xxxx	Mnium ambiguum	x
Catoscopium nigrum	x	Mnium spinosum	xxx
Ceratodon purpureus	xxxx	Mnium stellare	xxx
Cinclidium stygium	xxxx	Oligotrichum hercynicum	(x)
Cirriphyllum piliferum	x	Oncophorus virens	xxx
Climacium dendroides	xx	Paludella squarrosa	xxx
Cratoneuron commutatum	xxxx	Paraleucobryum longifolium	xxxx
Cratoneuron decipiens	xxx	Philonotis calcarea	xx
Cratoneuron filicinum	x	Philonotis fontana	xxx
Ctenidium molluscum	x	Philonotis tomentella	(x)
Cynodontium strumiferum	(x)	Plagiomnium elatum	xxx
Cynodontium tenellum	(x)	Plagiomnium ellipticum	xxx
Desmatodon latifolius	(x)	Plagiothecium cavifolium	x
Dichelyma falcatum	(x)	Plagiothecium curvifolium	x
Dichodontium pellucidum	x	Plagiothecium denticulatum	xxx
Dicranella cerviculata	(x)	Plagiothecium laetum	x
Dicranella crispa	(x)	Pleurozium schreberi	xxxx
Dicranella grevilleana	(x)	Pogonatum urnigerum	x
Dicranella palustris	x	Pohlia bulbifera	x
Dicranella subulata	(x)	Pohlia cruda	xx
Dicranoweisia crispula	xxx	Pohlia drummondii	x
Dicranum affine	xxxx	Pohlia filum	x
Dicranum acutifolium (=D. muehlenb.)	(x)	Pohlia nutans	xxx
Dicranum angustum	xx	Pohlia prolifera	(x)
Dicranum bonjeanii	xxx	Pohlia wahlenbergii	xx
Dicranum drummondii	x	Polytrichum alpinum	x
Dicranum elongatum	x	Polytrichum commune	xxxx
Dicranum fuscescens s.l.	xxx	Polytrichum formosum	x
Dicranum majus	xxx	Polytrichum hyperboreum	(x)
Dicranum montanum	xx	Polytrichum juniperinum	xxx



App. B Table 2 continued

	Freq.		Freq.
<i>Polytrichum longisetum</i>	x	<i>Calyptogeia integristipula</i>	xx
<i>Polytrichum piliferum</i>	x	<i>Calyptogeia neesiana</i>	x
<i>Polytrichum strictum</i>	xxx	<i>Calyptogeia sphagnicola</i>	xx
<i>Pseudobryum cinclidioides</i>	xx	<i>Cephalozia bicuspidata</i>	xxx
<i>Pseudoleskeella nervosa</i>	(x)	<i>Cephalozia leucantha</i>	x
<i>Pterigynandrum filiforme</i>	(x)	<i>Cephalozia loitlesbergeri</i>	x
<i>Ptilium crista-castrensis</i>	(x)	<i>Cephalozia lunulifolia</i>	xxx
<i>Racomitrium aciculare</i>	(x)	<i>Cephalozia pleniceps</i>	x
<i>Racomitrium canescens</i>	(x)	<i>Cephaloziaella</i> spp.	x
<i>Racomitrium ericoides</i>	x	<i>Chiloscyphus pallescens</i>	xx
<i>Racomitrium fasciculare</i>	(x)	<i>Conocephalum conicum</i>	(x)
<i>Racomitrium microcarpon</i>	xxxx	<i>Cryptothallus mirabilis</i>	(x)
<i>Racomitrium sudeticum</i>	(x)	<i>Diplophyllum taxifolium</i>	(x)
<i>Rhizomnium magnifolium</i>	xxx	<i>Gymnocolea inflata</i>	x
<i>Rhizomnium pseudopunctatum</i>	xxx	<i>Harpanthus flotoianus</i>	xxx
<i>Rhizomnium punctatum</i>	xx	<i>Hygrobiella laxifolia</i>	(x)
<i>Rhodobryum roseum</i>	xxx	<i>Jungermannia atrovirens</i>	(x)
<i>Rhytidadelphus squarrosus</i>	xxx	<i>Jungermannia exsertifolia</i>	xx
<i>Rhytidadelphus subpinnatus</i>	xx	<i>Jungermannia obovata</i>	x
<i>Rhytidadelphus triquetrus</i>	xx	<i>Jungermannia sphaerocarpa</i>	xx
<i>Saelania glaucescens</i>	(x)	<i>Lophocolea bidentata</i>	xx
<i>Schistidium agassizii</i>	(x)	<i>Lophocolea minor</i>	x
<i>Schistidium apocarpum</i> s.l.	x	<i>Lophozia bantriensis</i>	xxx
<i>Scorpidium scorpioides</i>	xxxx	<i>Lophozia bicrenata</i>	y
<i>Sphagnum angustifolium</i>	xxx	<i>Lophozia borealis</i>	xxx
<i>Sphagnum balticum</i>	x	<i>Lophozia excisa</i>	x
<i>Sphagnum capillifolium</i>	xxx	<i>Lophozia gillmanii</i>	x
<i>Sphagnum centrale</i>	xx	<i>Lophozia grandiretis</i>	x
<i>Sphagnum contortum</i>	(x)	<i>Lophozia heterocolpos</i>	xxx
<i>Sphagnum fuscum</i>	xxxx	<i>Lophozia incisa</i>	x
<i>Sphagnum girgensohnii</i>	xxx	<i>Lophozia laxa</i>	x
<i>Sphagnum jensenii</i>	x	<i>Lophozia longidens</i>	xxx
<i>Sphagnum lindbergii</i>	x	<i>Lophozia obtusa</i>	xx
<i>Sphagnum n.n.</i>	xx	<i>Lophozia rutheana</i>	xxx
<i>Sphagnum platyphyllum</i>	x	<i>Lophozia ventricosa</i>	xxx
<i>Sphagnum riparium</i>	x	<i>Lophozia wenzelii</i>	(x)
<i>Sphagnum russowii</i>	xxx	<i>Marchantia alpestris</i>	xxx
<i>Sphagnum subnitens</i>	(x)	<i>Marchantia polymorpha</i>	x
<i>Sphagnum teres</i>	x	<i>Moerckia hibernica</i>	x
<i>Sphagnum warnstorffii</i>	xxxx	<i>Mylia anomala</i>	xxx
<i>Splachnum luteum</i>	(x)	<i>Mylia taylorii</i>	(x)
<i>Splachnum sphaericum</i>	(x)	<i>Nardia geoscyphus</i>	x
<i>Splachnum vasculosum</i>	xx	<i>Odontoschisma elongatum</i>	x
<i>Tayloria lingulata</i>	xx	<i>Pellia neesiana</i>	xx
<i>Tayloria tenuis</i>	(x)	<i>Plagiochila asplenoides</i>	(x)
<i>Tetraphis pellucida</i>	xx	<i>Plagiochila porelloides</i>	xxx
<i>Tetraplodon mnioides</i>	(x)	<i>Pleurocladula albescens</i>	(x)
<i>Thuidium recognitum</i>	xx	<i>Preissia quadrata</i>	x
<i>Tortella fragilis</i>	xx	<i>Ptilidium ciliare</i>	xxx
<i>Tortella tortuosa</i>	xxx	<i>Ptilidium pulcherrimum</i>	xx
<i>Tortula ruralis</i>	(y)	<i>Riccardia latifrons</i>	x
<i>Hepatics</i>		<i>Scapania aequiloba</i>	xx
<i>Anastrophyllum minutum</i>	xxx	<i>Scapania curta</i>	x
<i>Aneura pinguis</i>	xxx	<i>Scapania hyperborea</i>	(x)
<i>Anthelia juratzkana</i>	(x)	<i>Scapania irrigua</i>	xxx
<i>Barbilophozia attenuata</i>	xxx	<i>Scapania paludicola</i>	x
<i>Barbilophozia barbata</i>	(x)	<i>Scapania paludosa</i>	x
<i>Barbilophozia binsteadii</i>	xx	<i>Scapania subalpina</i>	x
<i>Barbilophozia floerkei</i>	xx	<i>Scapania umbrosa</i>	(x)
<i>Barbilophozia hatcheri</i>	xx	<i>Scapania undulata</i>	(x)
<i>Barbilophozia kunzeana</i>	xxx	<i>Tritomaria polita</i>	xxx
<i>Barbilophozia lycopodioides</i>	xxxx	<i>Tritomaria quinquedentata</i>	xx
<i>Barbilophozia quadriloba</i>	xxx		
<i>Blasia pusilla</i>	(x)		
<i>Blepharostoma trichophyllum</i>	xxx		

# APPENDIX C. ECOLOGICAL AND PHYTOSOCIOLOGICAL TABLES FOR MIRE AND SPRING VEGETATION AT SØLENDET

Table 1 Details of the 80 stands used for the mire and spring vegetation analyses in section 5.

Cl. = cluster; R = residual sample. Further details in table 1 of Appendix A.

Cl. no.	Stand sample no.	Locality and stand quadrats	Ng. x size in m <sup>2</sup> of small quadrats
M1	068	68	5x0.25
	190	73b	5x0.25
M2	067	67A+B	5x0.25
	073	73a	5x0.25
	096	96	5x0.25
M3	007	7A+B	5x0.25
	015	15A+B	5x0.25
	065	65A+B	5x0.25
	069	69A+B	5x0.25
	200	69D	2x0.25
M4	001	1A+B	5x0.25
	009	9A+B	5x0.25
	010	10A+B	5x0.25
	012	12A+B	5x0.25
	061	61A+B	5x0.25
	063	63A+B	5x0.25
	064	64A+B	5x0.25
	110	110D+C	3x0.25
	111	111A+B	3x0.25
	112	111D+U	3x0.25
	115	111C	3x0.25
	116	1D	3x0.25
	117	1U	2x0.25
	198	61E	2x0.25
M5	002	2A+B	5x0.25
	121	2C	3x0.25
	122	2F	3x0.25
	123	2J+U	2x0.25
M6	004	4A+B	5x0.25
	006	6A+B	5x0.25
	011	11A+B	5x0.25
	013	13A+B	5x0.25
	014	14A+B	5x0.25
	016	16A+B	5x0.25
	087	87	5x0.25
	140	4A	3x0.25
	141	4C+D+E	3x0.25
	144	4D+G	2x0.25
	147	4G	2x0.25
	201	13C	2x0.25
M7	003	3A+B	5x0.25
	101	101	3x0.25
	102	102+101	3x0.25
	131	3F	2x0.25

Cl. no.	Stand sample no.	Locality and stand quadrats	Ng. x size in m <sup>2</sup> of small quadrats
M8	074	74A+B	5x0.25
	192	74c	2x0.25
M9	104	104	1x1
	274	prf1 q7-8	2:1.9, 1.0
	275	prf1 q9	1x2.5
	279	prf1 q18-20	3:1.8, 0.7, 0.7
M10	070	70A+B	5x0.25
	199	70D	2x0.25
M11	017	17A+B	5x0.25
	018	18A+B	5x0.25
M12	019	19	5x0.25
	062	62	5x0.25
	099	99	2:0.5, 1.0
	276	prf1 q11-12	2:2.5, 1.7
M13	277	prf1 q15	1x4
	278	prf1 q16-17	2:4.1, 2.1
	280	prf1 q13-14	2:3.7, 4.1
M14	082	82	4x4
	083	83	2x4
	103	103	1x4
M15	084	84	1x4
	085	85	1x4
M16	095	95	3x0.25
	194	92c	4x0.25
	197	94b	2x0.25
M17	093	93a+b	3x1
	195	93c	4x0.25
	196	93d	4x0.25
M18	071	71	5x0.25
	089	89	1x4
MR	060	60	5x0.25
	066	66	5x0.25
	091	91	4x0.25
	092	92a	2x0.25
	098	98	2x1
	193	92b	2x0.25



## APPENDIX C

Table 3 Mire and spring vegetation at Sølendet, cf. section 5. Complete list of species, with cover values for the 74 samples in the 18 clusters, M1-18. A: tree layer; B: shrub layer. II. Constant species of one or two neighbouring clusters. III. Constant species of other clusters. IV. Species not constant in any cluster. V. Single occurrence. Limit for constants: 70%.

Cluster no. (M)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Sample no.	69 80	679 736	6 601 57905	61911611 45807116132290	11 1 22 2	1211 1 8 140441141	111 030	1 79	1222 0777	1 79	11 11	2 7169	222 877	1 088	88 999	1 1 999	11 999	87 91
II Carex flava x C. hostiana	..	..	..	..	2usu	..	..	..	..	..	..	..	..	..	..	..	..	..
Ditrichum flexicaule	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Tortella tortuosa	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Betula nana - B	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Salix nigricans coll. - B	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Salix nigricans coll.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Listera ovata	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Hylocomium pyrenaicum	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Pleurozium schreberi	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Barbilophozia lycopodioides	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Rhinanthus minor	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Agrostis capillaris	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Anthoxanthum odoratum	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Paludella squarrosa	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Rhizomnium pseudopunctatum	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Luzula sudetica	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Aulacomnium palustre	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Vaccinium myrtillus	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Dicranum angustum	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Dicranum bonjeanii	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Barbilophozia kunzeana	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Cephalozia lunulifolia coll.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Lophozia ventricosa	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Triglochin palustre	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Utricularia minor	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Carex limosa	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Carex heleonastes	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Carex magellanica	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Juncus triglumis	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Moerckia hibernica	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Salix phylicifolia	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Plagiomnium elatum	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Salix glauca	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Ranunculus acris	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Hierochloa odorata	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Salix glauca - B	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Alchemilla sp.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Rumex acetosa	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Calamagrostis purpurea	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Chiloscyphus pallescens	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Pellia neesiana	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Cicerbita alpina	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Epilobium angustifolium	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Equisetum sylvaticum	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Stellaria calycantha	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

App. C Table 3 continued

Cluster no. (M)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Sample no.	69 80	679 736	6 601 57905	61911611 45807116132290	611 1 22 2	11 1 8 140441141	111 030	1222 0777	1 09	11 78	2 6929	222 087	1 088	88 45	1 1 999	1 1 999	87 653	87 91
<i>Trientalis europaea</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Brachythecium reflexum</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Harpanthus flotovianus</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Lophozia obtusa</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Carex atrofusca</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Cratoneuron decipiens</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Philonotis calcarea</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Cratoneuron commutatum</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Equisetum arvense</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Philonotis fontana/toment.</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Polytrichum strictum</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Sphagnum fuscum</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Calypogeia sphagnicola</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Cephalozia pleniceps</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Mylia anomala</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
III <i>Carex lasiocarpa</i>	1u	111	1s343	331441434u4ss.	....	u+2.1.111.u.	....	u.	....	13	..	....	....	....	....	u..	321	..
<i>Carex rostrata</i>	13	u12	..sus	u1.1u.2u1su11.	....	....	....	....	....	23	..	....	....	....	....	..	321	..
<i>Eleocharis quinqueflora</i>	11	22+	s2s..	s....	....	....	....	....	....	11	u.2u	....	....	....	..	s..	..	..
<i>Eriophorum angustifolium</i>	u1	11u	uuu1s	1u111uuuu11s1u	uuuu	1su111u1su+u	..	1.	1u.	u1	1s	2221	211	1s	..	1	u..	..
<i>Calliergon trifarium</i>	11	1u1	s.uu.	..u.	..u.	..u.	..u.	..s	..	..	11su	..	..	..	..	..	..	..
<i>Drepanocladus revolvens</i>	u1	344	34343	335u151uu3+133	3231	u32uuu112u11	2213	..	..u.	+	44	5544	544	..	..	s..	..	..
<i>Scorpidium scorpioides</i>	22	543	2....	....	....	....	....	....	..	..	us	113u	u11	..	..	..	..	..
<i>Andromeda polifolia</i>	..	uu1	11uu	u.1..u.	....	....	1..	u.1.	..	11	..	..s.	..	..	..	..	1u	..
<i>Euphrasia frigida</i>	..	sss	ss.us	2+uu.+..u	..11	u...u.1....	..+	..	s...	..	..	..	..	..	..	uu	..	..
<i>Menyanthes trifoliata</i>	1.	1ss	s3...	2....	....	....	....	....	..	23	..	..	..	..	..	..	..	..
<i>Pedicularis palustris</i>	..	1u+	1s+u.	1uuu1uu1+suuuu	....	u..s.	....	....	..	u.	u1	1uu1	111	u.	..	..	..	..
<i>Carex dioica</i>	..	111	11111	11121111211121	1111	222123111121	1111	1.	s2u1	12	11	1111	121	u.	..	1uu	..	..
<i>Eriophorum latifolium</i>	..	11u	s1s+	uu3...3...3.131	2221	3usu.u.+..u.	..	..	..	..	..	..	..	..	..	..	..	..
<i>Scirpus cespitosus</i>	..	223	43332	u3314313243144	4334	211433uu1323	3231	u.	..	11	..	3u3u	..	..	..	..	..	..
<i>Campylium stellatum</i>	..	u44	54556	45355364565645	6666	345246655455	5656	2u	21uu	..	2	3231	234	2.u	..	u..	..	..
<i>Cinclidium stygium</i>	..	u1u	u1u+	1.1u.s...+1.u.s	..u.	uuu11+1.us.s	....	u.	s2.1	..	s	1112	1.1	11	1.	u.u	..	..
<i>Aneura pinguis</i>	..	s	11u	uus1s	1u1...1...1uu1u	..u.	uuu11+1.us.s	....	u.	s2.1	..	s	1112	1.1	11	1.	u.u	..
<i>Lophozia rutheana</i>	..	suu	..ss1	212+u3u1uuu3u	..u	u.s...1u..u.u	....	..	..	..	2	2us1	u.1	..	..	..	..	..
<i>Betula nana</i>	..	..	s.uu1	u.u..u...1....	..s.	....1u.11us	3u3u	24	..3u1	12	..s	..u	..1	..	..	..	..	..
<i>Dactylorhiza cruenta</i>	..	..	..uu+s	uuuuuuuu+uu..	uuu.	....1..u..u.	..u.	..	..	..	++	1++	..	..	..	..	..	..
<i>Equisetum palustre</i>	..	..	uuu+	111u1u11u1u1s.	u111	1.u1u111u1..	..u.	..	s1u1	11	21	2111	323	s32	..	+	uu1	..
<i>Equisetum variegatum</i>	..	..	u11+1	1u1u11111uu1u	11u1	21111111111u	uuu1	1.	s...	11	1u	..1	..	s..	..	uu	s..	..
<i>Pinguicula vulgaris</i>	..	..	..ss	1s1s	s.1..u...u.suu	u.u1	s11uuuu1suu.	u+u.	..	..	..	..	..	..	..	s..	..	..
<i>Selaginella selaginoides</i>	..	..	u111u1	1uuuu11u1111u1	1111	u121u11u1111	1211	u+	s111	1u	..	u..u	u.	s..	..	s..	..	..
<i>Thalictrum alpinum</i>	..	..	u1	22112	1222233313223	3333	224333433444	4234	22	3322	u2	..u	21su	321	2..	..	1uu	..
<i>Toffeldia pusilla</i>	..	..	..u	sus..u	u1...1..su.uu1	1111	111uu.+u1u.	u111	..	u22u	..	2	2u1u	222	..	..	..	..
<i>Carex panicea</i>	..	..	..11	21222	2121221212121	2211	222u22123312	3212	1.	u22u	..	2	2u1u	222	..	..	..	..
<i>Molinia caerulea</i>	..	..	..u1	32222	3222212322323	2212	22323233232	3342	33	..	..	+	..	..	..	s..	..	..
<i>Bryum pseudotriquetrum</i>	..	..	..u.	u1u1u	111u11u2u11111	uuuu	u111111111u1u	u1u1	u.	..u.	u	12	1113	2u1	21u	..	121	s..
<i>Fissidens adianthoides</i>	..	..	..uu211	31u32113214u1u	uuu1	u12u2112113u	1u1u	1.	..	..	..	u...	..1	s..	..	..	..	..
<i>Lophozia borealis</i>	..	..	..s1	s.u11	s1+uuu11.1..u	1111	u.1.uu1u21	1211	..	..	..	..	..	..	..	..	..	..
<i>Polygonum viviparum</i>	..	..	..	..s	uu1+11uuuuu11u	..su	111111u11u11	1111	u+	u121	11	1u	1u11	111	12.	..	11.	..
<i>Potentilla erecta</i>	..	..	..s	..s	u12312332u3332	2222	32231221.u1u	uuuu	su	21	..	..	..	..	..	..	..	..
<i>Saussurea alpina</i>	..	..	..	..s.u1	u.1u111u111u2	22u1	2uu111u11u2	12uu	23	3332	12	..	..	uu+	212	12	341	2..
<i>Carex flava</i>	..	..	..	..u..s	uu2121u11121u1	1uuu	ss222422u121	....	..	1.1.	..	11	21u1	311	1..	..	..	..



App. C Table 3 continued

Cluster no. (M)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Sample no.	69 80	679 736	6 601 57905	1111 11 1 61911611 611 1	11 1 22 2	8 140441141 764141076314	111 030	79 0777 2113	1 1222 4594	79 0777 09	11 2 78	2 7169 6929	222 1 087	1 088 332	88 999 45	1 1 457	11 999 653	87 91
Sphagnum warnstorffii	..	..	..	..	..	4.s2...+s31.	..	..	5544	56	.s	..	uu1	264	11	..	..	..
Dactylorhiza pseudocordig.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Pedicularis oederi	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Saxifraga aizoides	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Succisa pratensis	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Carex capillaris	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Carex hostiana	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Kobresia simpliciuscula	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Angelica sylvestris	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Bartsia alpina	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Crepis paludosa	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Gymnadenia conopsea	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Leontodon autumnalis	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Carex vaginata	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Deschampsia cespitosa	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Nardus stricta	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Homalothecium nitens	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Barbilophozia quadriloba	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Tritomania quinqueidentata	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Festuca ovina	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Galium boreale	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Geranium sylvaticum	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Hylocomium splendens	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Salix lapponum	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Parnassia palustris	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Viola palustris/epipsila	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Carex nigra	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Plagionium ellipticum	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Empetrum hermaphroditum	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Oxycoccus microcarpus	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Vaccinium uliginosum	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Filipendula ulmaria	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Geum rivale	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Listera cordata	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Solidago virgaurea	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Eriophorum vaginatum	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Pohlia nutans	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Caltha palustris	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Epilobium palustre	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Potentilla palustris	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Calliergon giganteum	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Meesia triquetra	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Epilobium alsinifolium	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
IV Salix pentandra - A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Betula pubescens - B	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Salix lapponum - B	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Salix pentandra - B	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Salix phylicifolia - B	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Betula pubescens	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Calluna vulgaris	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

App. C Table 3 continued

Cluster no. (M)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Sample no.	69 80	679 736	6 601 57905	1111 11 1 61911611 611 1 45807116132290	11 1 22 2	1211 1 8 140441141 764141076314	111 030	1 2113	1222 0777	1 79	2 11	2 7169	222 877	1 088	88 45	1 1 999 999	11 653	87 91
<i>Juniperus communis</i>	..	..	..	..	u.u.	..s...u....	u.+.	..	..	..	..	1s.	..	..	..	..	..	..
<i>Salix hastata</i>	..	..	..	..	s.	..	..	..	..	..	..	1s.	..	..	..	..	..	..
<i>Salix myrsinites</i>	..	..	..	..	..	..	..	..	..	..	..	1s.	..	..	..	..	..	..
<i>Salix pentandra</i>	..	..	..	..	..	..	..	..	..	..	..	u..1	..	..	..	..	..	..
<i>Salix reticulata</i>	..	..	..	..	..	..	..	..	..	..	..	u..1	..	..	..	..	..	..
<i>Vaccinium vitis-idaea</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Antennaria dioica</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Cardamine pratensis</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Cirsium helenioides</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Cirsium palustre</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Coeloglossum viride</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Dactylorhiza incarnata</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Dactylorhiza maculata</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Epilobium hornemanii</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Equisetum scirpoides</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Erigeron boreale</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Melampyrum sylvaticum</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Paris quadrifolia</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Petasites frigidus</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Pyrola minor</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Pyrola rotundifolia</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Viola biflora</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Agrostis mertensii</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Calamagrostis stricta</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Carex buxbaumii</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Carex canescens</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Carex capitata</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Carex saxatilis</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Deschampsia flexuosa</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Festuca rubra</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Juncus castaneus</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Luzula multiflora</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Phleum alpinum</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Scirpus hudsonianus</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Brachythecium mildeanum</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Brachythecium turgidum</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Bryum weigelii</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Calliergon richardsonii</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Calliergon sarmentosum</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Calliergon stramineum</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Drepanocladus badius</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Drepanocladus uncinatus</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Fissidens osmundoides</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Hypnum bambergeri</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Hypnum lindbergii</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Hypnum pratense</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Meesia uliginosa</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Pohlia wahlenbergii</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Rhizomnium magnifolium</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Sphagnum angustifolium</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Sphagnum contortum</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

App. C Table 3 continued

Cluster no. (M)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Sample no.	1 69 80	2 679 736	3 6 57905	4 61911611 45807116132290	5 111111 222	6 121111 8140441141	7 111 030	8 1 79	9 1222 0777	10 1 79	11 2 7169	12 222 877	13 1 088	14 88 332	15 999 45	16 11 457	17 11 653	18 87 91
<i>Jungermannia exsertifolia</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Lophozia bantriensis/gillma.</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Marchantia alpestris</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Plagiochila porelloides</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Scapania irrigua</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Tritomaria polita</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

## V Additional species (cluster no. - sample no.):

- 2 - 73: *Juncus alpino-articulatus* s;  
 3 - 7: *Catoscopium nigrum* 1;  
 4 - 12: *Carex chordorrhiza* 4;  
 6 - 87: *Thuidium recognitum* s;  
 6 - 4: *Pressia quadrata* s;  
 6 - 14: *Juncus filiformis* s;  
 7 - 101: *Blepharostoma trichophyllum* u, *Scapania aequiloba* u;  
 8 - 192: *Rhytidadelphus squarrosus* u;  
 9 - 104: *Ranunculus repens* s, *Scapania paludicola* s;  
 9 - 279: *Ranunculus auricomus*, *Taraxacum* sp. u, *Carex norvegica* u, *Bryum* sp. u, *Climacium dendroides* 2;  
 10 - 70: *Hieracium* sect. *Vulgata* +, *Dicranum majus* 1, *Sphagnum* n.n. 1;  
 12 - 99: *Carex stenolepis* 3, *C. vesicaria* +, *Tayloria lingulata* u;  
 13 - 277: *Galium palustre* 1, *Distichium capillaceum* 1;  
 14 - 103: *Epilobium lactiflorum* s, *Equisetum pratense* s, *Poa pratensis* s;  
 14 - 83: *Cerastium fontanum* 1;  
 14 - 82: *Salix nigricans* coll. A +, *Angelica archangelica* +, *Valeriana sambucifolia* 1, *Poa remota* 2, *Sphagnum subnitens* 1;  
 15 - 85: *Betula pubescens* A 2, *Rhodobryum roseum* 4;  
 16 - 194: *Salix arbuscula* u, *Oncophorus virens* s;  
 16 - 95: *Poa alpigena* u, *Cratoneuron filicinum* 1;  
 17 - 93: *Drepanocladus exannulatus* 4;  
 18 - 89: *Lophozia laxa* 1;  
 18 - 71: *Arctostaphylos alpina* u, *Rubus chamaemorus* 3, *Carex pauciflora* s, *Dicranum affine* 2, *D. fuscescens* s, *Sphagnum russowii* 3, *Barbilophozia binsteadii* s, *Cephalozia leucantha* 3, *Cladina arbuscula* coll. s.

## APPENDIX C

Table 4 The species composition of the rich fen vegetation at Sølandet for the 15 clusters (a-o) resulting from the 97-sample data set analyses of section 6. Three residual samples are omitted, the 94 samples listed are 57 samples dealt with in section 5 plus 37 of Gaare's samples of section 6.1. These are the complete lists of vascular plants, mosses and lichens, hepatic species omitted. Species groups II - V and the letters A and B as in table 3 of Appendix C. Limits for constant species = 70%.

Clusters no.	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o
Sample no.	1 69 80	697 763	11 87	69187 29906	3233222333 1634578256	2 6061 75095	111111 91 9 9 6111911 4166313 1 40578161021382990	11 1 22 2 3221	9 9 282 473	999 1 1 9929911 201141410102244 0581744349121014	9 9 9999 19 111 1101 30 66567314312	91199999999 0000001011 9218760321	1 79 42	22 77 54	1 97 90
II <i>Menyanthes trifoliata</i>	1. 1ss 32	.....	4s..+555..	3s... 2.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Caltha palustris</i>	.. .. 1+	..u21	..s..+	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Epilobium palustre</i>	.. .. ut	..u.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Potentilla palustris</i>	.. .. uu	..u1u	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Triglochin palustre</i>	.. .. ut	s...u	.....	s.+s.	u...u.+...u...u.	..uu.	.....	s..s.	.....+	.....	.....	.....	s..	.....	.....
<i>Utricularia minor</i>	.. .. +u	uu	u...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Carex limosa</i>	.. .. 1	23	12	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Carex heleonastes</i>	.. .. u2	s21u1	1.....	..s	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Calliergon giganteum</i>	.. .. 23	u.232	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Meesia triquetra</i>	.. .. 12	22222	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Carex magellanica</i>	.. .. ..	uu1u	u...u.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Calliergon richardsonii</i>	.. .. ..	2..u	u.uu.s+uuu	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Drepanocladus badius</i>	.. .. s.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Carex flava</i> x <i>C. hostiana</i>	.. .. ..	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Carex hostiana</i>	.. .. ..	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Dactylorhiza maculata</i>	.. .. ..	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Scirpus hudsonianus</i>	.. .. s+	u..+	..s.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Calliergon stramineum</i>	.. .. ..	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Ditrichum flexicaule</i>	.. .. ..	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Juniperus communis</i>	.. .. ..	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Tortella tortuosa</i>	.. .. ..	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Pleurozium schreberi</i>	.. .. ..	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Betula nana</i> - B	.. .. ..	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Salix nigricans</i> coll. - B	.. .. ..	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Salix nigricans</i> coll.	.. .. ..	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Geranium sylvaticum</i>	.. .. ..	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Listera ovata</i>	.. .. ..	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Hylocomium pyrenaicum</i>	.. .. ..	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Rhinanthus minor</i>	.. .. ..	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Viola palustris/epipsila</i>	.. .. ..	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Agrostis capillaris</i>	.. .. ..	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Plagiomnium elliptikum</i>	.. .. ..	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Rhizomnium pseudopunctatum</i>	.. .. ..	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Eriophorum vaginatum</i>	.. .. ..	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Luzula sudetica</i>	.. .. ..	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Empetrum hermaphroditum</i>	.. .. ..	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Oxycoccus microcarpus</i>	.. .. ..	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Vaccinium myrtillus</i>	.. .. ..	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Vaccinium uliginosum</i>	.. .. ..	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Geum rivale</i>	.. .. ..	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Listera cordata</i>	.. .. ..	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Solidago virgaurea</i>	.. .. ..	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Dicranum angustum</i>	.. .. ..	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Dicranum bonjeanii</i>	.. .. ..	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Pohlia nutans</i>	.. .. ..	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....



App. C Table 4 continued

Clusters no.	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o
Sample no.	1 69 80	697 763 87	11 69187 29906	22 3233222333 1634578256	9999999999 3233222333 1634578256	2 6061 75095	111111 91 9 9 6111911 4166313 1 40578161021382990	11 1 22 2 3221	9 9 282 473	999 1 1 9929911 201141410102244 0581744349121014	9 9 9999 19 111 1101 30 66567314312	9119999999 0000001011 9218760321	1 79 42	22 77 54	1 97 90
III Carex lasiocarpa	1u	111	..	.....	.....	s1433	34341434.41u.s.s.	....	.u.	....1.1.....1u2	.1.+.....	.....	u.	..	31
Carex rostrata	13	u21	..	.....	u+.1+u...	..uss	u11u.2u15u.s4111.	....	....	....s...+u...	....+s...	.....	....	..	32
Eleocharis quinqueflora	11	2+2	11	2u..u	2s.s.	2s.s.	11u11u11u11s11u	uuu	111	..111u1u.u1u+u+u	ss+ssu1u.u+	....u+.s	1.	1.	1u
Eriophorum angustifolium	u1	1u	s1	21222	111u11u1u1	uu1us	11u11u11u11s11u	uuu	111	..111u1u.u1u+u+u	ss+ssu1u.u+	....u+.s	1.	1.	1u
Calliergon trifarium	11	11u	..u	su1u1	st..s..us	..suu	11u11u11u11s11u	uuu	111	..111u1u.u1u+u+u	ss+ssu1u.u+	....u+.s	1.	1.	1u
Drepanocladus revolvens	u1	344	44	44555	6343353454	43433	3u3151u4+5321133	1332	uuu	11u11u11u11u112	22231211321	221122111u	..	..	+
Scorpidium scorpioides	22	534	s4	3u1u1	..ss.....	2.	11u11u11u11s11u	uuu	111	..111u1u.u1u+u+u	ss+ssu1u.u+	....u+.s	1.	1.	1u
Andromeda polifolia	..	u1u	..	.....	.....	1.u1u	11u11u11u11s11u	uuu	111	..111u1u.u1u+u+u	ss+ssu1u.u+	....u+.s	1.	1.	1u
Euphrasia frigida	..	sss	..	.....	.....	ssu.s	11u11u11u11s11u	uuu	111	..111u1u.u1u+u+u	ss+ssu1u.u+	....u+.s	1.	1.	1u
Pedicularis palustris	..	1+u	1u	u1u11	2uuuss11u	s1u+	11u11u11u11s11u	uuu	111	..111u1u.u1u+u+u	ss+ssu1u.u+	....u+.s	1.	1.	1u
Carex dioica	..	111	11	11111	21uu1u1.11	11111	12111112s11111u21	1111	121	1u111121u.3+1122	s1u2s11111u	u11+...s+	1.	21	21
Eriophorum latifolium	..	u1	s+	....	u.11..s112	1s+s.	u.11..s112	1222	u.1	u.s..u..+uuu	31312.4.125	1334224511	u.	..	..
Scirpus cespitosus	..	232	..	3uu.3	22u132232	34332	u1343132u334u1344	4433	u21	44u4u333423u2u21	31312.4.125	1334224511	u.	..	..
Campylidium stellatum	..	u43	2.	31223	3641646234	45556	45553645553666545	6666	u32	6562554466666655	65646555665	4552441621	2u	1u	u.
Cinclidium stygium	..	uu1	23	13222	uuuu+u1us	1u+u.	1u.1..+1.s1u+u.s	....	....	....s...+u...	....+s...	.....	....	..	..
Salix lapponum	..	su	s1u1	1..u11	....	....	....	....	....	....	....	....	....	..	+
Dactylorhiza cruenta	..	++	+.1	u..uu1.s+	....	u..u+	uuuuuuu+.usu	....	uuu	s+.u.1.s..+u.u.	..s..sss.uu	....ss.+	..	..	..
Equisetum palustre	..	uu	12	11132	112u111112	us+u.	1u11111uuuu1111s.	1u11	111	1u11111uuuu1111s.	1u111111111	1112u.s.1us	uuuu+u	1.	11
Equisetum variegatum	..	u	s	u1	1..	1u+1	1u11111uuuu1111s.	1u11	111	1u11111uuuu1111s.	1u111111111	1112u.s.1us	uuuu+u	1.	11
Polygonum viviparum	..	u1	11u11	u2s+211..+s	....	u+u11uuuu11111u	u.s.	111	1u11111uuuu1111s.	1u111111111	1112u.s.1us	uuuu+u	1.	11	11
Carex flava	..	11	u1132	u1111111u	u..s	u1u22u11u211u11u1	u1u1	u.s1	31522121114u1222	1u1s1ss+.+	....u+.u	....	..	..	..
Bryum pseudotriquetrum	..	u	21	13121	uus+ssu+u	1u1u	1u111u2uu111u1u11	uuuu	uuu	1su11u1us11u+111	u1u1u1s111s	uuu+uuu+u	u.	..	..
Parnassia palustris	..	u	..	us21	u11u+s+u	....	....	....	....	....	....	....	....	..	+
Thalictrum alpinum	..	1u	..	su132	241u312u23	22112	1222233323132323	3333	122	445334344434444	43425443424	4433343322	22	32	2u
Carex nigra	..	++	u	11343	111u11	....	....	....	....	....	....	....	....	..	..
Carex panicea	..	s	11	2.	1uu22	u31u221121	12222	21122121u12211121	1212	121	11u222311233112	13121212221	u31111111u	1.	2u
Juncus triglumis	..	..	..	u1u1	....	....	....	....	....	....	....	....	....	..	..
Selaginella selaginoides	..	u.	..	u.uu	u+s+u1..+u	11u11	1uuuuu1u1s111111u1	1111	1u1	11u1u1u111111112	11111111121	1111111111	u+	11	u1
Molinia caerulea	..	1u	..	1uuu	1uuu+s+u2	23222	3222232131222133	2212	u2u	11u2323211211333	23222112232	2343333123	33	1+	..
Betula nana	..	..	s.	u.	....	....	....	....	....	....	....	....	....	..	..
Pinguicula vulgaris	..	ss	..	..	....	1.sss	u..1..s..uuu+u	1uu	usu	u1u1u1u1u+uuu1	uss1.uuu.+1	1uu1u1u1u	..	..	..
Tofieldia pusilla	..	u.	..	..	....	u.s.	u..1..s..uuu+u	1111	u.u	1u1+u1u.uuu.u1	1u11.uuu111	1u11111111	..	..	s
Fissidens adianthoides	..	..	..	u.	....	u..+	u..+	....	....	....	....	....	....	..	..
Potentilla erecta	..	s.	..	..	sss+u..s1	..ss	u3112332u32u13132	2222	131	11.31u1u1u2u1212	2.122111u	1uuu1u1u21	su	1.	+
Saussurea alpina	..	..	..	u.	....	s.u.1	uu.1112u2111s1u1s	12u2	221	u1112112u111uuu	11u11111u21	11u1.u1u11	23	32	21
Komolothecium nitens	..	..	..	u	....	u..+	u..+	....	....	....	....	....	....	..	..
Sphagnum warnstorffii	..	..	s.	..	u.	u.s+s	uuu..uu+1uu.2s+.u	u.	646	u22+..3u..+1.s	..s.....	....	..	54	65
Dactylorhiza pseudocordig.	..	..	..	..	....	....	....	....	....	....	....	....	....	..	..
Pedicularis oederi	..	..	..	..	....	....	....	....	....	....	....	....	....	..	..
Saxifraga aizoides	..	..	..	..	....	....	....	....	....	....	....	....	....	..	..
Succisa pratensis	..	..	..	..	....	....	....	....	....	....	....	....	....	..	..
Carex capillaris	..	..	..	..	....	....	....	....	....	....	....	....	....	..	..
Kobresia simpliciuscula	..	..	..	..	....	....	....	....	....	....	....	....	....	..	..
Angelica sylvestris	..	..	..	..	....	....	....	....	....	....	....	....	....	..	..
Bartsia alpina	..	..	..	..	....	....	....	....	....	....	....	....	....	..	..
Crepis paludosa	..	..	..	..	....	....	....	....	....	....	....	....	....	..	..
Filipendula ulmaria	..	..	..	..	....	....	....	....	....	....	....	....	....	..	..
Galium boreale	..	..	..	..	....	....	....	....	....	....	....	....	....	..	..
Gymnadenia conopsea	..	..	..	..	....	....	....	....	....	....	....	....	....	..	..
Carex vaginata	..	..	..	..	....	....	....	....	....	....	....	....	....	..	..
Deschampsia cespitosa	..	..	..	..	....	....	....	....	....	....	....	....	....	..	..
Nardus stricta	..	..	..	..	....	....	....	....	....	....	....	....	....	..	..



App. C Table 4 continued

Clusters no.	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o
Sample no.	1 69 80	697 763	11 87	22 69187 29906	9999999999 3233222333 1634578256	2 6061 75095	111111 91 9 9 6111911 4166313 1 40578161021382990	11 1 22 2 3221	9 9 282 473	999 1 1 9929911 201141410102244 0581744349121014	9 9 9999 19 111 1101 30 66567314312	9119999999 0000001011 9218760321	1 79 42	22 77 54	1 97 90
<i>Aulacomnium palustre</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Paludella squarrosa</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Leontodon autumnalis</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Festuca ovina</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Hylacomium splendens</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
IV <i>Salix lapponum</i> - B	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Betula pubescens</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Calluna vulgaris</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Salix glauca</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Salix hastata</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Salix myrsinites</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Salix pentandra</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Salix phylicifolia</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Salix repens</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Vaccinium vitis-idaea</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Alchemilla</i> sp.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Antennaria dioica</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Cirsium palustre</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Coeloglossum viride</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Dactylorhiza incarnata</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Equisetum pratense</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Equisetum scirpoides</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Erigeron boreale</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Hieracium</i> sp.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Melampyrum sylvaticum</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Pyrola minor</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Pyrola rotundifolia</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Ranunculus acris</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Taraxacum</i> sp.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Agrostis canina</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Agrostis mertensii</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Anthoxanthum odoratum</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Carex atrofusca</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Carex buxbaumii</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Carex canescens</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Carex capitata</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Carex chordorrhiza</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Carex echinata</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Carex saxatilis</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Festuca rubra</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Juncus castaneus</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Brachythecium turgidum</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Calliergon sarmentosum</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Ceratodon purpureus</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Climacium dendroides</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Cratoneuron commutatum</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Dicranum majus</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Fissidens osmundoides</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Hypnum bambergeri</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Hypnum lindbergii</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Hypnum pratense</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

App. C Table 4 continued

Clusters no.	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o
Sample no.	1 69 80	697 763	11 87	22 69187 29906	99999999999 3233222333 1634578256	2 6061 75095	111111 91 9 9 6111911 4166313 1 40578161021382990	11 1 22 2 3221	9 9 282 473	999 1 1 9929911 201141410102244 0581744349121014	9 9 9999 19 111 1101 30 66567314312	9119999999 0000001011 9218760321	1 79 42	22 77 54	1 97 90
Philonotis fontana/toment.	..	..	..	.u..	.....	.....	.....S..	.....	.....	.....	.....	.....	.....	.....	..
Plagiomnium elatum	..	..	..	..1.	.....	.....	.....S...S.	.....	.....	.....+..1.....uus	.....	.....	.....	.....	..
Sphagnum contortum	..	..	..	..su.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	..
Thuidium recognitum	..	..	..	.....	.....	.....	.....	.....	..S.	.....	.....u.+...	.....+..u..u..	.....	.....	..
Tortella fragilis	..	..	..	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	..
Cetraria islandica	..	..	..	.....	.....	.....	.....	.....	.....	.....	.....S.+...	.....u..u..1..	.....	.....	..
Cladonia fimbriata	..	..	..	.....	.....	.....	.....	.....	.....	.....	.....	.....u..u..+s	.....	.....	..
Peltigera aphthosa	..	..	..	.....	.....	.....	.....	.....	.....	.....	.....S.+...	.....u..+s+...s	.....	.....	..

## V Additional species (cluster no. - sample no.):

- b - 73: Juncus alpino-articulatus s;  
 d - 99: Salix pentandra-B 1, Epilobium hornemanii u, Petasites frigidus +, Carex stenolepis 3, C. vesicaria +, Meesia uliginosa u,  
 Tayloria lingulata u;  
 d - 280: Viola biflora u;  
 f - 7: Catoscopium nigrum 1;  
 g - 117: Calamagrostis stricta u;  
 i - 87: Drepanocladus uncinatus s;  
 j - 918: Poa alpina s;  
 j - 14: Juncus filiformis s;  
 j - 4: Hierochloë odorata s;  
 l - 910: Cladina arbuscula coll. u;  
 l - 903: Equisetum sylvaticum u, Amblystegium serpens u;  
 m - 192: Rhytidiadelphus subpinnatus u;  
 n - 274: Luzula multiflora u;  
 o - 70: Rumex acetosa +, Trientalis europaea u, Polytrichum strictum 1, Sphagnum angustifolium s, S. n.n. 1.

## APPENDIX C

Table 5 Analyses of rich fen vegetation, lawn communities. Complete phytosociological table for the 36 small (0.25 m<sup>2</sup>) quadrats of the 13 sample stands from locality no. 1. 7 samples are included in cluster M4 of section 5. Quadrats nos. 31, 33 & 35 and nos. 32, 34 & 36, respectively, represent the same permanent quadrats.

Small quadrat no.	12345	678	901	234	567	890	123	456	78	90	12	34	56
Year of analysis	1974	75	75	77	77	79	79	79	81	81	84	85	86
Year(s) of scything before analysis	-	-	74	-	76	78	77	-	-	74-74-74-74-	80	83	83
Cluster no. (M)	4	4	4	4	-	-	4	4	4	-	-	-	-
Stand sample no.	1	1	1	1	1	1	1	1	1	1	1	1	1
	1	0	1	2	3	4	5	6	7	8	9	1	2
Field layer cover	66666	565	554	666	544	544	554	655	66	45	43	54	64
Field layer height in cm	40	35	30	45	30	35	40	45	40	20	10	15	15
Bottom layer cover	65565	554	566	666	666	566	666	556	66	66	65	65	65
Litter cover	66656	666	534	666	111	1ss	322	665	66	11	11	21	32
<i>Betula pubescens</i>	++++	++r	...	...	...	...	...	...	r	r	...	...	...
<i>Angelica sylvestris</i>	++++	1+	1+	1+	1+	+	+	+	+	+	+	+	+
<i>Dactylorhiza cruenta</i>	1+++	1+	11	1+	1+	ss	ss	11	ss	ss	ss	ss	ss
<i>Equisetum palustre</i>	11111	1+	11	1+	11	11	ss	11	ss	ss	ss	ss	ss
<i>Equisetum variegatum</i>	++++	1+	...	...	...	...	+	+	...	...	+	+	...
<i>Euphrasia frigida</i>	...	...	...	+	...	...	...	...	...	...	...	...	...
<i>Gymnadenia conopsea</i>	...	...	...	+	...	...	...	...	...	...	...	...	...
<i>Parnassia palustris</i>	...	...	...	+	...	...	...	...	...	...	...	...	...
<i>Pedicularis oederi</i>	++++	1+	1+	1+	1s	1s	211	ss	+	+	+	+	+
<i>Pedicularis palustris</i>	1+++	1+	1+	1+	11	11	ss	ss	ss	ss	ss	ss	ss
<i>Polygonum viviparum</i>	22222	331	332	323	332	322	2ss	332	u1	uu	us	1s	1s
<i>Potentilla erecta</i>	1+11	1+	211	221	111	s+s	...	122	su	...	s+	s+	+
<i>Saussurea alpina</i>	1+++	...	...	...	...	...	...	...	...	...	...	...	...
<i>Saxifraga aizoides</i>	11211	1+	11	11	1+	1+	1s	s+s	+	s+	...	...	...
<i>Selaginella selaginoides</i>	2+11	1+	1+	122	1+	...	...	2+1	22	...	...	...	...
<i>Succisa pratensis</i>	33332	222	232	332	223	222	222	333	22	33	21	21	21
<i>Thalictrum alpinum</i>	1+1+	...	...	...	...	...	...	...	...	...	...	...	...
<i>Tofieldia pusilla</i>	++++	...	1+	...	...	...	...	...	...	...	s+	s+	s+
<i>Triglochin palustre</i>	...	...	...	...	...	+	+	...	...	...	...	...	...
<i>Viola palustris/epipsila</i>	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>Calamagrostis stricta</i>	++++	1+	...	...	...	...	...	...	1+	...	...	...	...
<i>Carex buxbaumii</i>	21222	212	121	111	211	111	111	111	11	21	31	31	31
<i>Carex capillaris</i>	11111	111	1+	222	111	111	1+	111	21	11	2u	32	32
<i>Carex dioica</i>	43344	444	433	434	332	222	432	243	43	22	1u	1u	11
<i>Carex flava</i>	2+1+	1+	...	...	...	...	...	...	1+	+	s2	s3	s3
<i>Carex lasiocarpa</i>	11111	111	111	112	111	111	112	222	2u	21	1+	u+	u+
<i>Carex nigra</i>	11112	112	221	1+	111	...	...	211	1+	+	+	+	+
<i>Carex panicea</i>	1+1+	111	1+	111	111	111	1+	+	ss	uu	22	u2	12
<i>Carex rostrata</i>	...	...	...	...	...	...	...	...	...	ss	ss	+	+
<i>Eriophorum angustifolium</i>	...	...	...	...	...	...	...	...	...	ss	ss	+	+
<i>Eriophorum latifolium</i>	1+++	1+	...	...	...	...	...	...	...	...	...	...	...
<i>Eriophorum vaginatum</i>	31212	222	222	223	111	111	221	333	12	u1	us	ss	ss
<i>Festuca ovina</i>	21222	111	111	342	121	222	333	313	43	22	32	42	43
<i>Molinia caerulea</i>	...	...	...	...	...	...	...	...	...	...	s+	s+	s+
<i>Scirpus cespitosus</i>	1+1+	1+	1+	111	111	111	11s	122	s1	s+	s+	s+	s+
<i>Scirpus hudsonianus</i>	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>Bryum pseudotriquetrum</i>	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>Calliergon richardsonii</i>	55554	554	666	455	565	565	455	445	46	54	64	64	64
<i>Calliergon trifarium</i>	++++	1+	...	...	...	...	...	...	...	...	...	...	...
<i>Campylium stellatum</i>	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>Cinclidium stygium</i>	1+111	1+	111	...	...	...	...	...	...	...	+	+	+
<i>Drepanocladus badius</i>	21233	141	211	534	323	423	111	332	12	33	21	21	21
<i>Drepanocladus revolvens</i>	112+	11+	...	12+	...	...	...	1s+	s1	...	...	...	...
<i>Fissidens adianthoides</i>	++++	1+	1+	1+	1+	1+	1+	1+	...	1+	...	...	...
<i>Homalothecium nitens</i>	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>Sphagnum warnstorffii</i>	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>Aneura pinguis</i>	...	...	...	1+	...	...	...	...	...	+	u2	s2	s1
<i>Barbilophozia quadriloba</i>	11111	1+	1+	111	111	111	111	111	u+	uu	ss	ss	ss
<i>Lophozia borealis</i>	1+11	1+	1+	1+	1+	1s1	ss1	ss2	u+	...	s+	s+	s+
<i>Lophozia rutheana</i>	...	...	...	1+	...	...	...	...	...	u+	+	+	+
<i>Moerckia hibernica</i>	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>Scapania irrigua</i>	1+++	...	...	...	...	...	...	...	...	...	...	...	...
<i>Tritomania polita</i>	...	...	...	...	...	...	...	...	...	...	...	...	...
<b>Mud bottom</b>	...	...	...	...	...	...	...	...	...	...	s4	s4	s4
No. of vasculars	11111	111	111	111	111	111	111	111	21	11	11	11	11
	53446	536	555	676	767	665	346	948	08	86	85	84	64
No. of cryptogams	00000	000	000	000	000	000	000	000	00	00	00	00	00
	74565	356	464	984	457	768	878	965	86	75	76	76	77
Total no. of species	21122	112	121	222	222	222	222	222	22	22	22	22	22
	27901	882	919	550	114	323	114	803	84	51	51	50	31

## APPENDIX C

Table 6 Analysis of rich fen vegetation, lawn communities. Complete phytosociological table for the small (0.25 m<sup>2</sup>) quadrats of the sample stands from localities nos. 2 (quadrats 1-21) and 3 (q. 22-31). 4 samples are included in cluster M5 and 2 samples in cluster M7 of section 5. Quadrats nos. 19, 20 & 21 represent the same permanent quadrat.

Small quadrat no.	12345	678	901	111	111	111	111	1	2	2	22222	222	33
				234	56	78	9	0	1		23456	789	01
Year of analysis	1974	79	79	79	81	81	8	8	8		74	79	79
							4	5	6				
Year(s) of scything before analysis	-	74-78	77	-	-	74-80	74-83				-	74-78	-
Cluster no. (M)	5	-	5	5	5	-	-	-	-		7	-	7
Stand sample no.	2	1 2 0	1 2 1	1 2 2	1 2 3	1 2 4	1 2 5	1 2 6	1 2 7		3	1 3 0	1 3 1
Field layer cover	55455	444	555	655	55	44	4	4	5		65555	443	55
Field layer height in cm	18	12	14	18	18	10	8	1	1		15	10	15
Bottom layer cover	66666	666	666	666	66	66	6	6	6		66666	666	66
Litter cover	54334	111	445	554	45	11	1	1	2		44444	111	55
<i>Betula nana</i>	+++1+	...	...	...	...	...	...	...	...		+++1+	...	+1
<i>Betula pubescens</i>	++rrr	...	...	...	...	+	r	...	...		...	...	...
<i>Juniperus communis</i>	1+1++	...	...	+	s+	...	...	...	...		...	...	...
<i>Vaccinium vitis-idaea</i>	.....	...	...	...	...	...	...	...	...		.....	...	+s
<i>Bartsia alpina</i>	.....	...	...	+	1+	...	...	...	...		.....	...	...
<i>Crepis paludosa</i>	.....	...	...	...	...	...	...	...	...		+++++	...	+
<i>Dactylorhiza cruenta</i>	+++11	...	s+s	s+s	...	...	...	...	...		.....	+	+
<i>Dactylorhiza pseudocordigera</i>	11111	ss+	ss+	sss	us	u+	+	+	+		1++++	s+	ss
<i>Equisetum palustre</i>	11111	s1s	1ss	s+s	ss	ss	s	s	s		1++1+	+	ss
<i>Equisetum variegatum</i>	+1111	ss	111	111	su	ss	+	s	s		11111	11s	s+
<i>Euphrasia frigida</i>	1211+	ss+	...	...	ss	...	s	s	s		+++++	...	...
<i>Gymnadenia conopsea</i>	.....	...	...	...	...	...	...	...	...		1++1+	+	ss
<i>Leontodon autumnalis</i>	.....	...	...	...	...	...	...	...	...		1++++	111	s1
<i>Pedicularis oederi</i>	+1+11	++s	1+s	1s1	2u	us	+	+	+		11111	ss1	11
<i>Pinguicula vulgaris</i>	+1+11	11+	...	11+	ss	u1	+	+	+		11111	111	11
<i>Polygonum viviparum</i>	+1+1+	...	...	...	s+	ss	+	+	+		11111	111	11
<i>Potentilla erecta</i>	21222	221	222	222	22	11	s	s	s		1++1+	1++	+
<i>Saussurea alpina</i>	+1+12	s++	212	s22	11	2u	+	+	+		+1111	+	+
<i>Saxifraga aizoides</i>	11221	111	1+s	111	uu	uu	+	+	+		...	...	...
<i>Selaginella selaginoides</i>	11111	++s	111	111	su	ss	+	s	s		21211	1ss	22
<i>Succisa pratensis</i>	+1+1+	...	+	1+	su	+	+	+	+		33233	212	22
<i>Thalictrum alpinum</i>	32233	333	333	333	33	23	3	3	3		34343	333	22
<i>Tofieldia pusilla</i>	11111	s11	111	111	uu	ss	s	s	s		11111	111	ss
<i>Triglochin palustre</i>	1+111	sss	...	++s	...	ss	s	s	s		+1+++	...	...
<i>Carex buxbaumii</i>	+++++	++s	...	...	...	...	...	...	...		11121	111	11
<i>Carex capillaris</i>	+1112	sss	s++	...	s+	su	+	+	+		11111	111	11
<i>Carex dioica</i>	11112	111	211	111	11	21	2	2	3		11111	111	11
<i>Carex echinata</i>	.....	...	...	...	...	...	...	...	...		.....	...	...
<i>Carex flava</i>	1111+	++s	s1+	1s1	u+	u	+	+	+		1....	1+	...
<i>Carex flava</i> x <i>C. hostiana</i>	+1+++	++s	+11	231	1+	+	+	+	+		1....	1+	...
<i>Carex hostiana</i>	11213	s11	111	1++	32	s	s	u	u		+++++	...	...
<i>Carex panicea</i>	12121	111	222	222	11	1u	u	u	u		22212	222	22
<i>Carex vaginata</i>	.....	...	...	...	...	...	...	...	...		.....	...	+1
<i>Deschampsia cespitosa</i>	.....	s++	...	...	...	...	...	...	...		11111	111	2s
<i>Eriophorum angustifolium</i>	1++++	++ss	++s	s++	s+	s+	1	1	1		.....	...	+s
<i>Eriophorum latifolium</i>	22221	212	212	212	s1	23	3	3	3		.....	...	...
<i>Eriophorum vaginatum</i>	.....	...	...	...	...	+	s	u	s		.....	...	...
<i>Festuca ovina</i>	.....	s++	...	+	1+	ss	su	+	+		+++++	++s	1s
<i>Juncus triglumis</i>	+1+1+	...	...	...	...	+	s	+	+		.....	...	...
<i>Kobresia simpliciuscula</i>	11111	ss+	112	122	u1	su	+	+	s		32321	211	23
<i>Molinia caerulea</i>	21211	111	222	222	22	1u	s	s	s		32222	111	33
<i>Scirpus cespitosus</i>	33232	222	333	433	34	1u	2	2	3		11212	111	12
<i>Scirpus hudsonianus</i>	.....	...	...	...	...	+	s	...	...		.....	...	...
<i>Bryum pseudotriquetrum</i>	+111+	...	s++	++s	+	s	...	...	...		11111	++s	11
<i>Calliergon trifarium</i>	11111	11s	1+	...	s+	...	u	u	u		+++++	++s	...
<i>Campylium stellatum</i>	65666	666	666	666	66	66	4	4	4		66656	666	65
<i>Ditrichum flexicaule</i>	+1+1+	...	...	...	+	s	...	...	...		+1+1+	...	+2
<i>Drepanocladus revolvens</i>	24311	323	222	223	11	11	3	3	3		23343	222	22
<i>Fissidens adianthoides</i>	+1+11	...	+	+	+	su	1s	+	+		+1+1+	++s	+1
<i>Homalothecium nitens</i>	.....	...	...	...	...	...	...	...	...		+++++	...	...

App. C Table 6 continued

Small quadrat no.	12345	678	901	11 234	11 56	11 78	1 9	2 0	2 1	22222 23456	222 789	33 01
<i>Hylocomium pyrenaicum</i>	.....	...	...	...	..	..	..	..	..	+1+++	...	..
<i>Hypnum lindbergii</i>	.....	...	...	...	..	..	..	..	..	.....	...	+1
<i>Sphagnum warnstorffii</i>	.....	...	...	...	+s	..	..	..	..	.....	...	..
<i>Tortella tortuosa</i>	.....	...	...	...	..	..	..	..	..	.....	...	+2
<i>Aneura pinguis</i>	+++11	...	...	...	..	..	..	..	..	.....	...	..
<i>Barbilophozia lycopodioides</i>	.....	...	...	...	..	..	..	..	..	.....	...	+s
<i>Barbilophozia quadriloba</i>	+++1	...	...	...	+s	..	..	..	..	.....	...	+1
<i>Lophozia borealis</i>	11111	sss	111	11s	uu	11	s	s	s	11111	122	31
<i>Lophozia rutheana</i>	.....	...	...	...	+s	..	..	..	..	.....	...	..
Mud button	.....	...	...	...	..	..	2	2	2	.....	...	..
No. of vasculars	11222 99632	221 009	211 098	221 129	22 51	22 47	1 4	1 6	1 7	21111 06687	111 877	22 04
No. of cryptogams	00000 44678	000 444	000 453	000 344	00 59	00 44	0 4	0 4	0 4	00000 56575	000 336	01 40
Total no. of species	22333 33200	222 443	222 441	222 463	33 00	23 81	1 8	2 0	2 1	22222 52152	222 103	23 44





App. C Table 7 continued

Small quadrat no.	12345	678	901	11	111	11	11	11	122	22	22	2	2
	234	56	78	901	23	45	6	7					
<i>Mardus stricta</i>	++1+2	1+1	...	211	+u	s1	uu+	s+	ss	+	s		
<i>Scirpus cespitosus</i>	11111	1+1	311	111	2u	23	sus	us	+1	s	s		
<i>Scirpus hudsonianus</i>	.....	...	...	...	...	...	+++	..	..	+	+		
<i>Bryum pseudotriquetrum</i>	11111	111	111	111	ss	ss	sss	ss	11	s	s		
<i>Calliergon richardsonii</i>	1++++	+1+	...	++s	s+	s+	...	...	...	...	...		
<i>Campylium stellatum</i>	65544	566	554	555	66	43	666	66	55	6	6		
<i>Cinclidium stygium</i>	11111	21+	1++	s++	12	ss	1u1	11	s+	1	1		
<i>Cratoneuron commutatum</i>	11111	21+	1++	221	12	ss	1u1	11	s+	1	1		
<i>Ditrichum flexicaule</i>	++++1	+1+	...	++1	...	...	...	...	...	...	...		
<i>Drepanocladus revolvens</i>	21122	111	111	211	11	1+	112	11	1u	2	2		
<i>Fissidens adianthoides</i>	22223	121	134	111	12	12	su1	11	12	1	1		
<i>Homalothecium nitens</i>	.....	+2	1+1	...	..	+s	+u+	1+	1+	+	+		
<i>Hypnum pratense</i>	++++1	+11	+1+	++1	..	11	...	21	+s	..	..		
<i>Plagiomnium elatum</i>	+++1+	11+	+1+	...	s+	2+	...	ss	++	..	..		
<i>Plagiomnium ellipticum</i>	+1+1+	11+	...	+s+	..	s+	...	..	++	..	..		
<i>Sphagnum warnstorffii</i>	+1+1+	...	+2	...	...	...	...	b+	++	..	..		
<i>Aneura pinguis</i>	+1111	111	...	+s+	+u	su	+su	ss	..	u	u		
<i>Barbilophozia quadriloba</i>	11111	211	111	sss	ss	ss	sss	ss	ss	s	s		
<i>Lophozia bantriensis</i>	12322	111	111	221	ss	..	suu	21	2+	u	u		
<i>Lophozia borealis</i>	11112	+2	+2	+s+	s2	+1	+s+	su	+s	+	+		
<i>Lophozia rutheana</i>	+++1+	+1+	...	1++	...	...	...	...	...	..	..		
<i>Moerckia hibernica</i>	.....	+1+	...	...	...	...	...	...	...	..	..		
<i>Pellia neesiana</i>	11111	+++	233	s++	..	+2	...	..	s+	..	..		
<i>Plagiochila porelloides</i>	+11++	+1+	...	++	..	...	++u	..	1+	..	..		
<i>Preissia quadrata</i>	+++1+	...	+1+	...	..	...	++u	..	..	u	u		
<i>Tritomaria polita</i>	23222	+1+	+21	111	ss	ss	+su	ss	..	u	u		
<i>Tritomaria quinqueidentata</i>	+++11	+1+	...	+11	...	...	+s+	..	1s	+	+		
No. of vasculars	22222	222	222	223	32	22	232	33	32	2	2		
	86946	597	864	550	09	66	737	32	28	6	8		
No. of cryptogams	11111	111	011	111	11	11	011	11	10	1	1		
	02253	043	903	132	10	21	720	42	18	0	0		
Total no. of species	33433	344	333	334	43	33	343	44	43	3	3		
	88199	530	767	682	19	87	457	74	36	6	8		

## APPENDIX C

Table 8 Analyses of rich fen vegetation, mud bottom and carpet communities. Complete phytosociological table for the small (0.25 m<sup>2</sup>) quadrats of the samples of clusters M1 and 2; cf. section 5.

Small quadrat no.	1		11111		11112		22222	
	12345	67890	12345	67890	12345	67890	12345	67890
Year of analysis	1977	1982	1977	1980	1986			
Cluster no. (M)	1	1	2	2	2			
Stand sample no.	6	9	6	7	9			
	8	0	7	3	9			
Field layer cover	22222	33332	44444	55555	55454			
Field layer height in cm	10	40	15	20	15			
Bottom layer cover	12233	22324	66566	66666	66666			
Litter cover	11111	22111	32222	3342	34344			
<i>Andromeda polifolia</i>	.....	.....	11+1+	111s+	11sss			
<i>Dactylorhiza incarnata</i>	.....	.....	.....	++++1	+1ss+			
<i>Equisetum palustre</i>	.....	.....	.....	s+ss+	sss+			
<i>Equisetum variegatum</i>	.....	ss+s+	.....	+s+	.....			
<i>Euphrasia frigida</i>	.....	.....	1++++	1++++	1++++			
<i>Menyanthes trifoliata</i>	1221+	.....	11111	1++++	+1++			
<i>Parnassia palustris</i>	.....	.....	.....	1+1s+	.....			
<i>Pedicularis palustris</i>	.....	.....	11111	1+1s+	.....			
<i>Pinguicula vulgaris</i>	.....	.....	.....	+1+++	+1++			
<i>Potentilla erecta</i>	.....	.....	.....	.....	+1+++			
<i>Selaginella selaginoides</i>	.....	.....	.....	.....	s+sss			
<i>Thalictrum alpinum</i>	.....	.....	.....	+s+s+	111ss			
<i>Tofieldia pusilla</i>	.....	.....	.....	.....	1ss+s			
<i>Triglochin palustre</i>	1++++	.....	++++1	.....	.....			
<i>Utricularia minor</i>	.....	.....	.....	11+++	+++++			
<i>Carex dioica</i>	.....	ssssu	11111	11111	11211			
<i>Carex lasiocarpa</i>	11111	1111+	21111	1+2uu	11u11			
<i>Carex limosa</i>	.....	121++	.....	33213	13222			
<i>Carex nigra</i>	.....	.....	.....	+++++	+++++			
<i>Carex panicea</i>	.....	s++++	.....	11111	11111			
<i>Carex rostrata</i>	11122	33222	+1111	121s2	22s21			
<i>Eleocharis quinqueflora</i>	11111	111us	13232	11321	+++++			
<i>Eriophorum angustifolium</i>	1+1++	sssss	11111	sss+s	ssu++			
<i>Eriophorum latifolium</i>	.....	s+us+	11111	1111s	11+uu			
<i>Juncus alpino-articulatus</i>	.....	.....	.....	+11++	.....			
<i>Molinia caerulea</i>	.....	.....	.....	+111	11uuu			
<i>Scirpus cespitosus</i>	.....	.....	31122	32131	33332			
<i>Scirpus hudsonianus</i>	.....	.....	.....	+++++	+s+s+			
<i>Bryum pseudotriquetrum</i>	.....	.....	.....	1+1++	.....			
<i>Calliergon trifarium</i>	11122	11111	11211	+++1s	11sss			
<i>Campylium stellatum</i>	.....	.....	1++1+	24255	55423			
<i>Cinclidium stygium</i>	.....	.....	1++1	1121+	1++ss			
<i>Drepanocladus badius</i>	.....	.....	.....	.....	+1+++			
<i>Drepanocladus revolvens</i>	+11+1	1u111	43233	34554	34454			
<i>Fissidens osmundoides</i>	.....	.....	.....	+s+++	.....			
<i>Scorpidium scorpioides</i>	12232	21323	45455	33245	21224			
<i>Aneura pinguis</i>	.....	+s+++	11111	111s1	11+s+			
<i>Lophozia borealis</i>	.....	.....	.....	+1+++	11uss			
<i>Lophozia rutheana</i>	.....	.....	1++++	+1+++	11s++			
<i>Tritomaria polita</i>	.....	.....	.....	+1+++	+s++			
Mud bottom	66666	66665	32423	.....	11132			
No. of vasculars	00000	00000	11011	11111	11111			
	64543	97774	00900	62641	56522			
No. of cryptogams	00000	00000	00000	00000	00000			
	23323	34333	74455	69665	88776			
Total no. of species	00000	11110	11111	22221	22211			
	87866	21007	74355	21206	34298			

## APPENDIX C

Table 9 Analyses of rich fen vegetation, lawn communities. Complete phytosociological table for the small (0.25 m<sup>2</sup>) quadrats of the samples of clusters M3 and 4; cf. section 5.

Small quadrat no.	1 11111 11112 22					22222 22333 33333 33444 44444 44555 55
	12345 67890	12345 67890	12			34567 89012 34567 89012 34567 89012 34
Year of analysis	1975 1976 1977 1978 82					1976 1976 1976 1977 1977 1977 82
Cluster no.(M)	3 3 3 3 3					4 4 4 4 4 4 4
Stand sample no.					2	
	7 1 6 6 0					9 1 1 6 6 6 9
	5 5 5 9 0					0 2 1 3 4 8
Field layer cover	55444	55555	55555	55555	56	65556 55656 65555 55555 56555 55656 55
Field layer height in cm	14	30	25	30	30	30 20 30 30 30 40 30
Bottom layer cover	66666	66666	66566	66666	66	56665 65555 66666 66666 66666 66565 66
Litter cover	33233	56455	55555	65565	46	55435 55555 66656 54554 45445 45646 34
Andromeda polifolia	11111	11++1	1+...	11111	s+	..... +1111 1+++1 s1
Betula nana	.....	111+2	1+...	1+2+	s+	++1+1 ..... +++++ 11111 11+++ +1
Betula pubescens	.....	.....	1+...	.....	..	..... +1+1 .....

App. C Table 9 continued

Small quadrat no.	12345	67890	11111	11112	22	22222	22333	33333	33444	44444	44555	55
	12345	67890	12345	67890	12	34567	89012	34567	89012	34567	89012	34
<i>Juncus triglumis</i>	.....	1++++	.....	1++1+	..	++1++	+++1+	.....	+++1+	++11+	.....	+s
<i>Kobresia simpliciuscula</i>	.....	1++++	.....	1++1+	..	+++++	11221	+++1+	+++1+	.....	.....	..
<i>Molinia caerulea</i>	22122	22222	34332	22122	12	33233	33331	22222	21111	22222	22333	22
<i>Nardus stricta</i>	.....	.....	.....	.....	..	111++	.....	.....	.....	.....	.....	..
<i>Scirpus cespitosus</i>	34333	22232	43443	33333	32	34434	44445	11121	33333	35334	1++11	32
<i>Scirpus hudsonianus</i>	.....	+++++	.....	.....	..	.....	+1++1	++++1	.....	.....	.....	..
<i>Aulacomnium palustre</i>	.....	.....	.....	.....	..	.....	.....	+++1+	.....	.....	.....	..
<i>Bryum pseudotriquetrum</i>	11111	++11+	1111+	1+11	ss	11112	11111	11111	11111	11111	21111	su
<i>Calliergon giganteum</i>	.....	.....	1++++	++11+	..	.....	.....	111+1	.....	.....	.....	..
<i>Calliergon trifarium</i>	.....	.....	.....	.....	..	.....	.....	.....	.....	.....	.....	..
<i>Campylium stellatum</i>	45445	56566	56353	56455	45	55453	55555	66666	23333	55666	24443	32
<i>Catoscopium nigrum</i>	11111	.....	.....	.....	..	.....	.....	.....	.....	.....	.....	..
<i>Cinclidium stygium</i>	11111	.....	1111+	1+11	++	.....	++1++	+1+1+	+++1+	11111	11111	ss
<i>Cratoneuron commutatum</i>	31+++	.....	.....	.....	..	.....	.....	++1+1	+++2+	.....	++1+1	ss
<i>Ditrichum flexicaule</i>	.....	1++++	.....	.....	..	.....	.....	.....	+1+++	.....	.....	..
<i>Drepanocladus badius</i>	.....	1++++	.....	.....	..	.....	.....	.....	.....	.....	.....	..
<i>Drepanocladus revolvens</i>	45444	32322	32434	22423	53	12432	42221	11121	55544	33332	42243	55
<i>Fissidens adianthoides</i>	1++1+	11111	1++1+	31+31	ss	11111	11+1+	11+1+	21121	21111	33312	+s
<i>Homalothecium nitens</i>	.....	.....	.....	.....	+s	.....	32111	11+++	+++3	.....	+1+++	..
<i>Hylocomium pyrenaicum</i>	.....	.....	.....	.....	..	.....	+++1+	.....	+++1+	.....	.....	..
<i>Paludella squarrosa</i>	.....	.....	.....	.....	..	.....	.....	.....	.....	.....	+1+++	..
<i>Philonotis fontana/toment.</i>	.....	.....	.....	.....	..	.....	.....	+1+++	.....	.....	.....	..
<i>Plagiommium elatum</i>	.....	.....	.....	.....	..	++1++	.....	.....	+++1+	.....	.....	..
<i>Scorpidium scorpioides</i>	.....	.....	1+124	.....	..	.....	.....	.....	.....	.....	.....	..
<i>Sphagnum warnstorffii</i>	.....	.....	.....	.....	..	.....	2++++	1++++	+++21	.....	+1+++	..
<i>Aneura pinguis</i>	1+111	++1++	++111	+++1+	ss	11111	+1111	1111+	11111	11111	11111	1s
<i>Barbilophozia quadriloba</i>	.....	.....	.....	.....	..	11+1+	1++++	1++++	+++11	++1++	++1+1	..
<i>Lophozia borealis</i>	.....	11111	1++++	1++1+	su	.....	11+1+	.....	11111	.....	+1+++	++
<i>Lophozia rutheana</i>	++++1	.....	.....	1+++	su	13331	11+1+	1111+	32242	111++	13211	12
<i>Moerckia hibernica</i>	.....	.....	.....	+++1	..	.....	.....	.....	.....	.....	.....	..
<i>Scapania irrigua</i>	.....	.....	.....	.....	..	.....	.....	+++1+	.....	.....	.....	..
<i>Tritomaria polita</i>	++1+1	.....	.....	1+11	+s	.....	11211	.....	11111	.....	+++1	..
<i>Tritomaria quinqueidentata</i>	.....	.....	.....	.....	..	+++1+	.....	.....	+++1+	.....	.....	..
No. of vasculars	11111	11111	11101	11111	11	22221	22111	12121	22222	22221	11112	22
	65758	55817	70192	53323	50	10149	10885	83919	00351	20139	96570	05
No. of cryptogams	00000	00000	00000	00000	00	00000	10010	11000	00011	00000	01001	00
	86778	64654	84674	86397	89	77768	09706	00786	89842	77866	71970	78
Total no. of species	22222	21212	21111	21122	21	22232	32222	23222	22333	22222	22223	23
	41426	19461	54766	39610	39	87807	19581	83695	89193	97995	67440	73



## APPENDIX C

Table 10 Analyses of rich fen vegetation, lawn communities. Complete phytosociological table for the small (0.25 m<sup>2</sup>) quadrats of the samples of clusters M6, 7, 8 and 10; cf. section 5.

Small quadrat no.	12345	67890	11111	11112	22222	22223	33	333	333	34444	44	44445	55
Year of analysis	1975	1976	1976	1976	1976	1981	82	86	86	1980	82	1978	82
Cluster no. (M)	6	6	6	6	6	6	6	7	7	8	8	10	10
Stand sample no.	6	1	1	1	1	8	0	1	1	7	1	7	1
Field layer cover	55565	66566	66555	66656	55555	55545	66	655	555	34555	55	55555	55
Field layer height in cm	18	30	20	25	18	20	20	20	20	40	40	40	40
Bottom layer cover	66666	55655	65555	55556	66656	66666	66	566	666	32242	20	66666	66
Litter cover	55554	54356	56545	65553	55445	34534	55	543	454	66666	66	33343	55
<i>Betula nana</i> B	.....	.....	.....	.....	.....	.....	..	++3	+21	55524	55	.....	..
<i>Salix nigricans</i> coll. B	.....	.....	.....	.....	.....	.....	..	.....	.....	++++1	++	.....	..
<i>Andromeda polifolia</i>	.....	.....	11112	1+++	11111	.....	ss	uuu	+su	22313	44	11111	su
<i>Betula pubescens</i>	.....	1+++	.....	.....	.....	.....	..	3+3	+41	.....	..	21111	s2
<i>Calluna vulgaris</i>	.....	.....	.....	.....	.....	.....	..	s++	.....	.....	..	.....	..
<i>Empetrum hermaphroditum</i>	.....	.....	.....	.....	.....	.....	..	.....	.....	.....	..	23323	++
<i>Juniperus communis</i>	.....	.....	.....	.....	.....	.....	..	+++	+s	.....	..	.....	..
<i>Oxycoccus microcarpus</i>	.....	.....	.....	.....	.....	.....	..	.....	.....	.....	..	11222	21
<i>Salix glauca</i>	.....	.....	.....	.....	.....	.....	..	.....	.....	.....	..	.....	..
<i>Salix lapponum</i>	.....	.....	.....	.....	.....	.....	..	++s++	.....	.....	..	.....	..
<i>Salix nigricans</i> coll.	.....	.....	.....	.....	.....	.....	..	.....	.....	.....	..	.....	..
<i>Salix phylicifolia</i>	.....	.....	.....	.....	.....	.....	..	.....	.....	++++1	++	.....	..
<i>Vaccinium myrtillus</i>	.....	.....	.....	.....	.....	.....	..	.....	.....	.....	..	2+1+2	++
<i>Vaccinium uliginosum</i>	.....	.....	.....	.....	.....	.....	..	s++	+s+	.....	..	3+++	++
<i>Alchemilla</i> sp.	.....	.....	.....	.....	.....	.....	..	.....	.....	.....	..	.....	..
<i>Angelica sylvestris</i>	+1+1+	2+111	.....	+++++	+++1+	++s+s	+s	s++	+++	+++++	s+	+1+1+	1s
<i>Antennaria dioica</i>	.....	.....	.....	.....	.....	.....	..	u++	s++	.....	..	.....	..
<i>Bartsia alpina</i>	1+++	+++++	+11+	1+1+	+11+	21+ss	++	+++	+++	.....	..	+11+	+s
<i>Caltha palustris</i>	.....	.....	.....	.....	.....	.....	..	.....	.....	.....	..	.....	..
<i>Cirsium palustre</i>	.....	++11+	.....	.....	.....	.....	..	.....	.....	.....	..	.....	..
<i>Coeloglossum viride</i>	.....	.....	.....	.....	.....	.....	..	.....	.....	.....	..	.....	..
<i>Crepis paludosa</i>	.....	11111	111+1	23324	.....	u22uu	+u	+++	+++	+1+s+	s+	+++++	..
<i>Dactylorhiza maculata</i>	.....	1211+	.....	.....	.....	.....	..	+++	+++	.....	..	.....	..
<i>Dactylorhiza pseudocordig.</i>	1+++	+1111	.....	.....	+11+	.....	..	+++	+++	.....	..	.....	..
<i>Equisetum palustre</i>	.....	11111	11111	.....	+11+	11u1u	ss	+ss	.....	.....	..	11111	ss
<i>Equisetum scirpoides</i>	.....	.....	.....	.....	.....	.....	..	s+s	s+s	.....	..	.....	..
<i>Equisetum variegatum</i>	21221	11111	11111	+11+	11111	.....	ss	+s+	ss+	sssss	..	11111	ss
<i>Erigeron boreale</i>	.....	.....	.....	.....	.....	.....	..	+++	+++	.....	..	.....	..
<i>Euphrasia frigida</i>	.....	.....	.....	.....	.....	.....	..	+++	+++	.....	..	.....	..
<i>Euphrasia frigida</i>	.....	.....	.....	.....	.....	.....	..	+++	+++	.....	..	.....	..
<i>Filipendula ulmaria</i>	.....	.....	.....	.....	.....	.....	..	+++	+++	.....	..	12111	++
<i>Galium boreale</i>	.....	.....	.....	.....	.....	.....	..	+++	+++	.....	..	.....	..
<i>Geranium sylvaticum</i>	.....	rr+++	.....	.....	.....	.....	..	ss+	s+	.....	..	111+1	ss
<i>Geum rivale</i>	.....	.....	.....	.....	.....	.....	..	ss+	s+	.....	..	.....	..
<i>Gymnadenia conopsea</i>	1+1+	+1++	11+11	+++++	+++1+	++s++	++	sss	sss	s+++	++	+++++	++
<i>Hieracium sect. Vulgata</i>	.....	.....	.....	.....	.....	.....	..	.....	.....	.....	..	.....	..
<i>Leontodon autumnalis</i>	1+111	1+11+	11111	11111	+++++	.....	+s	ssu	ssu	.....	..	.....	..
<i>Listera cordata</i>	.....	.....	.....	.....	.....	.....	..	+++	+++	.....	..	1+111	+s
<i>Listera ovata</i>	.....	+++++	.....	.....	.....	.....	..	+++	+++	+++++	+u	.....	..
<i>Parnassia palustris</i>	.....	11111	.....	11111	.....	ussus	..	+++	+++	.....	..	.....	..
<i>Pedicularis oederi</i>	11111	2111+	11211	21223	21222	sus+1	us	us+	uuu	.....	..	+++++	..
<i>Pedicularis palustris</i>	.....	++1++	.....	.....	.....	+su++	..	.....	.....	.....	..	.....	..
<i>Pinguicula vulgaris</i>	11111	+1111	11+11	.....	.....	+++s+	s+	ss+	s+s	.....	..	.....	..
<i>Polygonum viviparum</i>	11111	11112	11+1+	11111	11111	ussuu	uu	sss	sss	11s+	++	11111	1s
<i>Potentilla erecta</i>	22211	33323	1+1+	+111	.....	22332	12	uu+	s+s	+1++	+u	++1+	++
<i>Pyrola minor</i>	.....	.....	.....	.....	.....	.....	..	.....	.....	.....	..	.....	..
<i>Pyrola rotundifolia</i>	.....	+++1	.....	.....	.....	.....	..	.....	.....	.....	..	.....	..
<i>Ranunculus acris</i>	.....	.....	.....	11111	.....	.....	..	+++	+++	.....	..	.....	..
<i>Rumex acetosa</i>	.....	.....	.....	.....	.....	.....	..	.....	.....	.....	..	.....	..
<i>Saussurea alpina</i>	+111+	11111	21112	12222	11111	2+123	u1	1++	ssu	22321	32	11211	22
<i>Saxifraga aizoides</i>	.....	.....	.....	.....	.....	.....	..	.....	.....	.....	..	.....	..
<i>Selaginella selaginoides</i>	11111	11111	11111	11111	11111	uss+s	ss	su1	1ss	.....	..	.....	..
<i>Solidago virgaurea</i>	.....	.....	.....	.....	.....	.....	..	sss	sss	+sss+	++	11111	s+
<i>Succisa pratensis</i>	11+11	11212	33333	21+44	22212	+++++	32	334	323	+1s31	s+	11111	+s
<i>Thalictrum alpinum</i>	32222	33433	44433	43434	23223	22221	32	333	433	12221	22	+1111	22
<i>Tofieldia pusilla</i>	11111	11111	11111	.....	+1111	.....	+s	sss	s+s	.....	..	.....	..
<i>Trientalis europaea</i>	.....	.....	.....	.....	.....	.....	..	.....	.....	.....	..	.....	..
<i>Triglochin palustre</i>	.....	.....	.....	.....	.....	.....	..	.....	.....	.....	..	.....	..
<i>Viola palustris/epipsila</i>	.....	.....	.....	.....	.....	.....	..	.....	.....	.....	..	.....	..
<i>Anthoxanthum odoratum</i>	.....	.....	.....	.....	.....	.....	..	.....	.....	.....	..	.....	..
<i>Carex atrofusca</i>	.....	1+121	+++11	.....	.....	.....	..	.....	.....	.....	..	.....	..
<i>Carex buxbaumii</i>	.....	.....	.....	.....	.....	.....	..	.....	.....	.....	..	.....	..
<i>Carex capillaris</i>	11111	11111	11111	11111	21222	+++++	u1	1uu	2u2	1ss+	++	.....	..
<i>Carex capitata</i>	11+1	.....	.....	.....	.....	.....	..	.....	.....	.....	..	.....	..
<i>Carex dioica</i>	22222	11111	11121	11111	11111	22212	33	uss	uss	sss2s	..	11111	2u
<i>Carex flava</i>	1+++	32222	22111	22111	+1111	u++++	44	.....	.....	.....	..	.....	..
<i>Carex flava</i> x <i>C. hostiana</i>	.....	.....	.....	.....	.....	.....	..	.....	.....	.....	..	.....	..
<i>Carex hostiana</i>	+++++	.....	.....	.....	.....	.....	..	+++	+++	.....	..	.....	..

App. C Table 10 continued

Small quadrat no.	12345	67890	11111	11112	22222	22223	33	333	333	34444	44	44445	55
	12345	67890	12345	67890	12345	67890	12	345	678	90123	45	67890	12
Carex lasiocarpa	++++	111+	1111	1111	1111	ss++	..	...	...	+++ss	..	21111	23
Carex nigra	22213	11++	33332	22212	43333	12212	22	112	322	s1u1s	..	...	..
Carex panicea	22121	21232	1111	1231+	112+1	s+12+	1u	1+s	...	+111+	+1	11111	21
Carex rostrata	1+1+	+2++	11+1	111+	++1+	++s+	++	s+1	12s	22211	21	+1211	++
Carex vaginata	1+++	21111	1+11	11+1	1+1+	1111s	1u	...	...	sssuu	..	1+++1	ss
Deschampsia cespitosa	32333	+1++	...	...	++++	...	...	...	...	...	...	+++	s+
Eriophorum angustifolium	...	+1++	...	...	++1+	++s+	s+	...	...	...	...	+++	s+
Eriophorum latifolium	...	11++	++1+	1111	...	++su	su	2uu	u2u	11uu1	1u	1+111	+1
Eriophorum vaginatum	...	11++	++1+	1111	...	++su	su	...	...	...	...	...	...
Festuca ovina	++++	...	...	...	...	...	...	...	...	...	...	...	...
Juncus castaneus	...	...	...	...	...	...	...	...	...	...	...	...	...
Juncus filiformis	...	...	...	...	...	...	...	...	...	...	...	...	...
Juncus triglumis	11111	+11+	1+++	++1+	...	...	...	...	...	...	...	...	...
Kobresia simpliciuscula	33332	+11+	++1+	++1+	1+21	...	...	u21	1uu	...	...	+++	+
Luzula sudetica	21232	21233	22221	22222	23223	23222	21	443	133	23443	33	++++	2+
Molinia caerulea	...	...	...	...	...	...	...	...	...	...	...	...	...
Nardus stricta	...	...	...	...	...	...	...	...	...	...	...	...	...
Scirpus cespitosus	1+1+2	44215	24324	23331	11121	23212	33	233	323	11uu+	...	...	...
Scirpus hudsonianus	...	...	...	...	1+++	++s+	...	...	...	...	...	...	...
Aulacomnium palustre	...	...	++11	1+1+	++1+	s++us	..	...	...	...	...	32232	+s
Brachythecium turgidum	11111	11111	+1+1	111+	11111	1+sss	ss	s+s	su+	+++ss	..	...	s+
Bryum pseudotriquetrum	...	...	++1+	...	++s+	...	...	...	...	...	...	...	...
Calliergon richardsonii	...	...	++1+	...	++s+	...	...	...	...	...	...	...	...
Calliergon stramineum	...	...	++1+	...	++s+	...	...	...	...	...	...	...	...
Calliergon trifarium	...	...	++1+	...	++s+	...	...	...	...	...	...	...	...
Campylium stellatum	44545	22223	54544	55555	55556	21432	66	455	555	11132	s+	...	s+
Cratoneuron commutatum	+++11	++32+	...	...	...	...	...	...	...	...	...	...	...
Dicranum angustum	...	...	++1+	...	1+++	1++s+	..	...	...	1+s+	..	1+111	11
Dicranum bonjeanii	...	...	++1+	...	1+++	1++s+	..	...	...	1+s+	..	1+111	11
Dicranum majus	...	...	++1+	...	1+++	1++s+	..	...	...	1+s+	..	1+111	11
Ditrichum flexicaule	+++1+	...	++1+	...	1+++	1++s+	..	1s+	112	...	...	...	...
Drepanocladus badius	...	...	++1+	...	1+++	1++s+	..	...	...	1+s+	..	1+111	11
Drepanocladus revolvens	22343	+11+	111+	11111	22221	1+uuu	1+	uu2	311	...	...	...	++
Drepanocladus uncinatus	...	...	++1+	...	++s+	...	...	...	...	...	...	...	...
Fissidens adianthoides	11111	1+111	11111	++11	12111	u+s+	1u	uuu	u2u	11u21	..	...	...
Fissidens osmundoides	...	...	++1+	...	++s+	...	...	...	...	...	...	...	...
Homalothecium nitens	...	44222	33423	42123	1211+	43333	s+	...	1+	++uu+	ss	22121	1s
Hylocomium pyrenaicum	...	...	++11	...	2+++	...	...	...	...	ss+++	2+	++111	+s
Hylocomium splendens	...	...	++1+	...	1+++	...	...	...	...	++s+	++	++111	+s
Hypnum bambergeri	...	...	1+++	11+++	...	43421	+s	11u	++u	...	...	...	...
Hypnum lindbergii	...	...	1+++	11+++	...	11+s	...	...	...	...	...	...	...
Hypnum pratense	...	...	1+++	11+++	...	1+s	...	...	...	...	...	...	...
Paludella squarrosa	...	...	1+++	11+++	...	1+s	...	...	...	...	...	...	...
Plagiommium ellipticum	...	...	1+++	11+++	...	1+s	...	...	...	...	...	...	...
Pleurozium schreberi	...	...	1+++	11+++	...	1+s	...	...	...	11s++	s+	...	...
Pohlia nutans	...	...	1+++	11+++	...	1+s	...	...	...	...	...	11111	s+
Polytrichum strictum	...	...	1+++	11+++	...	1+s	...	...	...	...	...	3+111	..
Rhizomnium pseudopunctatum	...	211+1	...	...	++s+	...	...	...	...	...	...	...	...
Rhytidiadelphus squ./sub.	...	...	...	...	++s+	...	...	...	...	...	...	...	...
Sphagnum angustifolium	...	...	...	...	++s+	...	...	...	...	...	...	1+111	...
Sphagnum n.n.	...	...	...	...	++s+	...	...	...	...	...	...	22+++	...
Sphagnum warnstorffii	...	33111	1+143	...	++1+	35355	...	...	...	...	...	45656	66
Thuidium recognitum	...	...	...	...	++s+	...	...	...	...	...	...	...	...
Tortella tortuosa	...	...	...	...	++s+	...	...	11s	u23	...	...	...	...
Aneura pinguis	++111	11111	++1+	++1+	11++	1ss+s	++	...	...	++ss+	..	11111	+1
Barbilophozia kunzeana	...	...	...	...	...	...	...	...	...	++s+	ss	++1++	..
Barbilophozia lycopodioides	1111+	21111	11111	11+11	1+11+	sssu+u	+s	++s	++s+	...	...	...	...
Barbilophozia quadriloba	...	...	...	...	...	...	...	...	...	...	...	...	...
Blepharostoma trichophyllum	...	...	...	...	...	...	...	s++	...	...	...	...	...
Calypogeia sphagnicola	...	...	...	...	...	...	...	...	...	...	...	11+1+	...
Cephalozia lunulif. coll.	...	...	...	...	...	...	...	...	...	++s	..	31111	s1
Lophozia bantriensis	44131	+11+	...	...	...	...	...	...	...	...	...	...	...
Lophozia bantriensis/gil.	...	...	...	...	...	...	...	...	...	...	...	...	...
Lophozia borealis	...	...	111+	11111	11111	s+s+	+s	uuu	1uu	...	...	...	...
Lophozia rutheana	...	...	++1+	1+1+	...	su+u	ss	...	...	...	...	1+11+	s+
Lophozia ventricosa	...	...	++1+	1+1+	...	su+u	ss	...	...	...	...	1+1+	...
Mylia anomala	...	...	++1+	...	...	++s+	...	...	...	...	...	...	...
Pellia neesiana	...	...	++1+	...	...	++s+	...	...	...	...	...	...	...
Plagiochila porelloides	...	+1+11	...	++1+	...	...	...	...	...	...	...	...	...
Scapania aequiloba	...	...	...	...	...	...	...	+	s+	...	...	...	...
Scapania irrigua	...	11+++	...	...	...	+	uuuu	...	...	21+s+	...	...	...
Tritomaria polita	12+11	...	...	...	++1+	...	...	...	...	...	...	...	...
Tritomaria quinqueidentata	...	11++	1121	1+11	++1+	s+++s	++	...	...	++s+	s+	11211	ss
No. of vasculars	22222	23322	22222	22222	12222	22222	22	322	222	12111	11	22222	12
	60100	92186	63152	43653	93431	01312	24	042	546	61875	22	32745	90
No. of cryptogams	00010	11111	00111	00000	10110	10111	00	000	001	00000	00	11111	00
	77708	02101	87220	89799	17036	69418	78	988	790	59763	64	44341	99
Total no. of species	32232	34433	33333	33333	33332	33334	23	333	333	23221	11	33433	22
	37808	94287	40372	22342	00467	60720	92	920	236	10538	86	76086	89

## APPENDIX C

Table 11 Analyses of rich fen vegetation, carpet-lawn communities. Complete phytosociological table for the small quadrats (no. 21 = 0.5 m<sup>2</sup>; nos. 22, 37 & 38 = 1 m<sup>2</sup>; the rest = 0.25 m<sup>2</sup>) of the samples of clusters M11 and 12, and the residual (R) samples; cf. section 5.

Small quadrat no.	1	11111	11112	22	22222	22333	33333	33
Year of analysis	1976	1976	1977	1977	83	1976	1977	1982
Cluster no. (M)	11	11	12	12	12	R	R	R
Stand sample no.	1	1	1	6	9	6	6	9
	7	8	9	2	9	0	6	1
Field layer cover	45454	55545	55555	55655	55	45655	55545	1111
Field layer height in cm	20	25	20	20	40	40	30	5
Bottom layer cover	66666	56666	66666	66666	66	66564	44323	6656
Litter cover	32222	44333	35543	44555	33	34535	44535	1111
<i>Betula nana</i> B	.....	.....	.....	.....	..	.....	.....	..
<i>Salix glauca</i> B	.....	.....	.....	.....	..	.....	.....	1+
<i>Salix lapponum</i> B	.....	.....	.....	.....	..	.....	.....	2+
<i>Salix pentandra</i> B	.....	.....	.....	.....	2+	.....	.....	..
<i>Salix phylicifolia</i> B	.....	.....	.....	.....	..	.....	.....	345s
<i>Andromeda polifolia</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Betula nana</i>	.....	++1++	.....	.....	..	.....	.....	..
<i>Salix glauca</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Salix hastata</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Salix lapponum</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Salix myrsinites</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Salix nigricans</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Salix pentandra</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Salix phylicifolia</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Caltha palustris</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Cardamine pratensis</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Dactylorhiza cruenta</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Dactylorhiza incarnata</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Epilobium hornemanii</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Epilobium palustre</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Equisetum palustre</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Equisetum variegatum</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Filipendula ulmaria</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Galium palustre</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Geum rivale</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Gymnadenia conopsea</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Menyanthes trifoliata</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Parnassia palustris</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Pedicularis palustris</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Petasites frigidus</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Polygonum viviparum</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Potentilla erecta</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Potentilla palustris</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Saussurea alpina</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Selaginella selaginoides</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Thalictrum alpinum</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Triglochin palustre</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Utricularia minor</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Veronica scutellata</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Viola epipsila</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Agrostis capillaris</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Agrostis mertensii</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Carex appropinquata</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Carex atrofusca</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Carex buxbaumii</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Carex canescens</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Carex capillaris</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Carex dioica</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Carex flava</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Carex heleonastes</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Carex limosa</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Carex magellanica</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Carex nigra</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Carex panicea</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Carex rostrata</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Carex saxatilis</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Carex stenolepis</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Carex vaginata</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Carex vesicaria</i>	.....	.....	.....	.....	..	.....	.....	..
<i>Deschampsia cespitosa</i>	.....	.....	.....	.....	..	.....	.....	..

App. C Table 11 continued

Small quadrat no.	12345	67890	11111	11112	22	22222	22333	33333	33
	12345	67890	12345	67890	12	34567	89012	3456	78
<i>Eleocharis quinqueflora</i>	21121	22111	.....	22222	s+	.....	.....	.....	..
<i>Eriophorum angustifolium</i>	11111	++++1	32222	11222	uu	+1+++	11121	....	+s
<i>Eriophorum latifolium</i>	+++++	1++++	.....	.....	..	.....	.....	.....	..
<i>Juncus alpino-articulatus</i>	.....	.....	.....	.....	..	.....	+++11	.....	..
<i>Juncus castaneus</i>	.....	.....	.....	.....	..	.....	+1++1	.....	..
<i>Juncus filiformis</i>	.....	.....	.....	.....	..	.....	.....	.....	s+
<i>Juncus triglumis</i>	.....	.....	111++	+++++	..	.....	.....	.....	..
<i>Molinia caerulea</i>	.....	.....	.....	.....	..	.....	+++1	.....	..
<i>Nardus stricta</i>	.....	.....	.....	.....	..	.....	.....	.....	+2
<i>Scirpus cespitosus</i>	.....	.....	+111+	32433	+s	.....	.....	.....	+s
<i>Scirpus hudsonianus</i>	.....	.....	+++++	1++1	..	.....	.....	.....	++
<i>Aulacomnium palustre</i>	.....	.....	.....	.....	..	.....	.....	.....	+s
<i>Brachythecium turgidum</i>	.....	.....	.....	.....	..	.....	.....	.....	+1
<i>Bryum pseudotriquetrum</i>	11111	23112	11112	11111	s4	11111	12112	ss+s	+s
<i>Calliergon giganteum</i>	43233	22122	22222	+1+1	..	.....	.....	ss++	..
<i>Calliergon richardsonii</i>	.....	.....	.....	.....	i2	.....	.....	.....	45
<i>Calliergon sarmentosum</i>	.....	.....	.....	+11+1	s+	.....	.....	.....	..
<i>Calliergon stramineum</i>	.....	.....	.....	.....	..	11+1+	.....	.....	..
<i>Calliergon trifarium</i>	++1+1	.....	11111	+1++	1+	.....	.....	.....	..
<i>Campylium stellatum</i>	.....	32111	12221	41343	1s	11+13	111++	+sss	2i
<i>Cinclidium stygium</i>	33131	23113	22113	11212	42	.....	.....	.....	..
<i>Cratoneuron commutatum</i>	.....	.....	.....	.....	..	.....	32112	.....	..
<i>Cratoneuron decipiens</i>	.....	.....	.....	.....	..	.....	1++1	.....	..
<i>Dichodontium pellucidum</i>	.....	.....	.....	.....	..	.....	.....	s++s	..
<i>Drepanocladus revolvens</i>	33344	34553	55555	34445	44	.....	32212	344s	33
<i>Drepanocladus sendtneri</i>	.....	.....	.....	.....	..	.....	.....	uss	..
<i>Fissidens adianthoides</i>	.....	.....	.....	.....	..	+1++	.....	us41	+u
<i>Fissidens osmundoides</i>	.....	.....	.....	.....	..	.....	.....	s+++	..
<i>Homalothecium nitens</i>	.....	.....	.....	.....	..	22121	.....	.....	..
<i>Hypnum lindbergii</i>	.....	.....	.....	.....	..	.....	.....	.....	1i
<i>Hypnum pratense</i>	.....	.....	.....	.....	..	.....	.....	.....	+s
<i>Meesia triquetra</i>	31221	11111	21222	13211	+3	.....	.....	.....	..
<i>Meesia uliginosa</i>	.....	.....	.....	.....	1+	.....	.....	.....	s+
<i>Paludella squarrosa</i>	.....	111++	.....	.....	11	11+11	.....	.....	..
<i>Philonotis fontana/tomentella</i>	.....	.....	.....	.....	+s	.....	.....	.....	..
<i>Plagiomnium ellipticum</i>	.....	.....	.....	.....	..	+1+1	.....	.....	..
<i>Rhizomnium pseudopunctatum</i>	.....	.....	.....	.....	..	11222	.....	.....	..
<i>Scorpidium scorpioides</i>	+++21	+++1	21111	13233	s+	.....	.....	.....	..
<i>Sphagnum contortum</i>	.....	.....	+1++	.....	..	.....	.....	.....	2s
<i>Sphagnum platyphyllum</i>	.....	.....	.....	.....	..	.....	.....	.....	..
<i>Sphagnum warnstorfii</i>	.....	+1++	.....	.....	..	66463	.....	+++s	..
<i>Tayloria linguata</i>	.....	.....	.....	.....	+s	.....	.....	.....	..
<i>Tortella tortuosa</i>	.....	.....	.....	.....	..	.....	.....	6s26	..
<i>Aneura pinguis</i>	.....	1++++	11111	21121	2s	.....	11+++	s+++	+u
<i>Cephaloziella sp.</i>	.....	.....	.....	.....	..	.....	.....	1+s1	..
<i>Chiloscyphus pallescens</i>	.....	.....	.....	.....	..	+2++	.....	.....	..
<i>Jungermannia atrovirens</i>	.....	.....	.....	.....	..	.....	.....	s4+s	..
<i>Lophozia bantriensis</i>	.....	.....	.....	.....	33	.....	.....	u1ss	..
<i>Lophozia borealis</i>	.....	.....	.....	11111	..	.....	.....	234s	..
<i>Lophozia rutheana</i>	.....	121+3	+11++	1++++	11	.....	.....	.....	..
<i>Moerckia hibernica</i>	.....	.....	+1++	1++++	..	.....	.....	.....	..
<i>Plagiochila porelloides</i>	.....	.....	.....	.....	..	.....	.....	s+++	..
<i>Scapania irrigua</i>	.....	.....	.....	.....	+s	.....	.....	.....	..
<i>Tritomaria polita</i>	.....	.....	.....	.....	+s	.....	.....	.....	..
Mud bottom	2++++	32122	.....	.....	..	.....	44535	+143	..
No. of vasculars	11111 11111	11111 11111	11111 11111	11	01111 01000	0000 12			
	33312 57618	35672 21215	98	92444 51869	6545 50				
No. of cryptogams	00000 00000	01100 10101	11	00000 00000	1101 01				
	55667 98968	90299 09180	34	78686 66535	3082 61				
Total no. of species	11111 22212	22222 22212	33	12222 11101	1111 23				
	88979 45576	25861 20395	22	60020 17394	9527 11				



## APPENDIX C

Table 12 Analyses of spring communities. Complete phytosociological table for the small quadrats (nos. 10-12 = 1 m<sup>2</sup>; nos. 23-25 = 0.1 m<sup>2</sup>; the rest = 0.25 m<sup>2</sup>) of the samples of clusters M16 and 17 and residual (R) samples; cf. section 5. The quadrats of sample 94 are dealt with in section 7.2.

Small quadrat no.	123	4567	89	111	1111	1112	22	222	22
Cluster no. (M)	16	16	16	17	17	17	R	-	R
Stand sample no.	9	9	9	9	9	9	9	9	9
	5	4	7	3	5	6	2	4	3
Locality no.	95	92	94	93	93	93	92	94	92
Field layer cover	545	5546	66	341	5665	6555	34	232	23
Field layer height in cm	10	8	10	15	15	20			
Bottom layer cover	666	6666	66	666	6666	6666	66	666	66
Litter cover	111	1112	11	111	1111	1111	11	111	ss
<i>Salix arbuscula</i>	...	+++2	..	...	...	...	..	u+u	..
<i>Salix glauca</i>	...	...	..	...	...	...	..	+s1	..
<i>Salix nigricans</i> coll.	...	...	1+	...	...	...	..	s++	..
<i>Vaccinium myrtillus</i>	...	...	..	...	...	...	..	...	..
<i>Alchemilla</i> sp.	...	1+++	..	...	...	3333	..	s++	..
<i>Angelica sylvestris</i>	...	+++s	+s	...	...	+++s	..	su+	..
<i>Bartsia alpina</i>	...	...	..	...	...	...	..	...	..
<i>Caltha palustris</i>	...	...	..	221	3341	1+++	21	...	+r
<i>Cardamine pratensis</i>	...	...	..	...	...	...	+s	...	+s
<i>Cirsium palustre</i>	...	...	+u	...	...	...	...	...	..
<i>Crepis paludosa</i>	1u1	s1++	+2	...	...	...	+1	+u+	..
<i>Epilobium alsinifolium</i>	s+u	...	..	121	2141	2+ss	us	...	ss
<i>Equisetum arvense</i>	++s	...	..	22s	3431	211u	ss	+	ss
<i>Equisetum palustre</i>	+++	...	..	sss	+ss+	ss+s	ss	+	ss
<i>Equisetum variegatum</i>	+ss	...	s+	...	...	+++s	..	...	..
<i>Euphrasia frigida</i>	+s+	s++s	..	...	...	...	..	...	..
<i>Geranium sylvaticum</i>	+ss	...	..	...	...	...	..	+	..
<i>Gymnadenia conopsea</i>	...	...	..	...	...	...	..	+	..
<i>Leontodon autumnalis</i>	s+s	+s++	..	...	...	...	..	+	..
<i>Pedicularis oederi</i>	+s1	1u+u	..	...	...	...	..	+	..
<i>Petasites frigidus</i>	...	...	..	+++	+++3	...	+1	...	..
<i>Pinguicula vulgaris</i>	...	u+++	..	...	...	...	...	sss	..
<i>Polygonum viviparum</i>	s11	21s1	..	...	...	...	..	++s	s+
<i>Potentilla erecta</i>	...	...	+s	...	...	...	..	...	..
<i>Potentilla palustris</i>	...	...	..	++u	...	...	..	...	..
<i>Ranunculus acris</i>	++s	...	..	...	...	...	..	...	..
<i>Rumex acetosa</i>	++s	...	..	...	+++	+++	..	...	..
<i>Saussurea alpina</i>	433	3223	+2	...	...	+331	..	s+	..
<i>Saxifraga aizoides</i>	543	4444	66	...	...	...	..	s3+	..
<i>Selaginella selaginoides</i>	...	s+++	..	...	...	...	..	...	..
<i>Solidago virgaurea</i>	...	s+++	..	...	...	...	..	...	..
<i>Thalictrum alpinum</i>	s++	us12	1+	...	...	...	..	+u+	..
<i>Triglochin palustre</i>	...	+s++	..	...	...	...	..	+s+	..
<i>Calamagrostis purpurea</i>	...	...	..	...	11s1	1113	+s	...	+u
<i>Calamagrostis stricta</i>	...	...	..	...	...	...	..	12s	..
<i>Carex atrofusca</i>	+su	s1ss	s+	...	...	...	..	s++	..
<i>Carex capillaris</i>	...	...	..	...	...	...	..	u++	..
<i>Carex dioica</i>	+ss	ssss	+s	...	...	...	..	u++	1+
<i>Carex lasiocarpa</i>	...	+s+s	..	...	...	...	..	...	+s
<i>Carex nigra</i>	...	...	+s	...	...	...	..	...	..
<i>Carex panicea</i>	...	...	u+	...	...	...	..	...	..
<i>Carex rostrata</i>	...	...	..	11s	2312	2233	..	...	..
<i>Carex vaginata</i>	++u	3223	..	...	...	...	..	...	1+
<i>Deschampsia cespitosa</i>	111	ssss	s2	...	2111	2+++	23	++u	..
<i>Eleocharis quinqueflora</i>	...	+s++	..	...	...	...	..	+s+	..
<i>Eriophorum angustifolium</i>	...	...	ss	...	...	+s1u	us	+s+	s1
<i>Festuca ovina</i>	...	...	..	...	...	...	..	+s+	..
<i>Festuca rubra</i>	s+s	...	..	...	...	...	..	+	..
<i>Juncus alpino-articulatus</i>	...	...	..	...	...	...	..	+s+	..
<i>Juncus castaneus</i>	+ss	...	..	...	...	++s+	..	...	..
<i>Juncus triglumis</i>	ss+	s+++	..	...	...	...	..	+	..
<i>Molinia caerulea</i>	...	s+++	..	...	...	...	..	...	..
<i>Poa alpina</i>	++s	...	..	...	...	...	..	...	..
<i>Andreea rupestris</i>	...	...	..	...	...	...	..	++s	..
<i>Blindia acuta</i>	...	...	..	...	...	...	..	+11	..
<i>Bryum pseudotriquetrum</i>	231	s211	11	...	...	++s+	11	311	su
<i>Calliergon giganteum</i>	...	...	..	...	...	...	11	...	66
<i>Campylium stellatum</i>	...	us+u	..	...	...	...	+s	31u	..
<i>Cinclidium stygium</i>	...	...	..	...	...	...	..	1s+	s+



App. C Table 12 continued

Small quadrat no.	123	4567	89	111	1111	1112	22	222	22
	012	3456	7890	11	345	67	12	345	67
<i>Cratoneuron commutatum</i>	652	6555	23	24+	5666	6655	11	136	ss
<i>Cratoneuron decipiens</i>	116	1+++	55	...	...	++1+	+1	++u	..
<i>Cratoneuron filicinum</i>	111	...	..	...	...	...	..	...	..
<i>Dicranella palustris</i>	...	...	..	...	...	...	..	+1+	..
<i>Dicranoweisia crispula</i>	...	...	..	...	...	...	..	++s	..
<i>Dicranum majus</i>	...	...	..	...	...	...	..	+s+	..
<i>Drepanocladus exannulatus</i>	...	...	..	1s6	...	...	..	...	..
<i>Drepanocladus revolvens</i>	...	+s++	..	...	...	...	+s	231	+s
<i>Fissidens adianthoides</i>	...	...	..	...	...	...	..	us+	..
<i>Fissidens osmundoides</i>	...	...	..	...	...	...	..	ss+	..
<i>Homalothecium nitens</i>	...	+s++	..	...	...	...	..	...	..
<i>Meesia uliginosa</i>	...	...	..	...	...	...	..	1ss	..
<i>Oncophorus virens</i>	...	s+++	..	...	...	...	+s	++u	..
<i>Philonotis calcarea</i>	11+	3ss2	11	...	...	...	..	2s+	u+
<i>Philonotis fontana/tomentella</i>	s11	...	+s	s1s	1112	2334	54	++u	us
<i>Pohlia wahlenbergii</i>	++u	++s+	..	...	...	...	..	...	..
<i>Racomitrium aciculare</i>	...	...	..	...	...	...	..	++1	..
<i>Rhizomnium pseudopunctatum</i>	...	...	..	...	...	...	..	++s	..
<i>Rhizomnium punctatum</i>	...	...	..	...	...	...	..	+1s	..
<i>Tayloria lingulata</i>	...	...	..	...	...	...	..	+u+	..
<i>Anastrophyllum minutum</i>	...	...	..	...	...	...	..	+s+	..
<i>Aneura pinguis</i>	...	s+++	s+	...	...	...	..	s11	..
<i>Barbilophozia attenuata</i>	...	...	..	...	...	...	..	+1+	..
<i>Barbilophozia floerkei</i>	...	...	..	...	...	...	..	2++	..
<i>Barbilophozia quadriloba</i>	...	...	..	...	...	...	..	s+s	..
<i>Blepharostoma trichophyllum</i>	...	...	..	...	...	...	..	s1+	..
<i>Cephalozia sp.</i>	...	...	..	...	...	...	..	+ss	..
<i>Hygrobiella laxifolia</i>	...	...	..	...	...	...	..	u+s	..
<i>Jungermannia exsertifolia</i>	...	...	..	641	321+	...	45	++s	..
<i>Lophozia bantriensis</i>	++1	s322	..	...	...	...	..	s1s	..
<i>Lophozia grandiretis</i>	...	...	..	...	...	...	..	+s+	..
<i>Lophozia ventricosa</i>	...	...	..	...	...	...	..	++s	..
<i>Marchantia alpestris</i>	...	...	..	...	...	...	..	...	+s
<i>Mylia anomala</i>	...	...	..	...	...	...	..	+u+	..
<i>Odontoschisma elongatum</i>	...	...	..	...	...	...	..	+us	..
<i>Scapania irrigua</i>	...	...	..	...	...	...	..	++2	..
<i>Tritomaria polita</i>	...	+ss+	..	...	...	...	..	u1s	..
Mud bottom	...	...	..	311	...	...	..	...	..
No. of vasculars	111	1101	01	000	0000	0001	00	110	00
	039	7483	80	557	6777	8780	59	148	67
No. of cryptogams	000	0000	00	000	0000	0000	00	122	00
	667	8866	55	443	3332	2242	59	644	66
Total no. of species	112	2211	11	001	0110	1011	11	233	11
	696	5249	35	990	9009	0922	08	782	23

## APPENDIX C

Table 13 Analyses of ombrotrophic vegetation, hummock communities. Complete phytosociological table for the small quadrats (0.25 m<sup>2</sup>) of sample no. 71; cf. section 5.

Small quadrat no.	12345
Year of analysis	1978
Cluster no. (M)	18
Stand sample no.	7
	1
Field layer cover	45544
Field layer height in cm	8
Bottom layer cover	66666
Litter cover	11111
<i>Andromeda polifolia</i>	+1111
<i>Arctostaphylos alpina</i>	+++2
<i>Betula nana</i>	21321
<i>Empetrum hermaphroditum</i>	34323
<i>Oxycoccus microcarpus</i>	12211
<i>Vaccinium myrtillus</i>	11111
<i>Vaccinium uliginosum</i>	11311
<i>Vaccinium vitis-idaea</i>	1+++1
<i>Rubus chamaemorus</i>	34333
<i>Carex pauciflora</i>	+1+++
<i>Eriophorum vaginatum</i>	11211
<i>Dicranum affine</i>	+42+2
<i>Dicranum angustum</i>	++2++
<i>Dicranum fuscescens</i>	++1++
<i>Pleurozium schreberi</i>	+41+1
<i>Pohlia nutans</i>	11111
<i>Polytrichum strictum</i>	23142
<i>Sphagnum angustifolium</i>	1+11+
<i>Sphagnum fuscum</i>	53115
<i>Sphagnum russowii</i>	+4142
<i>Barbilophozia binsteadii</i>	++1++
<i>Calypogeia sphagnicola</i>	21111
<i>Cephalozia leucantha</i>	++5+1
<i>Cephalozia lunulifolia</i> c	11123
<i>Cephalozia pleniceps</i>	111++
<i>Lophozia ventricosa</i>	+1+++
<i>Mylia anomala</i>	32322
<i>Cladina arbuscula</i> coll.	++1++
No. of vasculars	00001
	89880
No. of cryptogams	01101
	81680
Total no. of species	12212
	60460



App. D Table 1 continued

Cluster no. (W)	Heathland communities						Grassland communities				
	1	2	3	4	5	6	7	8	9	10	11
Stand sample no.	45 95	4444 7465	2 2 7578 0710	4442 2318	3242233 0385492	33	22 2 337535332 462071852	2522 1606	2222 225555 795687	2 222 22 54555 665 302498010	8888 5423
III <i>Potentilla erecta</i>	11	....	..11	1311	121.+1.	..	.11s1s11.	3.31	141111	.....	1..
<i>Festuca ovina</i>	11	....	1.1	....	1.1.1	..	..s.1.11	111	111	.....	...1
<i>Nardus stricta</i>	55	4511	1111	4355	2211.1.	1.	..1.1.11	1313	222111	.....	....
<i>Dicranum scoparium</i>	11	1111	1111	1131	21311.1	11	.2.2.312.	1112	11ss..	.....	....
<i>Pleurozium schreberi</i>	33	1111	4442	1221	2122111	1.	..21.2.1.	1112	.....	.....	....
<i>Polytrichum commune</i>	12	3656	1.12	1234	5312324	12	..1.1.1.1.	2221	.....	.....	....
<i>Polytrichum juniperinum</i>	54	4221	111.	..1.	..1.1.1.	..	11.1.1.1.	..1	.....	.....	....
<i>Sphagnum russowii</i>	11	3141	....	..4	.....	..	.....	121.	.....	.....	....
<i>Barbilophozia floerkei</i>	31	1212	..4	4252	.....	..	.....	1.2	1..s1.	.....	....
<i>Vaccinium myrtillus</i>	..	s1.1	2124	4311	1111111	11	11s1.111s	s111	1..s	ssss..	....
<i>Vaccinium vitis-idaea</i>	..	1211	2322	1..	1113+1	..	s12.2.3	..	..	..	1..
<i>Juniperus communis</i> - B	..	....	3335	1112	464421	11	1.1..112	1..2	1..	1s.....	....
<i>Empetrum hermaphroditum</i>	..	....	1514	....	11.12.1	..	..s.1	s.1	.....	.....	....
<i>Melampyrum pratense</i>	..	....	1112	....	2212222	12	11.1.1.1.	1111	.....	.....	....
<i>Brachythecium reflexum</i>	..	....	ss1	....	1111111	11	1321111	11	1111	1111s1321	111.
<i>Hylocomium splendens</i>	..	....	2431	....	11.1112	..	13112111	2214	11ss11	11ss11	1..
<i>Anthoxanthum odoratum</i>	..	....	s.1	1111	1111133	22	2223.3231	2131	221111	11111+11.	1..2
<i>Luzula pilosa</i>	..	....	1.1	1s.1	1222112	11	11.1.111.	1.1.	11	.....	....
<i>Lophozia obtusa</i>	..	....	..112	1111112	11	111s.1111	1.1.	.....	s1s.s..s1	311.	....
<i>Dactylorhiza fuchsii</i>	..	....	....	..1ss1s	11	1s..s.1s	1.1	11ss1s	ss,ss+.1	.....	....
<i>Geranium sylvaticum</i>	..	....	..1.	..s+1s31	1	563464566	4241	351334	464455442	3331	....
<i>Gnaphalium norvegicum</i>	..	....	....	..1	1.1s11	1	11.111111	111s	1s111.111	.....	....
<i>Melampyrum sylvaticum</i>	..	....	..1.	..s+111	12	111s1111.	s111	11....	1..11112	..11	....
<i>Oxalis acetosella</i>	..	....	....	..1s.212	11	1..s1..s.	..	..	s.132221	.....	....
<i>Brachythecium salebrosum</i>	..	....	..1.	1111111	25	141312111	1..	.....	332423443	.....	....
<i>Rhododryum roseum</i>	..	....	....	1111112	13	111212131	2121	211323	s1s2131s1	4..	....
<i>Euphrasia frigida</i>	..	....	..1.	..1	1s1	1.1.1.s1	1ss	1s.s1.	.....	..s1	....
<i>Hieracium</i> spp.	..	....	..1.	....	s11	11.11111.	1111	11..s	2s2s	.....	....
<i>Polygonum viviparum</i>	..	....	....	..1	s..1	11.1121111	1121	111111	1111s.ss	....2	....
<i>Pyrola minor</i>	..	....	....	....	11	ss.111111	11s.	1.s12	1111	1..1	....
<i>Rumex acetosa</i>	..	....	....	..s.	11.11	11.11s1.1	111.	..1s1s	111111121	2111	....
<i>Viola biflora</i>	..	....	..s.	....	s1	43.324321	....	1	212221333	.....	....
<i>Mnium spinosum</i>	..	....	..2.	....	1..	11.1211112	..	1.	322311442	.....	....
<i>Salix glauca</i> - B	..	....	....	....	..	13s.+111	211	..	1.121.1+	16s3	....
<i>Alchemilla</i> spp.	..	....	....	....	..	322312424	1131	324444	452432231	24s3	....
<i>Filipendula ulmaria</i>	..	....	....	....	..	2s1s111	....	11.211	222312121	2331	....
<i>Geum rivale</i>	..	....	....	....	..	+112.2s2	....	112223	s21232112	1242	....
<i>Myosotis decumbens</i>	..	....	....	....	..	11.s1s1s.	....	..s.s	1111s111.	....	....
<i>Parnassia palustris</i>	..	....	....	....	..	1.121211	1..	12ss1s	ss.s..ss.	..22	....
<i>Ranunculus acris</i>	..	....	....	....	..	111s1s111	11	112221	111211111	..s1	....
<i>Saussurea alpina</i>	..	....	....	....	..	13222111	1.11	41123	111.21111	2121	....
<i>Thalictrum alpinum</i>	..	....	..1.	11..1.	..	112.211s	3	51221s	.....	....	....
<i>Agrostis capillaris</i>	..	....	..1.	11..1.	..	23313122	5121	113232	21222213.	1..2	....
<i>Carex vaginata</i>	..	....	..1.	ss	1.	1s1..1s2.s	s112	322113	.....	1..2	....
<i>Deschampsia cespitosa</i>	..	....	..1.1	1..	....	2.3222214	3231	144424	342323322	2122	....
<i>Festuca rubra</i>	..	....	....	....	..	11s1111s.	1.	11s11	ss1s	.....	....
<i>Crepis paludosa</i>	..	....	....	....	..	1..1	1121	223333	312323231	2223	....
<i>Rhytidadelphus</i> sq./subp.	..	....	....	..1	....	1..1	1.11	15331	212121111	....	....
<i>Plagiochila porelloides</i>	..	....	....	..1	....	..s1s1.1	1.11	211312	111121212	1..	....
<i>Angelica sylvestris</i>	..	....	....	....	..	11+.11	....	11+.11	..s..11	1111	....
<i>Rhizomnium magnifolium</i>	..	....	....	....	..	11s11	....	11111	..s111.	141	....
<i>Chiloscyphus pallescens</i>	..	....	....	....	..	11s311	....	11s311	..2132.	1111	....
<i>Pellia neesiana</i>	..	....	....	....	..	12s11.	....	12s11.	..s213.	4223	....
IV <i>Salix nigricans</i> coll. - A	..	....	....	....	..	....	....	....	....+1+1.	..+	....
<i>Salix pentandra</i> - A	..	....	....	....	..	....	....	....	....	..14	....
<i>Sorbus aucuparia</i> - A	..	....	....	..+	11.	....	....	....	....	..1	....
<i>Betula nana</i> - B	4.	..s.	....	....	....	....	....	....	....	6..1	....
<i>Salix lapponum</i> - B	..	....	....	....	..	1+	..11	..+	11.s.s	....	....
<i>Salix nigricans</i> coll. - B	..	....	....	....	..	1+	..11	..+	11.s.s	....	....
<i>Salix pentandra</i> - B	..	....	....	....	..	..2.	....	....	....	5	....
<i>Salix phylicifolia</i> - B	..	....	..1.	1..111.	..	....	1.1.	....	....	5	....
<i>Sorbus aucuparia</i> - B	..	....	....	....	..	..1.	....	....	....	..1	....
<i>Betula nana</i>	..	....	....	....	..	..1.	....	....	....	..1	....
<i>Calluna vulgaris</i>	..	....	..11	....	....	....	....	....	....	....	....
<i>Salix lanata</i>	..	....	....	....	..	..1.	....	....	....	1..1	....
<i>Salix phylicifolia</i>	..	....	....	....	..	..1.	....	....	....	..1	....
<i>Sorbus aucuparia</i>	..	....	..1	1.	1.	....	....	....	....	....	....
<i>Vaccinium uliginosum</i>	..	....	..1.	..1	....	..s.	....	1	....	....	....
<i>Achillea millefolium</i>	..	....	..1.	..1	....	..s.s.s1s	....	1	1s1	....	....
<i>Anthriscus sylvestris</i>	..	....	....	....	..	1..s2.1	....	....	11s1	....	....
<i>Botrychium boreale</i>	..	....	....	....	..	..s.	....	....	....	....	....
<i>Botrychium lunaria</i>	..	....	....	....	..	..s.sss	....	....	....	....	....
<i>Campanula rotundifolia</i>	..	....	....	....	..	..s.s11	....	..s.	....	....	....
<i>Cerastium fontanum</i>	..	....	....	....	..	....	....	..s.	....	....	....
<i>Cirsium helenioides</i>	..	....	....	....	..	..s12..s.	1.s	1..1	1s	1.1	....
<i>Coeloglossum viride</i>	..	....	....	....	..s	ss.s.ss.	....	..s.1.	....	..s+	....

App. D Table 1 continued

Cluster no. (W)	Heathland communities						Grassland communities					
	1	2	3	4	5	6	7	8	9	10	11	
Stand sample no.	45	4444	7578	4442	3242233	33	337535332	2522	22222	2 222 22	8888	
	95	7465	0710	2318	0385492	31	462071852	1606	795687	302498010	5423	
<i>Epilobium alsinifolium</i>	..	..	..	..	..	..	..	..	..	..	11..	
<i>Epilobium angustifolium</i>	..	..	s..	..	..	s..	..	s..	..	..	2+	
<i>Equisetum palustre</i>	..	..	..	..	..	..	..	..	..	..	..23	
<i>Equisetum pratense</i>	..	..	..	..	..	..	..	..	..	..	..	
<i>Gymnadenia conopsea</i>	..	..	..	..	..	..	..	..	..	..	..+	
<i>Linnaea borealis</i>	..	..	1.1	..	..	..	..	..	..	..	..	
<i>Listera ovata</i>	..	..	..	..	..	..	..	..	..	..	..	
<i>Lycopodium annotinum</i>	..	..	1..	..	1..	..	..	..	..	..	..	
<i>Orthilia secunda</i>	..	..	..	..	1..	..	..	..	..	..	..	
<i>Pedicularis palustris</i>	..	..	..	..	..	..	..	..	..	..	..	
<i>Pinguicula vulgaris</i>	..	..	..	..	..	..	..	..	..	..	..	
<i>Polygonatum verticillatum</i>	..	..	..	..	..	..	..	..	..	..	..	
<i>Ranunculus auricomus</i>	..	..	..	..	..	..	..	..	..	..	..	
<i>Stellaria calycantha</i>	..	..	..	..	..	..	..	..	..	..	..	
<i>Taraxacum</i> spp.	..	..	..	..	..	..	..	..	..	..	..	
<i>Trifolium repens</i>	..	..	..	..	..	..	..	..	..	..	..	
<i>Valeriana sambucifolia</i>	..	..	..	..	..	..	..	..	..	..	..	
<i>Viola palustris/epipsila</i>	..	..	..	..	..	..	..	..	..	..	..	
<i>Carex capillaris</i>	..	..	..	..	..	..	..	..	..	..	..	
<i>Carex pallescens</i>	..	..	..	..	..	..	..	..	..	..	..	
<i>Eriophorum angustifolium</i>	..	..	..	..	..	..	..	..	..	..	..	
<i>Hieracium odorata</i>	..	..	..	..	..	..	..	..	..	..	..	
<i>Juncus filiformis</i>	..	2s..	..	..	..	..	..	..	..	..	..	
<i>Poa alpigena</i>	..	..	..	..	..	..	..	..	..	..	..	
<i>Poa pratensis</i>	..	..	..	..	..	..	..	..	..	..	..	
<i>Brachythecium mildeanum</i>	..	..	..	..	..	..	..	..	..	..	..	
<i>Brachythecium starkei</i>	..	..	..	..	..	..	..	..	..	..	..	
<i>Brachythecium velutinum</i>	..	..	..	..	..	..	..	..	..	..	..	
<i>Bryum pseudotriquetrum</i>	..	..	..	..	..	..	..	..	..	..	..	
<i>Bryum</i> spp.	..	..	..	..	..	..	..	..	..	..	..	
<i>Calliergon stramineum</i>	..	1..	..	11..	..	..	..	..	..	..	..	
<i>Calliergonella cuspidata</i>	..	..	..	..	..	..	..	..	..	..	..	
<i>Cirriophyllum piliferum</i>	..	..	..	..	1..	..	..	..	..	..	..	
<i>Dicranum bonjeanii</i>	..	..	..	..	..	..	..	..	..	..	..	
<i>Dicranum fuscescens</i>	1..	..	1..	..	..	..	..	..	..	..	..	
<i>Homalothecium nitens</i>	..	..	..	..	..	..	..	..	..	..	..	
<i>Hylocomium pyrenaicum</i>	..	..	..	..	..	..	..	..	..	..	..	
<i>Plagiothecium denticulatum</i>	..	..	..	..	11..	..	..	..	..	..	..	
<i>Polytrichum alpinum</i>	..	..	..	..	..	..	..	..	..	..	..	
<i>Pseudobryum cinclidioides</i>	..	..	..	..	..	..	..	..	..	..	..	
<i>Rhizomnium pseudopunctatum</i>	..	..	..	..	..	..	..	..	..	..	..	
<i>Rhytidiadelphus triquetrus</i>	..	..	..	..	..	..	..	..	..	..	..	
<i>Sphagnum angustifolium</i>	1..	1..	..	..	..	..	..	..	..	..	..	
<i>Harpanthus flotoivanus</i>	..	..	..	..	..	..	..	..	..	..	..	
<i>Lophocolea minor</i>	..	1.1..	..	..	..	..	..	..	..	..	..	
<i>Scapania irrigua</i>	..	..	..	..	..	..	..	..	..	..	..	
<i>Scapania subalpina</i>	..	..	..	..	..	..	..	..	..	..	..	
<i>Cetraria islandica</i>	..	..	1.1..	..	..	..	..	..	..	..	..	
<i>Cladonia furcata</i>	..	..	..	..	1..	..	..	..	..	..	..	
<i>Cladonia gracilis</i>	1..	..	s..	..	..	..	..	..	..	..	..	
<i>Peltigera aphthosa</i>	..	..	s1..	..	..	..	..	..	..	..	..	

## V Additional species (cluster no. - sample no.):

- |   |   |
|---|---|
| <p>1- 49: <i>Cladonia bellidiflora</i> 1;<br/> 1- 55: <i>Peltigera polydactyla</i> 1;<br/> 2- 44: <i>Juniperus communis</i> 1;<br/> 2- 46: <i>Eriophorum vaginatum</i> s;<br/> 3-270: <i>Antennaria dioica</i> s, <i>Cladonia rangiferina</i> 1, <i>C. stellaris</i> 1, <i>Cladonia chlorophaea</i> s, <i>C. phyllophora</i> s, <i>C. sulphurina</i> s, <i>Stereocaulon paschale</i> 1;<br/> 3- 57: <i>Barbilophozia hatcheri</i> 1;<br/> 3- 80: <i>Cladonia pleurota</i> s;<br/> 7-272: <i>Salix starkeana</i> 1, <i>Ptilidium cilare</i> 1;<br/> 7-250: <i>Gentiana nivalis</i> s;<br/> 7-251: <i>Salix nigricans coll.</i> s;<br/> 7- 38: <i>Melica nutans</i> +;<br/> 7- 22: <i>Epilobium lactiflorum</i> s; <i>Lophozia</i> subg. <i>Lophozia</i> 1;<br/> 8- 56: <i>Festuca vivipara</i> 1, <i>Sphagnum girgensohnii</i> 5;<br/> 8- 20: <i>Equisetum variegatum</i> s;<br/> 8- 26: <i>Leucorchis albida</i> s, <i>Cephalozia</i> spp. 1;</p> | <p>9- 27: <i>Erigeron boreale</i> 1, <i>Carex flava</i> 1, <i>C. panicea</i> 1, <i>Kobresia simpliciuscula</i> s, <i>Thuidium recognitum</i> 1, <i>Barbilophozia quadriloba</i> 1;<br/> 9- 29: <i>Alnus incana</i> A1, <i>Carex ornitopoda</i> 1, <i>Rhizomnium punctatum</i> 1;<br/> 9-255: <i>Carex norvegica</i> s;<br/> 9-256: <i>Corallorhiza trifida</i> s; <i>Lophozia bantriensis/gillmanii</i>;<br/> 10-252: <i>Sagina procumbens</i> s;<br/> 10-259: <i>Galium palustre</i> s;<br/> 10-261: <i>Peltigera praetextata</i> s;<br/> 11- 84: <i>Lophozia borealis</i> 1;<br/> 11- 82: <i>Salix pentandra</i> s, <i>Cirsium palustre</i> 1, <i>Petasites frigidus</i> +, <i>Poa remota</i> 2, <i>Sphagnum subnitens</i> 1;<br/> 11- 83: <i>Salix hastata</i> +, <i>Menyanthes trifoliata</i> 2, <i>Carex dioica</i> 1.</p> |
|---|---|



## APPENDIX D

Table 2 Open grassland vegetation at Sølendet, cf. section 9. Complete list of species, with cover values for the 33 samples classified into 5 clusters (01-5). A, B, I-V as in table 1 of Appendix D. Limit for constants: 60 %.

Cluster no. (0)	1	2	3	4	5
Stand sample no.	222 77778887 86978975	2 22 222 78995999 38214034	11 11 00799 21412	87 62	2 22221 888888880 5534614523
I <i>Geranium sylvaticum</i>	.1311311	111111..	11111	45	3343122132
<i>Saussurea alpina</i>	.2111322	13323322	11223	12	1231112122
II <i>Salix phylicifolia</i>	1..1+11.	.1.113..	.....	..	...+...1..
<i>Vaccinium vitis-idaea</i>	.1111+1.	1.....1.	.....	..	...1.....
<i>Achillea millefolium</i>	1213144.	.....	.....	..	...+.....
<i>Antennaria dioica</i>	43112+11	.1..1... 11...	.....	..	.....
<i>Botrychium lunaria</i>	+11+11.	.....	.....	..	.....
<i>Campanula rotundifolia</i>	..11+111	.....	.....	..	.....
<i>Erigeron boreale</i>	..+1+1	.....	++...	..	.....
<i>Gentiana nivalis</i>	1+111+	.....	.....	..	.....
<i>Nigritella nigra</i>	..11111	11..1...	.....	..	.....
<i>Potentilla crantzii</i>	..11+1+	.....	.....	..	.....
<i>Viola montana</i>	.1.1111.	.....	.....	..	.....
<i>Luzula multiflora</i>	..1..+1+	1..1..1.	.....	..	.....
<i>Bryum sp.</i>	31..1+111	..111..	.....	..	1.....
<i>Dicranum muehlenbeckii</i>	..1.11+1.	.....	.....	..	.....
<i>Dicranum scoparium</i>	1..1..+11.	.....	.....	..	.....
<i>Drepanocladus uncinatus</i>	..1.1111.	..1111..	.....	3.	..11.1+..
<i>Hylocomium pyrenaicum</i>	1..1111+3	1..12..	..111	..	1.....
<i>Pleurozium schreberi</i>	221.3231	311...1.	..121	..	.....
<i>Polytrichum juniperinum</i>	111.1++	.....	.....	..	.....
<i>Tortula ruralis</i>	11.41421	.....	.....	..	.....
<i>Barbilophozia barbata</i>	..1.1111	.....	.....	1	.....
<i>Ptilidium ciliare</i>	11.11+11	.....	.....	..	.....
<i>Cladonia furcata</i>	..111111	.....	.....	..	.....
<i>Peltigera canina</i>	1.2..+1	.....	.....	..	.....
<i>Peltigera leucophlebia</i>	1.2..123	.....	.....	..	.....
<i>Leontodon autumnalis</i>	1..+1111	11...111	11...	..	1.....
<i>Rhinanthus minor</i>	..1111+11	11.11.11	.....	..	.....
<i>Nardus stricta</i>	1...+213	33334133	11...	..	1.....
<i>Pedicularis oederi</i>	.....2	11..1111	11...	..	.....
<i>Viola palustris/epipsila</i>	.....	..1.1111	.....	..	1.1.....1
<i>Scirpus cespitosus</i>	.....	..1.22.11	331..	..	.....
<i>Aulacomnium palustre</i>	1...1+1.	24222223	.....	..	1..2..1..
<i>Dicranum bonjeanii</i>	.....	11111.21	.....	..	.....
<i>Homalothecium nitens</i>	.....	141.1124	1.1.1	..	.....
<i>Rhizomnium pseudopunctatum</i>	.....	12221121	.....	..	.....
<i>Tritomaria quinqueidentata</i>	.....	12111212	.....	..	1.....
<i>Betula nana</i>	.....	211.1.11	33214	..	.....
<i>Gymnadenia conopsea</i>	.....	++...+11	1111+	..	.....
<i>Succisa pratensis</i>	.....1+14	31..3.32	341+1	..	1...2..2.1
<i>Carex dioica</i>	.....	..1..1111	1111.	..	.....
<i>Carex panicea</i>	.....	1222.1	3111.	..	.....
<i>Betula nana - B</i>	.....	1.....	124.5	..	.....
<i>Equisetum variegatum</i>	.....	.....	1111.	..	.....
<i>Listera ovata</i>	.....	.....	+++ 1	..	.....
<i>Potentilla erecta</i>	.....1++	3...1.	11111	..	11.....2
<i>Carex capillaris</i>	.....+1+2	..1.121..	2111+	..	.....
<i>Molinia caerulea</i>	.....1	.....	34323	..	.....
<i>Campylium stellatum</i>	.....	.....111.1	55211	1.	1..+...11.12
<i>Fissidens adianthoides</i>	.....	.....2...	1111.	..	.....
<i>Betula pubescens - A</i>	.....	.....	.....	++	+2.....
<i>Angelica archangelica</i>	.....	.....	.....	++	...+...+.
<i>Cicerbita alpina</i>	.....	.....	.....	2+	1.1.....
<i>Dactylorhiza fuchsii</i>	.....	.....	.....	++	1.....
<i>Gnaphalium norvegicum</i>	.....	.....	.....	++	.....
<i>Hieracium sect. Vulgata</i>	.....	.....	.....	12	.....
<i>Myosotis decumbens</i>	.....	.....	.....	11	.....
<i>Pyrola minor</i>	.....1	1.....1.	.....	1+	1..1
<i>Pyrola rotundifolia</i>	.....1	.....	.....	11	..1.21122.
<i>Viola biflora</i>	.....1	.....	.....	23	.....
<i>Carex atrata</i>	.....1	.....	.....	++	.....
<i>Festuca rubra</i>	.....	..11.1.	.....	+1	1.....
<i>Luzula sudetica</i>	.....	..1.1.11	.....	+1	1...1..1.1
<i>Phleum alpinum</i>	.....	.....1+	.....	12	.....
<i>Mnium stellare</i>	.....	.....	.....	31	.....
<i>Rhodobryum roseum</i>	.....1+1.	.....	.....	22	24.....
<i>Plagioclista porelloides</i>	.....	.....	.....	13	1..+...11.1
<i>Bartsia alpina</i>	.....	1.....1+	++...	+1	1..+...11+.
<i>Coeloglossum viride</i>	.....	.....	.....	1+	1.1.+++++
<i>Filipendula ulmaria</i>	.....	..11.4..	.....+	++	2233123134

App. D Table 2 continued

Cluster no. (O)	1	2	3	4	5
Stand sample no.	222 77778887 86978975	2 22 222 78995999 38214034	11 11 00799 21412	87 62	2 222221 888888880 5534614523
<i>Geum rivale</i>	.....	..21.1..	...+.	12	2132244233
<i>Rumex acetosa</i>	.....	.....	.....	12	1211111121
<i>Salix glauca</i> - B	.....	.....	.....	.....	1+63++212
<i>Salix glauca</i>	.....	..1.1.2..	...+.	11	1+12++13
<i>Caltha palustris</i>	.....	.....	.....	.....	3+3.2+11
<i>Epilobium palustre</i>	.....	.....	.....	.....	1+1111111
<i>Equisetum sylvaticum</i>	.....	.....	.....	.....	1111.++1.
<i>Calamagrostis purpurea</i>	.....	.....	.....	.....	111+2+121
<i>Carex nigra</i>	.....	..1.112..	.....	.....	1+..++1114
<i>Hierochloa odorata</i>	.....	.....	.....	.....	..+..++1+1
<i>Bryum pseudotriquetrum</i>	.....	.....	111..	.....	..+..1+112
<i>Bryum weigelii</i>	.....	.....	.....	.....	..11+1112.
<i>Rhizomnium magnifolium</i>	.....	.....	.....	.....	1.2115214.
<i>Aneura pinguis</i>	.....	.....	..1.11	.....	2.1111111.
<i>Chiloscyphus pallescens</i>	.....	.....	.....	.....	2111111113
<i>Marchantia alpestris</i>	.....	.....	.....	1.	123+++
<i>Pellia neesiana</i>	.....	.....	.....	.....	1422322233
III <i>Alchemilla</i> sp.	..11111.	..31.1..	.....	44	42+431+2+4
<i>Euphrasia frigida</i>	..2211+1.	.....	.....	+1	1+..1+1+1
<i>Galium boreale</i>	11111	.....	.....	+2	1.1.111112
<i>Polygonum viviparum</i>	12212221	12131111	1111+	11	1+..1..2.1
<i>Ranunculus acris</i>	111111+1	11	.....	11	1.1.1+1+1
<i>Selaginella selaginoides</i>	21113121	1..21111	111+.	1	1+1111++1
<i>Solidago virgaurea</i>	1321222.	1..+1	.....	13	1+1111++1
<i>Thalictrum alpinum</i>	2.13244.	4124322	43212	1	1.....2
<i>Agrostis capillaris</i>	1221111.	1111.11.	.....	23	3
<i>Anthoxanthum odoratum</i>	1111111	21111.2.	.....	11	11..1..2.1
<i>Carex vaginata</i>	11111112	1111.133	1111	11	11..1..2.3
<i>Deschampsia flexuosa</i>	2321111.	1.1.....	.....	11	1.....1
<i>Festuca ovina</i>	11111121	23..1...	11111	11	.....1..1..
<i>Brachythecium salebrosum</i>	11.2+11.	.....	.....	21	.....
<i>Hylocomium splendens</i>	1511214	13..2...	1+.	11	11.....
<i>Mnium spinosum</i>	221112	.....	.....	33	33
<i>Barbilophozia lycopodioides</i>	32.1++1	21111.2.	111	11	.....
<i>Equisetum palustre</i>	.....	11.1.111	1...	.....	2.312321
<i>Parnassia palustris</i>	.....	1.11111	.....	+1	1.1.212221
<i>Deschampsia cespitosa</i>	.....+32.	14122.	11222	21	222122222
<i>Plagiomnium ellipticum</i>	.....	1211311	.....	.....	1.32132244
<i>Sphagnum warnstorffii</i>	.....	24521344	.....	.....	1151516632
<i>Angelica sylvestris</i>	.....	.....	1+111	1.	1111111111
<i>Crepis paludosa</i>	...1++1.	.....	++111	23	3222312214
IV <i>Salix nigricans</i> coll. - A	.....	.....	.....	.....	..+..+++
<i>Salix pentandra</i> - A	.....	.....	.....	.....	1.42141.
<i>Betula pubescens</i> - B	.....	..2.....	.....	.....	1.....
<i>Salix lapponum</i> B	.....	.....	.....	.....	6..1...+.
<i>Salix nigricans</i> coll. - B	.....	.....	1+.	.....	1.....2
<i>Salix pentandra</i> - B	.....	.....	.....	.....	5.15514.
<i>Salix phylicifolia</i> - B	...1+43.	.....2..	.....	.....	.....+..1..
<i>Andromeda polifolia</i>	.....	.....	11	.....	.....
<i>Betula pubescens</i>	1..1...1	11..1..	.....	.....	.....
<i>Calluna vulgaris</i>	.....	3.....2.	1...	.....	.....
<i>Juniperus communis</i>	1...++1.	1.....	1+.	.....	.....
<i>Salix hastata</i>	.....	.....	.....	.....	.....
<i>Salix lapponum</i>	.....	.....	111.	.....	1..1...+.
<i>Salix nigricans</i> coll.	.....	.....	1+.	.....	1.....2
<i>Salix pentandra</i>	.....	.....	.....	.....	1.....+.
<i>Salix starkeana</i>	...2+1+.	.....	.....	.....	.....
<i>Vaccinium uliginosum</i>	.....	2.....1.	11	.....	.....
<i>Botrychium boreale</i>	+1+1	.....	.....	.....	.....
<i>Botrychium lanceolatum</i>	11	.....	.....	.....	.....
<i>Cerastium fontanum</i>	1...++1.	.....	.....	.....	.....
<i>Cirsium helenioides</i>	.....	2.....	.....	1	11..+1.1.
<i>Cirsium palustre</i>	.....	.....	.....	.....	1..11.+1
<i>Dactylorhiza maculata</i>	.....	.....	++	.....	.....1
<i>Dactylorhiza pseudocordigera</i>	.....	.....	+1	.....	.....
<i>Draba incana</i>	...+11.	.....	.....	.....	.....
<i>Epilobium alsinifolium</i>	.....	.....	.....	.....	1.1.....
<i>Epilobium angustifolium</i>	.....	.....	.....	.....	2+.....
<i>Equisetum scirpoides</i>	.....	.....	11	.....	.....
<i>Listera cordata</i>	.....	.....	.....	.....	1.1.....
<i>Melampyrum sylvaticum</i>	..1.....	1.1.....	.....	.....	1.11112.
<i>Menyanthes trifoliata</i>	.....	.....	.....	.....	2.1.....
<i>Paris quadrifolia</i>	.....	.....	.....	.....	1.1.21.11
<i>Pedicularis palustris</i>	.....	.....	.....	.....	.....+..1.
<i>Petasites frigidus</i>	.....	.....	.....	.....	.....++..+

App. D Table 2 continued

Cluster no. (Q)	1	2	3	4	5
Stand sample no.	222 77778887 86978975	2 22 222 78995999 38214034	11 11 00799 21412	87 62	2 222221 888888880 5534614523
<i>Pinguicula vulgaris</i>	...1111.	.....	11....	..	.....
<i>Ranunculus auricomus</i>	...1111.	.....	1....	..	.....
<i>Saxifraga aizoides</i>	.....	.....	11....	..	.....
<i>Stellaria calycantha</i>	.....	.....	.....	1.1....	.....
<i>Taraxacum</i> sp.	1.....	.....	1....	1....	.....
<i>Tofieldia pusilla</i>	.....	.....	11....	..	.....
<i>Trientalis europaea</i>	111....	1.....	.....	1. +1.11..+	.....
<i>Trifolium repens</i>	2.4....	.....	1.1....	..	.....
<i>Triglochin palustre</i>	.....	.....	1.1....	..	.....
<i>Valeriana sambucifolia</i>	...+111.	.....	.....	1.1.11.2.	.....
<i>Carex flava</i>	.....	12....	.....	.....	1
<i>Carex hostiana</i>	.....	.....	+	.....	.....
<i>Carex norvegica</i>	.....	1.1....	.....	.....	.....
<i>Eriophorum angustifolium</i>	.....	1....	11....	..	+1+11+
<i>Kobresia simpliciuscula</i>	.....	.....	11....	..	.....
<i>Poa alpigena</i>	...+1+1	.....	.....	1. 1....	.....
<i>Poa nemoralis</i>	.....	.....	.....	1. 1....	.....
<i>Poa remota</i>	.....	.....	.....	2. 22.1.	.....
<i>Scirpus hudsonianus</i>	.....	1.1....	.....	.....	.....
<i>Brachythecium mildeanum</i>	.....	.....	.....	11.11.1.	.....
<i>Brachythecium reflexum</i>	1. +11.	.....	.....	111.11.1.	.....
<i>Calliergon stramineum</i>	.....	.....	.....	1.1....	.....
<i>Climacium dendroides</i>	...1111.	1221....	.....	1....	1..
<i>Dicranum fuscescens</i>	...1+1	.....	.....	.....	.....
<i>Ditrichum flexicaule</i>	.....	.....	11....	.....	.....
<i>Drepanocladus revolvens</i>	.....	1....	21....	.....	.....
<i>Fissidens osmundoides</i>	.....	1....	1....	.....	.....
<i>Hypnum bambergeri</i>	.....	.....	11....	.....	.....
<i>Paludella squarrosa</i>	.....	1.1....	.....	.....	1
<i>Philonotis fontana/tomentella</i>	.....	1....	.....	.....	1
<i>Plagiomnium elatum</i>	.....	21....	.....	.....	.....
<i>Pohlia nutans</i>	.....	1....	11....	.....	.....
<i>Rhytidiadelphus sq./subpinnatus</i>	.....	.....	1. 3....	.....	.....
<i>Sphagnum subnitens</i>	.....	.....	.....	.....	3.
<i>Thuidium recognitum</i>	.....	2....	.....	.....	.....
<i>Tortella tortuosa</i>	.....	.....	21....	.....	.....
<i>Barbilophozia floerkei</i>	...+1.	.....	.....	1....	.....
<i>Barbilophozia kunzeana</i>	1.....	11....	1....	.....	.....
<i>Barbilophozia quadriloba</i>	.....	1.111.	11....	1....	1
<i>Cephalozia lunulifolia</i> coll.	.....	1....	11....	1....	.....
<i>Harpanthus flotoxianus</i>	.....	.....	.....	2.1....	.....
<i>Lophozia bantriensis/gillmanii</i>	.....	.....	1.1....	.....	1
<i>Lophozia borealis</i>	.....	1....	11....	.....	1
<i>Lophozia obtusa</i>	...1....	.....	.....	1. 311.+1.+.	.....
<i>Scapania irrigua</i>	.....	11.1.2	11....	.....	.....
<i>Cetraria islandica</i>	...11+.	1....	.....	.....	.....
<i>Cladonia arbuscula</i>	...2+1.	.....	.....	.....	.....
<i>Cladonia gracilis</i>	...+1.	.....	.....	.....	.....
<i>Cladonia phyllophora</i>	...+1.	.....	.....	.....	.....
<i>Stereocaulon paschale</i>	...11+.	.....	.....	.....	.....

## V Additional species (cluster no. - sample no.):

- 1- 78: *Botrychium multifidum* 1, *Carex brunnescens* 1, *Lophozia excisa* 1, *Cladonia chlorophaea* 1, *C. pyxidata* 1, *C. stellaris* 1;  
 1- 76: *Nephroma expallidum* 4;  
 1- 79: *Vaccinium myrtillus* 1, *Gentianella amarella* 1, *G. campestris* 1, *Hieracium sect. Piloselloidea* 1, *Knautia arvensis* 2, *Rubus saxatilis* +;  
 1- 77: *Stellaria graminea* 1;  
 1- 75: *Campylium chrysophyllum* 1;  
 2-273: *Nephroma arcticum* 1;  
 2-291: *Lophozia ventricosa* 1;  
 2-293: *Empetrum hermaphroditum* 1, *Dicranum angustum* 1;  
 2-294: *Eriophorum vaginatum* 1;  
 3-102: *Juncus castaneus* 1;  
 3-101: *Blepharostoma trichophyllum* 1, *Scapania aequiloba* 1;  
 3- 74: *Carex flava* x *C. hostiana* +, *C. lasiocarpa* 1;  
 4- 86: *Aconitum septentrionale* 2, *Melampyrum pratense* 1, *Brachythecium starkei* 2;  
 4- 72: *Anthriscus sylvestris* +, *Gymnocarpium dryopteris* +, *Ranunculus repens* 1, *Milium effusum* +;  
 5- 5: *Lophocolea bidentata* 1, *Scapania subalpina* +;  
 5-103: *Cardamine pratensis* 1, *Epilobium lactiflorum* 1, *Equisetum pratense* 1, *Calamagrostis stricta* 1, *Poa pratensis* 1, *Cratoneuron decipiens* 3, *Hypnum pratense* 1.

Table 3. Wooded grassland vegetation of the upper boreal region of Central Norway, cf. section 10. Complete species list, with cover values for the 101 samples classified into 7 clusters (U1-7). The 16 samples of subcluster 2b and the 6 samples of subcluster 3b are designated by a "b" in the cluster no. headings. Key to heading: I = Innerdalen, N = Nerskogen, S = Sylane, no symbol = Solendet. A, B, I-V as in table 1 of Appendix D. Limit for constants: 70%.

[illegible]



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Cluster no.

[illegible]

App. D Table 3 continued

Cluster no.

Cluster no.	U1	U2	U3	U4	U5	U6	U7
Cluster no.	b b	bbbbbbbbbbbbbb	bbbbbb				
Cluster no.	NNNNNNNNNNNS	NNNNNNNNNNNNSSSSSSSSSS	NNNNNNNNNNNNIIII		NNNNNNNNNN		
Cluster no.	1	222	111	222222	11111111	2222	2222
Cluster no.	335556666678812	23333355777777778888801122222333333	899999999900000004	45555566	889000000011	225555	2225
Cluster no.	135674567824831	24567801201345678901236742456789014567	901234568901212345	800234901	45735678901	795678	0166
Trifolium repens		214	1.1	1.1			
Valeriana sambucifolia	1	1	2.1	111	1.111		
Veronica alpina		1	1	11	11		
Veronica chamaedrys		1					
Veronica officinalis	1	21	1	1	221		
Vicia sylvatica		1	1	1	24		
Viola palustris/epipsila	1	1				1	
Avenula pubescens	11				111	1	
Calamagrostis purpurea		31211	1111	1	3	322	1
Carex bigelowii		11	1				
Carex capillaris	1	11					1.1.1
Carex palleseus	11	2.1					1
Melica nutans				21111			
Milium effusum	22224.31	1.1.1.2	1.1.11	11.211.21.2.1112	2.1	111	1
Poa alpigena		1		1			
Poa alpina		1			11		1.1
Poa pratensis	1	1			11		1
Roenneria canina			111		1111		
Aulacomnium palustre	1	1				11	11
Brachythecium curtum		1				1.1.1111	
Brachythecium stelkei	11.11.1	1.1.1.1	1.11111	1	1.321	111	
Brachythecium velutinum	1	11	1				
Bryum weigelii					1	111	
Calliergon cordifolium		1			1	11	1.1
Cirriophyllum piliferum	1.1	2	11.1.11.111111.1	111121	1	1.11.1	1.1.1
Dicranum bonjeanii							21
Hylocomium pyrenaicum	1	111.122.1	1.1.11.1	1	1.111		111.1
Plagiomnium elatum			111111			1	
Plagiothecium denticulatum	1.1.1.1.11	1	1		111		1
Pohlia sp.	1	1		1.1		1	1
Pohlia wahlenbergii		1				11	11.1
Polytrichum alpinum	1.1.1.1.111	1.111.111.11.1	3311	1	1		
Polytrichum juniperinum		11.11.1.11.1		1			1
Pseudobryum cinctidioides	1						
Rhizomnium pseudopunctatum		1			11	11	
Rhizomnium punctatum	1						1
Rhytidadelphus triguetrus	1	1.1.1.3	1.11.1	23	1	1	
Sphagnum warnstorffii							1.1.1
Aneura pinguis				1	1	111	
Barbilophozia barbata	1	1.1	1.1				1.1.1
Barbilophozia floerkei	1		11	1			2
Barbilophozia kunzeana		1					1
Harpanthus flotovianus		1					
Lophocolea minor	11	1.1		11111	1	1121	1
Lophozia sp.	1.1	1			1		
Marchantia alpestris			11	11	2	23	
Plagiochila asplenoides			11.1				
Ptilidium ciliare	1	1.1.1.1	1				
Scapania irrigua	1	1					11
Tritomaria quinqueidentata	11	1	1				11.1
Cladonia coccifera	1		11				11.1
Cladonia furcata	1	1					1

App. D Table 3 continued

Cluster no.	U1	U2	U3	U4	U5	U6	U7
Stand sample no.	NNNNNNNNNNNS	b b NNNNNNNNNNNNNNNSSSSSSSSSS	bbbbbbbbbbbbbb	bbbbbb	NNNNNNNNNN	NNNNNNNNNN	NNNNNNNNNN
	1	222	111	11177777	222222	11111111	2222
	335556666678812	23333355777777778888801122222333333	89999999999000000004	45555566	889000000011	225555	2225
	135674567824831	24567801201345678901236742456789014567	901234568901212345	800234901	45735678901	795678	0166
Peltigera aphthosa	.....1	.....1	.....1	.....1	.....1	.....1	.....
Peltigera canina coll.	.....1.....1	.....1.....1	.....1	.....1	.....1	.....1	.....
Peltigera polydactyla	.....1	.....1	.....1	.....1	.....1	.....1	.....

## V Additional species (cluster no. - sample no.):

1 - N 55: Nephroma bellum 1;  
 1 - N 57: Dryopteris expansa 2;  
 1 - N 66: Lycopodium annotinum 1;  
 1 - N 68: Dryopteris expansa 1;  
 1 - N 84: Sedum rosea 1, Bartramia ithyphylla 1, Plagiomnium medium 1;  
 1 - N 88: Peltigera degenii 1;  
 1 - S 21: Dicranum fuscescens 1, Sphagnum girgensohnii 1, Sphagnum squarrosum 1, Lophozia ventricosa 1, Cladonia bellidiflora 1, Cladonia crispata 1, Cladonia deformis 1, Cladonia gracilis 1, Cladonia pyxidata 1, Nephroma bellum 1, Psoroma hypnorum 1, Epilobium actiflorum 1;  
 2 - 22: Gentiana nivalis 1;  
 2 - 250: Botrychium boreale 1;  
 2 - 251: Betula nana 1, Salix starkeana 1, Botrychium boreale 1, Equisetum palustre 1, Pedicularis palustris 1;  
 2 - 272: Moneses uniflora 1;  
 2 - N 70: Pinus sylvestris A 2, Moneses uniflora 1;  
 2 - N 71: Salix repens 1, Mnium marginatum 1;  
 2 - N 73: Lathyrus pratensis 1, Vicia cracca 1;  
 2 - N 74: Phyllocladus caerulea 1;  
 2 - N 75: Phyllocladus caerulea 1, Bartramia ithyphylla 1, Lescurea incurvata 1, Mnium marginatum 1, Cephalozia sp. 1;  
 2 - N 76: Viola riviniana 1;  
 2 - N 77: Alnus incana B 1, Trifolium pratense 1;  
 2 - N 80: Betula nana 1, Salix reticulata 1;  
 2 - N 81: Salix aurita 1, Potentilla crantzii 1, Dicranum fuscescens 1;  
 2 - N 82: Prunella vulgaris 1;  
 2 - N 104: Carex canescens 1;  
 2 - N 112: Vicia cracca 1, Calliergon stramineum 1;  
 2 - S 25: Lescurea incurvata 1, Cladonia pyxidata 1;  
 2 - S 26: Calluna vulgaris 1, Sagina saginoides 1, Hierochloa odorata 1;  
 2 - S 27: Sagina saginoides 1;  
 2 - N 31: Gentiana nivalis 1;  
 2 - S 34: Galium palustre 1, Ranunculus repens 1, Carex brunnescentia 1, Lophozia ventricosa 1, Peltigera spuria 1;

2 - S 35: Carex brunnescentia 1;  
 2 - N 90: Poa trivialis 1;  
 2 - N 92: Alnus incana B 1;  
 2 - N 94: Trifolium pratense 1;  
 2 - N 95: Daphne mezereum 1;  
 2 - N 96: Poa trivialis 1;  
 2 - N 101: Poa remota 1;  
 2 - N 102: Sedum rosea 1;  
 2 - 1702: Gnaphalium sylvaticum 1;  
 2 - 1703: Gnaphalium sylvaticum 1, Thuidium abietinum 1;  
 2 - 1704: Prunus padus A 1;  
 2 - 1745: Equisetum hyemale 1, Erysimum hieracifolium 1, Viola montana 1;  
 4 - 8: Dicranum majus 1;  
 4 - 252: Sagina procumbens 1;  
 4 - 253: Calliergonella cuspidata 1;  
 4 - 259: Galium palustre 1;  
 4 - 261: Peltigera praetextata 1;  
 5 - 84: Epilobium alsinifolium 1, Epilobium palustre 1, Stellaria calycantha 1, Brachythecium mildeanum 1, Lophozia borealis 1;  
 5 - N 85: Pinus sylvestris A 1;  
 5 - N 97: Petasites frigidus 1, Brachythecium rivulare 1, Philonotis seriata 1;  
 5 - N 108: Calliergon giganteum 1, Cratoneuron decipiens 1;  
 5 - N 109: Petasites frigidus 1;  
 5 - N 110: Poa remota 1;  
 6 - 27: Erigeron boreale 1, Carex flava 1, Carex panicea 1, Kobresia simpliciuscula 1, Calliergon stramineum 1, Calliergonella cuspidata 1, Homalothecium nitens 1, Thuidium recognitum 1, Barbilophozia quadriloba 1;  
 6 - 29: Carex ornithopoda 1;  
 6 - 255: Carex norvegica 1, Scapania subalpina 1;  
 6 - 256: Lophozia badensis/gillmanii 1;  
 6 - 257: Hierochloa odorata 1;  
 6 - 258: Scapania subalpina 1;  
 7 - 20: Equisetum variegatum 1;  
 7 - 26: Leucorchis alba 1, Cephalozia sp. 1;  
 7 - 56: Festuca vivipara 1, Dicranum majus 1, Sphagnum girgensohnii 1;

## APPENDIX E. PRODUCTIVITY TABLE FOR THE PERMANENT QUADRATS AT SØLENDET

Table 1 Field layer production (in g/m<sup>2</sup> dry matter) from scything the different types of mire (M) vegetation described in section 5 and of woodland (W) vegetation described in section 9. The productivity at Sølendet is dealt with in section 13.2.

Cl = cluster. Second column: the scythed quadrats (usually 12.5 m<sup>2</sup>) for the particular locality. Mean values for 2 quadrats (scythed together) shown in brackets []. Production values minus litter value shown in parentheses (). + = quadrat scythed, but no production record.

Cl.	Loc.	no. quadr.	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
M2	67 A	.	.	.	76(55)	.	104(69)	71	.	.	89	.	61(42)	.	58	.	
	67 B	.	.	.	[76(55)]	.	.	50	.	.	73	.	.	.	.	.	
M2	73 B	.	.	.	.	.	.	+	.	.	86	.	.	.	.	.	
	73 C	.	.	.	.	.	.	+	.	.	88	.	.	.	.	.	
	73 D	.	.	.	.	.	.	+	.	.	83	.	.	.	.	.	
	73 E	.	.	.	.	.	.	+	.	.	107	.	.	.	.	.	
	73 G	.	.	.	.	.	.	+	.	.	104	.	.	.	.	.	
	73 H	.	.	.	.	.	.	+	.	.	.	125	.	.	.	.	
M3	7 A	.	115	60	.	.	.	52	.	83	.	52	.	.	57	.	68
	7 B	.	.	138	.	.	61	.	.	.	.	.	.	.	.	.	.
M3	15 A	.	.	163	65(57)	.	82(57)	86	.	99	.	.	.	.	.	+	.
	15 B	.	.	[163]	.	.	.	.	.	.	.	.	.	.	.	+	.
	15 C	.	.	.	198(113)	.	.	.	.	171	.	.	.	.	.	+	.
	15 E	.	.	.	.	.	193(122)	.	116	.	97	.	.	.	.	+	.
M3	65 A	.	.	.	171(111)	.	+	.	120	.	84	.	75(61)	.	100	.	.
	65 B	.	.	.	[171(111)]	.	+	.	.	145	.	85	.	.	.	.	.
	65 C	.	.	.	+	.	+	.	.	.	.	.	.	.	.	.	.
M3	69 A	.	.	.	192(80)	.	146(87)	.	117	.	113	.	71(52)	.	79	.	.
	69 B	.	.	.	[192(80)]	.	.	160	.	129	.	.	118(77)	.	.	.	.
M4	1 A	300	166	142	133(118)	115	93(88)	92	98	60	60	.	.	.	153	.	94
	1 B	[300]	[166]	[142]	.	163	.	142	.	150	.	103	.	.	.	.	.
	1 C	.	.	.	263(184)	.	206(149)	.	154	.	122	.	122(96)	.	123	.	.
	1 E	.	.	.	.	.	311(179)	.	226	.	219	127	134(121)	121	82	57	.
M4	9 A	.	.	182	123	.	148(138)	.	144	.	155	.	.	.	171	.	.
	9 B	.	.	[182]	.	141	.	158	.	127	.	141	.	137	.	138	.
M4	10 A	.	.	169	95	.	125(109)	.	109	.	162	.	121(93)	.	128	.	.
	10 B	.	.	[169]	.	146	.	122	.	108	.	128	.	131	.	105	.
M4	12 A	.	.	176	119	.	132(113)	.	161	.	156	.	153(122)	.	155	.	.
	12 B	.	.	[176]	.	127	.	145	.	102	.	126	.	164	.	134	.
M4	61 A	.	.	.	213(151)	+	106(89)	.	82	.	104	.	105(84)	77	62	62	.
	61 B	.	.	.	[213(151)]	+	.	117	.	112	.	88	.	115	.	125	.

App. E Table 1 continued

Cl. Loc. no. quadr.	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
M4 63 A	.	.	.	169(123)	.	+	.	145	.	145	.	125(110)	.	161	.
63 B	.	.	.	[169(123)]	.	+	.	.	184	.	101	.	.	183	.
63 C	.	.	.	+	.	+	.	.	.	.	.	.	.	.	.
M4 64 A	.	.	.	312(207)	.	+	.	159	.	153	.	145(109)	.	130	.
64 B	.	.	.	[312(207)]	.	+	.	.	243	.	190	.	.	259	.
M5 2 A	138	64	53	36(34)	34	47(40)	35	60	24	44	.	.	.	.	.
2 B	[138]	.	105	.	89	.	59	.	82	.	83	.	113	.	71
2 C	.	.	.	121(88)	.	81(55)	.	73	.	80	58	49(44)	53	44	45
2 D	.	.	.	+	.	.	.	.	.	.	131	.	.	133	.
2 E	.	.	.	.	141	.	62	.	73	.	82	.	117	109	61
2 F	.	.	.	.	.	136(86)	.	83	.	91	.	95(76)	.	109	61
2 G	.	.	.	.	.	.	97	.	83	.	107	.	117	.	61
2 H	.	.	.	.	.	.	.	.	.	.	.	.	179	.	80
2 I	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2 J	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2 K	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
M6 4 A	148	151	56	30(29)	87	82(77)	75	68	59	65	.	.	.	.	.
4 B	[148]	.	131	.	172	.	125	.	77	.	96	.	96	.	60
4 C	.	.	.	121(92)	.	144(120)	.	134	.	98	.	96(85)	73	98	62
4 D	.	.	.	.	.	197(142)	.	130	.	.	.	.	.	91	60
4 E	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
4 F	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
M6 6 A	.	147	59	.	75	.	41	.	88	.	60	.	65	.	64
6 B	.	.	166	.	.	.	.	.	.	.	.	.	.	.	.
M6 11 A	.	.	180	108(98)	.	151(129)	.	143	.	153	.	.	.	172	.
11 B	.	.	[180]	.	149	.	107	.	122	.	130	.	166	.	119
M6 13 A	.	.	137	161(151)	.	111(95)	.	123	.	126	.	112(86)	.	109	.
13 B	.	.	[137]	.	115	.	78	.	80	.	103	.	.	.	.
M6 14 A	.	.	190	194(178)	.	177(152)	.	176	.	218	.	143(114)	.	135	.
14 B	.	.	[190]	.	180	.	146	.	157	.	154	.	.	.	.
M6 16 A	.	.	95	56	.	68(54)	.	59	.	65	.	.	.	+	.
16 B	.	.	[95]	.	.	.	.	.	.	.	.	.	.	.	.
16 C	.	.	.	+	.	.	.	.	113	.	.	.	.	.	.
M6 87 A	.	.	.	.	.	.	.	+	96	.	146	.	175	125	.
M7 3 A	85	39	31	28(26)	22	22(20)	18	38	9	22	.	45(39)	44	44	12
3 B	[85]	.	57	.	54	.	36	.	30	.	44	.	56	.	29
3 C	.	.	.	109(88)	.	80(61)	.	79	.	62	35	.	55	.	.
3 D	.	.	.	.	.	88(68)	.	60	.	52	.	42(35)	69	48	36
3 E	.	.	.	.	.	.	92	.	45	.	55	.	.	.	.
M7 101 A	.	.	.	.	.	.	.	.	.	.	.	.	106	.	30
M8 74 A	.	.	.	.	.	.	.	88	.	84	.	105(92)	.	94	.
M10 70 A	.	.	.	81(48)	.	163(129)	.	95	.	132	.	87(73)	.	96	.



App. E Table 1 continued

Cl. Loc. no. quadr.	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
M11 17 A	.	.	58	.	69	.	75	.	135	120	85	119(111)	63	86	70
M11 18 A	.	.	79	50	50	.	60	85	72	58	56	.	66	.	96
18 B	.	.	[79]	.	66	63(55)	.	105	.	101	.	87(74)	.	90	.
MR 66 A	.	.	.	257(202)	.	165(127)	.	204	142	99	89	77(67)	.	121	.
W1 49 A	.	.	148	.	113	.	74	.	58	.	.	.	94	.	58
49 B	.	.	[148]	.	.	104(57)	.	.	.	.	.	.	.	.	102
49 C	.	.	.	.	.	129(64)	.	.	.	.	.	.	.	.	.
W1 55 A	.	.	155	.	98	.	.	.	119	.	.	.	140	.	.
W2 44 A+B	.	.	.	.	131	.	.	.	.	.	.	.	.	.	.
W2 46 A+B	.	.	.	.	13	.	.	.	.	.	.	.	.	.	.
W4 28 A	.	.	121	.	66	.	+	.	.	.	.	.	.	.	.
W4 41 A	.	.	149	.	73	.	.	.	.	.	.	.	.	.	.
W4 42 A+B	.	.	114	.	.	.	.	.	.	.	.	.	.	.	.
W4 43 A	.	.	157	.	95	.	.	.	.	.	.	.	.	.	.
W5 23 A	.	.	103	57(40)	.	68(38)	.	55	.	46	.	.	97	.	30
W5 25 A	.	.	59	.	48	.	45	.	.	.	.	.	.	.	.
W5 30 A	.	.	101	.	49	.	60	.	.	.	.	.	.	.	.
W5 32 A	.	.	122	67	.	.	.	.	.	.	.	.	.	.	.
32 B	.	.	[122]	.	100	.	72	.	73	.	.	.	.	.	.
W5 39 A	.	.	109	.	96	.	53	.	.	.	.	.	.	.	.
W6 31 A	.	.	123	52	48	.	.	.	.	.	.	.	.	.	.
31 B	.	.	[123]	.	69	.	45	.	62	.	50	.	53	.	44
W6 33 A	.	.	148	74(65)	.	125(98)	.	67	.	93	.	87(71)	.	73	.
33 B	.	.	[148]	.	102	.	70	.	.	.	.	.	.	.	.
W7 22 A	.	.	210	162	.	195(164)	.	132	.	123	.	141(110)	.	127	152
22 B	.	.	[210]	.	154	.	153	.	129	.	122	.	.	.	.
W7 34 A	.	.	168	94	.	130(98)	.	104	.	124	.	113(96)	.	93	.
W7 35 A	.	.	.	151	.	163(143)	.	128	.	106	.	111(78)	.	95	84
35 B	.	.	.	[151]	.	.	145	.	88	.	82	.	94	.	.
W7 36 A	.	.	.	94(78)	.	118(95)	.	85	.	92	.	95(80)	.	93	.

App. E Table 1 continued

Cl. Loc. no. quadr.	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
W7 37 A	.	.	215	.	167	140(132)	132	108	96	80	108	99(90)	.	137	.
W7 37 B	.	.	[215]	.	.	.	.	145	.	140	.	162(139)	.	.	.
W7 38 A	.	.	159	120	143	145(121)	120	109	112	123	113	96(80)	.	122	149
W7 38 B	.	.	[159]	.	.	.	.	.	.	.	.	.	.	.	.
W7 72 A	.	.	.	.	.	.	+	.	136	.	201	.	157	.	170
W7 72 B	.	.	.	.	.	.	+	.	131	.	.	.	210	.	.
W7 72 C	.	.	.	.	.	.	+	.	.	149	190	.	178	119	115
W7 72 D	.	.	.	.	.	.	+	.	136	.	.	.	.	.	.
W7 72 E	.	.	.	.	.	.	+	.	.	141	.	.	215	.	.
W7 72 F	.	.	.	.	.	.	+	.	153	.	.	.	.	.	231
W8 20 A	.	.	154	103(86)	.	174(117)	.	105	.	128	.	.	.	134	.
W8 20 B	.	.	[154]	.	130	.	122	.	84	.	111	.	140	.	105
W8 21 A	.	.	169	.	172	.	136	.	.	.	.	135(112)	.	110	.
W8 21 B	.	.	[169]	.	.	.	.	.	114	.	122	.	144	.	106
W8 56 A	.	.	.	.	225	112(94)	.	.	84	.	.	.	166	.	120
W9 5 A	[277]	.	[181]	148	140	136(121)	110	83	86	116	78	86(71)	86	52	69
W9 5 B	277	223	181	.	199	.	195	.	156	.	157	.	160	.	183
W9 5 C	+	.	.	.	.	356(290)	.	214	.	265	.	163(113)	.	157	.
W9 27 A	.	.	186	.	137	.	95	.	85	101	135	.	169	.	121
W9 27 B	.	.	[186]	.	.	185(144)	.	148	.	.	86	.	121	.	95
W9 27 C	.	.	.	.	145	.	.	.	.	.	.	.	.	.	.
W9 29 A	.	.	163	.	142	.	127	.	108	.	114	.	.	.	.
W10 8 A	.	240	134	.	167	.	145	.	173	.	147	.	156	.	151
W10 8 B	.	[240]	[134]	.	.	227(202)	.	157	.	185	.	173(143)	119	89	114
W10 40 A	.	.	225	144(130)	125	98(75)	115	95	85	60	86	74(58)	76	77	76
W10 40 B	.	.	[255]	.	197	.	142	.	144	.	159	.	142	.	132
W10 40 C	.	.	.	.	201	.	.	.	.	.	.	.	.	.	.
W10 40 D	.	.	.	185(172)	.	176(120)	.	131	.	136	.	201(175)	.	184	.
W10 40 E	.	.	.	.	.	329(221)	.	157	.	137	.	.	146	.	.
W10 50 A	.	.	240	97	187	110(99)	140	136	132	132	147	196(182)	121	175	192
W10 50 B	.	.	[240]	.	.	.	.	.	.	.	.	.	.	.	.

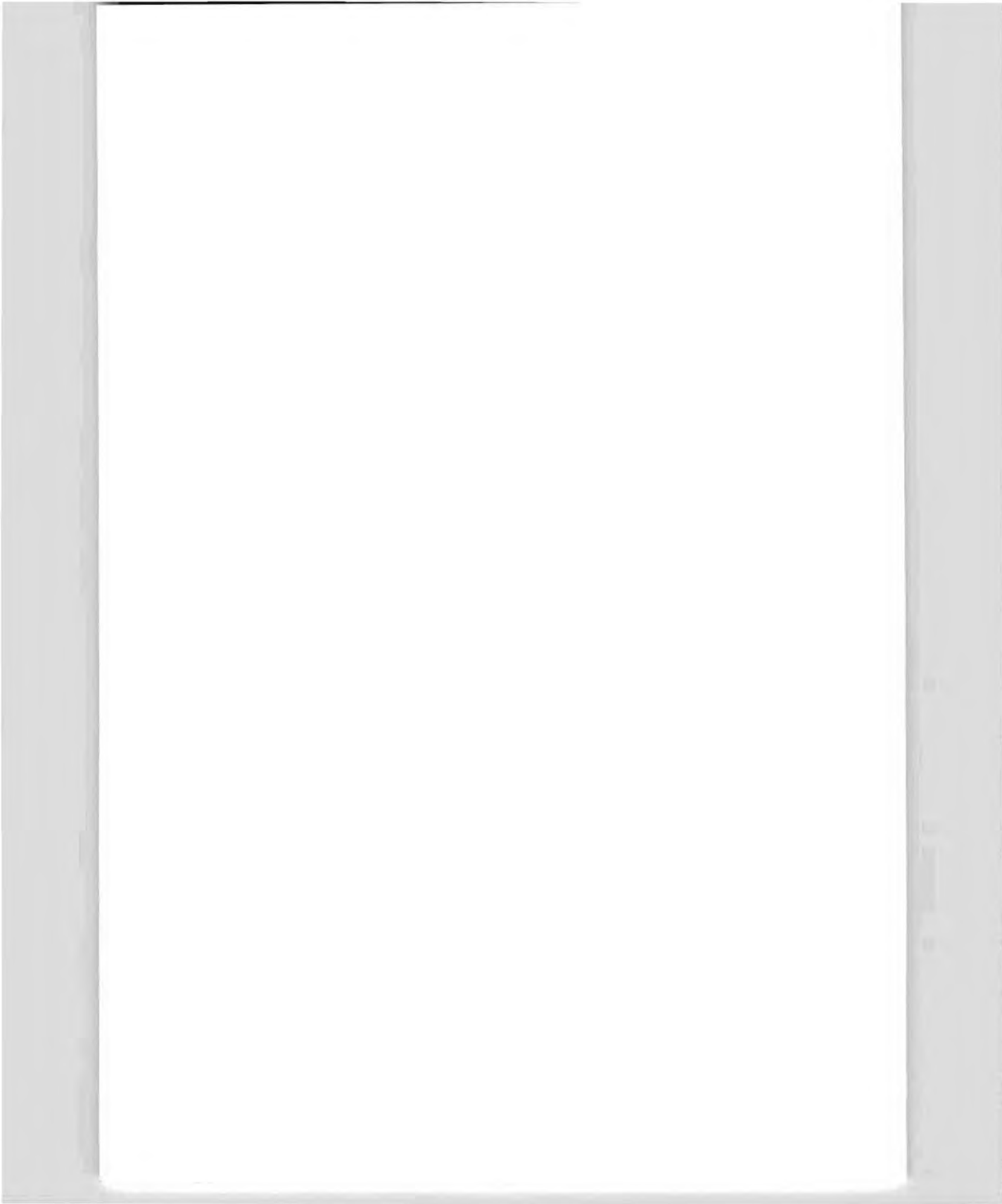
## APPENDIX F. LIST OF ABBREVIATIONS FOR SPECIES NAMES

Used in figures 5.2.7, 6.2.5 and 9.2.5.

ACON SE	<i>Aconitum septentrionale</i>	CRAT DE	<i>Cratoneuron decipiens</i>
AGRO CA	<i>Agrostis capillaris</i>	CREP PA	<i>Crepis paludosa</i>
ALCHEMI	<i>Alchemilla</i> spp.	DACT CR	<i>Dactylorhiza cruenta</i>
ANDR PO	<i>Andromeda polifolia</i>	DACT FU	<i>Dactylorhiza fuchsii</i>
ANEU PI	<i>Aneura pinguis</i>	DACT IN	<i>Dactylorhiza incarnata</i>
ANGE AR	<i>Angelica archangelica</i>	DACT MA	<i>Dactylorhiza maculata</i>
ANGE SY	<i>Angelica sylvestris</i>	DACT PS	<i>Dactylorhiza pseudocordigera</i>
ANTE DI	<i>Antennaria dioica</i>	DESC CE	<i>Deschampsia cespitosa</i>
ANTH OD	<i>Anthoxanthum odoratum</i>	DESC FL	<i>Deschampsia flexuosa</i>
ANTH SY	<i>Anthriscus sylvestris</i>	DICR AN	<i>Dicranum angustum</i>
AULA PA	<i>Aulacomnium palustre</i>	DICR BO	<i>Dicranum bonjeanii</i>
BARB FL	<i>Barbilophozia floerkei</i>	DICR MA	<i>Dicranum majus</i>
BARB KU	<i>Barbilophozia kunzeana</i>	DICR SC	<i>Dicranum scoparium</i>
BARB LY	<i>Barbilophozia lycopodioides</i>	DITR FL	<i>Ditrichum flexicaule</i>
BARB QU	<i>Barbilophozia quadriloba</i>	DREP BA	<i>Drepanocladus badius</i>
BART AL	<i>Bartsia alpina</i>	DREP RE	<i>Drepanocladus revolvens</i>
BETU NA	<i>Betula nana</i>	DREP UN	<i>Drepanocladus uncinatus</i>
BETU PU	<i>Betula pubescens</i>	ELEO QU	<i>Eleocaris quinqueflora</i>
BRAC RE	<i>Brachythecium reflexum</i>	EMPE HE	<i>Empetrum hermaphroditum</i>
BRAC SA	<i>Brachythecium salebrosum</i>	EPIL PA	<i>Epilobium palustre</i>
BRAC TU	<i>Brachythecium turgidum</i>	EQUI PA	<i>Equisetum palustre</i>
BRYU PS	<i>Bryum pseudotriquetrum</i>	EQUI PR	<i>Equisetum pratense</i>
BRYU WE	<i>Bryum weigelii</i>	EQUI SY	<i>Equisetum sylvaticum</i>
C ATROF	<i>Carex atrofusca</i>	EQUI VA	<i>Equisetum variegatum</i>
C BRUNN	<i>Carex brunnescens</i>	ERIO AN	<i>Eriophorum angustifolium</i>
C BUXBA	<i>Carex buxbaumii</i>	ERIO LA	<i>Eriophorum latifolium</i>
C CAPIL	<i>Carex capillaris</i>	ERIO VA	<i>Eriophorum vaginatum</i>
C CHORD	<i>Carex chordorrhiza</i>	EUPH FR	<i>Euphrasia frigida</i>
C DIOIC	<i>Carex dioica</i>	FEST OV	<i>Festuca ovina</i>
C FLAVA	<i>Carex flava</i>	FEST RU	<i>Festuca rubra</i>
C HELEO	<i>Carex heleonastes</i>	FILI UL	<i>Filipendula ulmaria</i>
C HOSTI	<i>Carex hostiana</i>	FISS AD	<i>Fissidens adianthoides</i>
C LASIO	<i>Carex lasiocarpa</i>	FLAV*HO	<i>Carex flava</i> x <i>C. hostiana</i>
C LIMOS	<i>Carex limosa</i>	GALI BO	<i>Galium boreale</i>
C MAGEL	<i>Carex magellanica</i>	GERA SY	<i>Geranium sylvaticum</i>
C NIGRA	<i>Carex nigra</i>	GEUM RI	<i>Geum rivale</i>
C PANIC	<i>Carex panicea</i>	GNAP NO	<i>Gnaphalium norvegicum</i>
C ROSTR	<i>Carex rostrata</i>	GYMN CO	<i>Gymnadenia conopsea</i>
C VAGIN	<i>Carex vaginata</i>	GYMN DR	<i>Gymnocarpium dryopteris</i>
CALA PU	<i>Calamagrostis purpurea</i>	HIERACI	<i>Hieracium</i> spp.
CALL GI	<i>Calliergon giganteum</i>	HIER/PO	<i>Hieracium</i> sect. <i>Piloselloidea</i>
CALL RI	<i>Calliergon richardsonii</i>	HOMA NI	<i>Homalothecium nitens</i>
CALL ST	<i>Calliergon stramineum</i>	HYLO PY	<i>Hylocomium pyrenaicum</i>
CALL TR	<i>Calliergon trifarium</i>	HYLO SP	<i>Hylocomium splendens</i>
CALT PA	<i>Caltha palustris</i>	HYPN LI	<i>Hypnum lindbergii</i>
CAMP ST	<i>Campylium stellatum</i>	HYPN PR	<i>Hypnum pratense</i>
CHIL PA	<i>Chiloscyphus pallescens</i>	JUNC CA	<i>Juncus castaneus</i>
CICE AL	<i>Cicerbita alpina</i>	JUNC TG	<i>Juncus triglumis</i>
CINC ST	<i>Cinclidium stygium</i>	JUNI CO	<i>Juniperus communis</i>
CLAD/AR	<i>Cladina arbuscula</i> coll.	KOBR SI	<i>Kobresia simpliciuscula</i>
CLAD CL	<i>Cladonia carneola</i>	LEON AU	<i>Leontodon autumnalis</i>
CLIM DE	<i>Climacium dendroides</i>	LIST CO	<i>Listera cordata</i>
CONV MA	<i>Convallaria majalis</i>	LIST OV	<i>Listera ovata</i>
CRAT CO	<i>Cratoneuron commutatum</i>	LOPH/BA	<i>Lophozia bantriensis/gillmanii</i>

## App. F continued

LOPH BI	<i>Lophocolea bidentata</i>	RUME AS	<i>Rumex acetosa</i>
LOPH BO	<i>Lophozia borealis</i>	SALI GA	<i>Salix glauca</i>
LOPH OB	<i>Lophozia obtusa</i>	SALI LA	<i>Salix lapponum</i>
LOPH RU	<i>Lophozia rutheana</i>	SALI/NI	<i>Salix nigricans</i> coll.
LOPH VE	<i>Lophozia ventricosa</i>	SALI PE	<i>Salix pentandra</i>
LUZU MU	<i>Luzula multiflora</i>	SALI PH	<i>Salix phylicifolia</i>
LUZU PI	<i>Luzula pilosa</i>	SAUS AL	<i>Saussurea alpina</i>
LUZU SU	<i>Luzula sudetica</i>	SAXI AI	<i>Saxifraga aizoides</i>
MAIA BI	<i>Maianthemum bifolium</i>	SCAP IR	<i>Scapania irrigua</i>
MARC AL	<i>Marchantia alpestris</i>	SCIR CE	<i>Scirpus cespitosus</i>
MEES TR	<i>Meesia triquetra</i>	SCIR HU	<i>Scirpus hudsonianus</i>
MELA PR	<i>Melampyrum pratense</i>	SCOR SC	<i>Scorpidium scorpioides</i>
MELA SY	<i>Melampyrum sylvaticum</i>	SELA SE	<i>Selaginella selaginoides</i>
MELI NU	<i>Melica nutans</i>	SILE DI	<i>Silene dioica</i>
MENY TR	<i>Menyanthes trifoliata</i>	SOLI VI	<i>Solidago virgaurea</i>
MILI EF	<i>Milium effusum</i>	SPHA RU	<i>Sphagnum russowii</i>
MNIU SP	<i>Mnium spinosum</i>	SPHA WA	<i>Sphagnum warnstorffii</i>
MNIU ST	<i>Mnium stellare</i>	SUCC PR	<i>Succisa pratensis</i>
MOLI CA	<i>Molinia caerulea</i>	THAL AL	<i>Thalictrum alpinum</i>
MYOS DE	<i>Myosotis decumbens</i>	TOFI PU	<i>Tofieldia pusilla</i>
NARD ST	<i>Nardus stricta</i>	TORT TO	<i>Tortella tortuosa</i>
NEPH AR	<i>Nephroma arcticum</i>	TRIE EU	<i>Trientalis europaea</i>
OXAL AC	<i>Oxalis acetosella</i>	TRIG PA	<i>Triglochin palustre</i>
OXYC MI	<i>Oxycoccus microcarpus</i>	TRIT PQ	<i>Tritomaria polita</i>
PALU SQ	<i>Paludella squarrosa</i>	TRIT QU	<i>Tritomaria quinquedentata</i>
PARI QU	<i>Paris quadrifolia</i>	UTRI MI	<i>Utricularia minor</i>
PARN PA	<i>Parnassia palustris</i>	VACC MY	<i>Vaccinium myrtillus</i>
PEDI OE	<i>Pedicularis oederi</i>	VACC UL	<i>Vaccinium uliginosum</i>
PEDI PA	<i>Pedicularis palustris</i>	VACC VI	<i>Vaccinium vitis-idaea</i>
PELL NE	<i>Pellia neesiana</i>	VIOL BI	<i>Viola biflora</i>
PHLE AL	<i>Phleum alpinum</i>	VIOL/PA	<i>Viola palustris/epipsila</i>
PING VU	<i>Pinguicula vulgaris</i>		
PLAG PO	<i>Plagiochila porelloides</i>		
PLAM ELA	<i>Plagiomnium elatum</i>		
PLAM ELL	<i>Plagiomnium ellipticum</i>		
PLEU SC	<i>Pleurozium schreberi</i>		
POA NE	<i>Poa nemoralis</i>		
POHL NU	<i>Pohlia nutans</i>		
POLY CO	<i>Polytrichum commune</i>		
POLY JU	<i>Polytrichum juniperinum</i>		
POLY VI	<i>Polygonum viviparum</i>		
POTE ER	<i>Potentilla erecta</i>		
POTE PA	<i>Potentilla palustris</i>		
PYRO MI	<i>Pyrola minor</i>		
PYRO RO	<i>Pyrola rotundifolia</i>		
RANU AC	<i>Ranunculus acris</i>		
RANU PL	<i>Ranunculus platanifolius</i>		
RHIN MI	<i>Rhinanthus minor</i>		
RHIZ MA	<i>Rhizomnium magnifolium</i>		
RHIZ PS	<i>Rhizomnium pseudopunctatum</i>		
RHOD RO	<i>Rhodobryum roseum</i>		
RHYT/SQ	<i>Rhytidiadelphus squarr./subpinn.</i>		
RUBU CH	<i>Rubus chamaemorus</i>		
RUBU SA	<i>Rubus saxatilis</i>		





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