Borrelyngen on Bornholm, Denmark

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Development of vegetation in an overgrown common
before and after nature conservation

By VALD. M. MIKKELSEN

Biologiske Skrifter **44**

Det Kongelige Danske Videnskabernes Selskab
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Abstract

Borrelyngen is part of the former common Højlyngen (The Highland Heath) on Bornholm, a Danish island in the Baltic Sea.

From about AD 1200, human influence changed vegetation in the central part of Bornholm from forest to common dominated by *Calluna* heath and open grassland, Højlyngen. Intensive grazing stopped at the end of the 19th century and most of Højlyngen became cultivated. Some areas, e.g. Borrelyngen, were not used by farmers and changed gradually to woodland.

The overgrowing is studied by determining the time of germination by counting the annual rings of trees felled after the start of nature conservation management in 1974. At that time sheep grazing began.

Development of the vegetation after the clearing of two areas was examined by analyses of the vegetation in 1981, 1984, and 1989 in the first area (Habbedam) and in 1986, 1991, 1992, and 1993 in the second (Knægten).

The thickness of the soil and its nutrient content was examined in both areas. The differences between the Habbedam area with *Calluna* heath generally on thin soil and a small number of species and the Knægten area with both thick and thin soil and with many more species in the heath as well as in the other communities are discussed.

The influence of sheep on the stump shoots, root-suckers and seedlings was investigated. The development of about 340 stumps of deciduous trees was followed in periods of 6 and 8 years. After 6-8 years about 20% of the stumps of *Quercus robur* were still alive, while the stumps of *Betula pendula, Carpinus betulus, Populus tremula, Prunus avium, Salix caprea,* and *Sorbus intermedia* were dead. Root-suckers of *Populus* were eaten and dead, as were all the seedlings of woody plants except *Juniperus communis,* which was avoided by sheep. *Juniperus* may thus be the prominent species in new overgrowing.

The influence of the sheep grazing on the rest of the vegetation was also investigated, as was the selection of food plants by sheep.

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Juniperus communis, mixed oak forest, self-sown *Pinus sylvestris,* stump shoots, root-suckers, overgrowing, nature conservation management, sheep grazing, selectivity of sheep, sheep and vegetation, succession: common → forest → open land.

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Contents

I. Introduction

From about AD 1200 to about AD 1800, Bornholm was roughly divided into two parts with different exploitations. Cultivation, farms and other built-up areas were placed in a brim along the coast, while the central part of the island, Højlyngen, was uninhabited and uncultivated, used only for the grazing of livestock.

Grazing, combined with the exploitation of

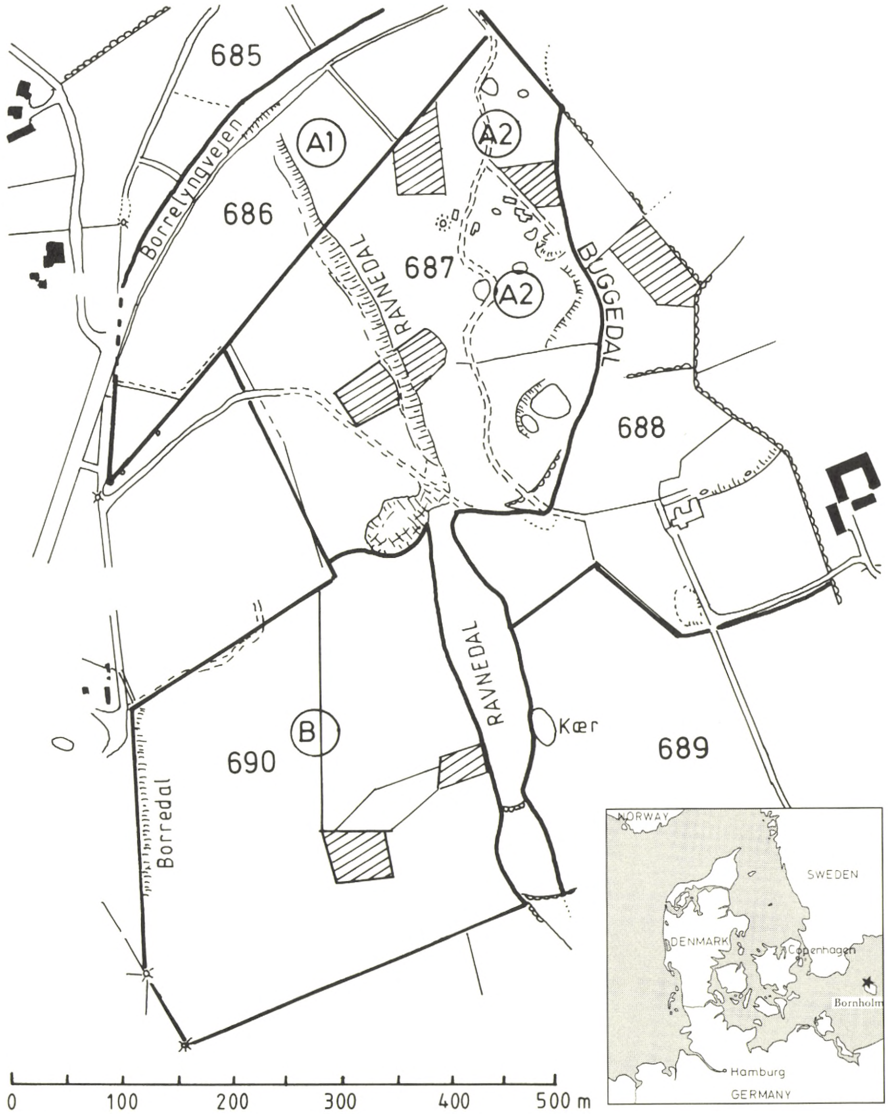

Fig. 1. Map of the forest district Borrelyngen. A1: oak-birch forest totally cleared 1986. A2: oak-birch forest thinned 1974, 1981, 1987, and 1991. B: Heath on rocky ground in part 690.

trees, shrubs, peat, etc., changed the former forest into an area of commons dominated by *Calluna* heath and grass. Scrubs were found only in valleys and other depressions at least during the last century.

At the end of the 19th century, most parts of Højlyngen were utilized for cultivation and planting of forest. The grazing decreased much or came to an end. However, some parts of Højlyngen were not used and could develop in their own ways.

The end of human influence caused a development of the vegetation in a natural direction, namely an overgrowing with woody plants.

The exploitation of and vegetation on Højlyngen are described in Mikkelsen 1991.

Borrelyngen (the heath of Borre), together with the two other heathland areas Slotslyngen and Hammeren, formed the northern part of the great common Højlyngen.

Today most of Borrelyngen is cultivated or covered by forest. However, in a part belonging to the State Forest District of Bornholm (cf. fig. 1) natural conservation management has taken place since 1974 in order to recreate the vegetation which characterized the area in preceding centuries.

From 1978 to 1993 the author made botanical-ecological investigations in two parts of the area: A. An area in parts 686 and 687 including an open forest dominated by oak and birch, and B. Part 690 dominated by heather on rocky ground.

A. The oak-birch forest in parts 686 and 687. Locally the area is called "Knægten" (the lad) after a well-known menhir in the middle of part 687 (figs. 5 and 6). Other names have been used, e.g. in Hansen 1979 the area was called Munkegaard after the farm in the vicinity.

The area (about 13 ha) has been grazed by sheep since the spring of 1974. From 1974 to 1978 Bülow-Olsen (1979) made botanical investigations in the area. In the forest areas in part 687 (A2 in fig. 1) the forest outside the 0-parcels was thinned early in 1974 and again in 1981, 1987 and 1991. The area marked A1 on the map fig. 1 was totally cleared of trees in March 1986.

From 1981 to 1993 the author investigated the influence of sheep grazing on the development of shoots from the stumps as well as on the vegetation in the cleared area.

B. The heath on rocky ground in part 690 (B in fig. 1). The Forestry Administration calls this part Habbedam after the nearby farm, to which the part previously belonged. The development of vegetation from 1979 to 1984 in the area (about 10 ha) is described in Mikkelsen 1991. The investigations of the N-S profile (length about 200 m) were repeated in 1989.

II. Knægten.
Grass and forest dominated areas in parts 686 and 687

1. Botanical-ecological investigations 1981-1993

When the investigations in part 690 were started in 1979, an investigation of the influence of sheep grazing on the development of shoots from the stumps was planned. However, the unstable grazing in part 690 made the area unsuitable. In March 1981 the forest in part 687 was thinned, and because sheep grazing was regular in this area, the investigations were placed here.

In the area marked A2 in fig. 1 slightly more than 100 stumps was marked with numbered plastic badges. The diameter of all stumps were measured. The number of annual rings was counted on the stumps of *Quercus robur, Populus tremula,* and *Salix caprea,* but it was not possible to count the annual rings on the stumps of *Betula pendula.*

During the following 8 years the development of stump shoots was followed by measuring the length of living shoots both at the beginning (May-June), and at the close (October-December) of the growth season. In the winter of 1988-89 there were still some living shoots from oak stumps, and four of them were surrounded by fences to prevent browsing by sheep.

Some stumps were excluded from the inves-

Fig. 2. Air photo from 1986 of the Knægten area seen from the north. Ravnedalen can be seen on the right side. The cleared area (marked A1 in fig. 1) is situated between Ravnedalen and open land and forest. The northern open land is the cultivated enclosure (cf. fig. 3). The open land to the south is the pasture. The texture seen in the pasture originates from clearing of the A1 area in 1986. Another pasture is situated in the southern part of the forest. The forest was thinned in 1974 and 1981 but was relatively dense in 1986. Jan Kofoed Winter phot.

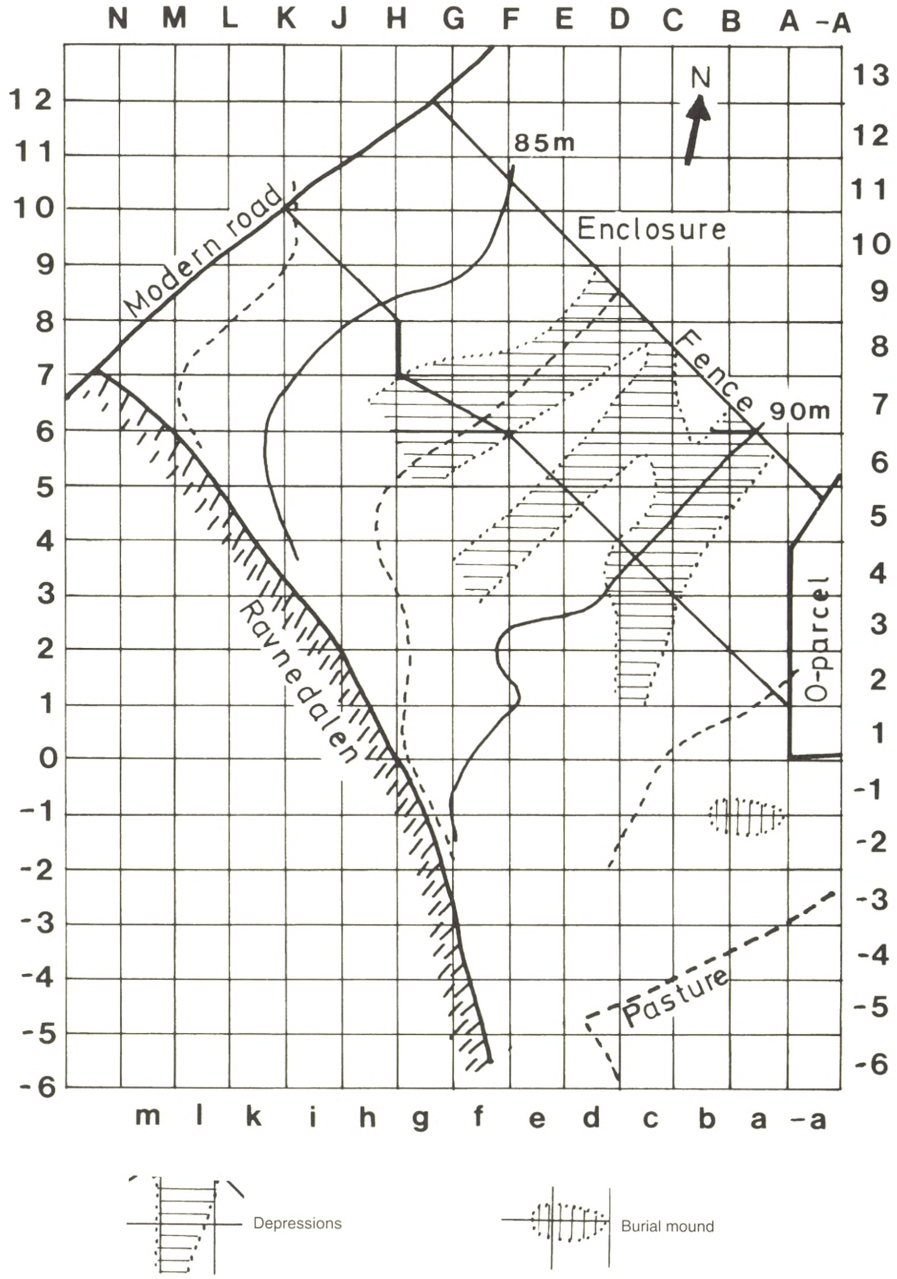

Fig. 3. Map of the A1 area divided into 10x10 m squares. The individual squares are numbered by combining the numerals to the right and the letters below. The corners of the squares are marked by combining the numerals to the left and the letters at the top. The investigated transect is marked and begins at A1 and ends at K10. A burial mound is marked by vertical hatching. Three NE-SW trending depressions (horizontal hatching) are shown based on the air photo, fig. 2. In this map (used in the following maps of distribution) the limits of the depressions are not quite accurate, but in the map used in fig. 23 they are corrected based on data from the transect.

tigation: a. those where only one of two or three trunks had been cut, b. those few birches where shoot more than one metre long had been left, because browsing sheep avoided such tall shoots.

As in earlier investigations (Bülow-Olsen 1979), the investigations started in open forest, but, as can be seen from the air photo from 1986 (fig. 2), this became relatively dense 5 years after the thinning.

The trees investigated prefer open land or open forest (cf. Vaupell 1863, pp. 76-100). It is therefore possible that the intensity of light may have an influence on the development of the stump shoots. In order to make possible an investigation of this aspect of stump survival the forest district totally cleared an area of about 1 ha (marked A1 on the map fig. 1) in March 1986.

The result was slightly more than 200 stumps of *Quercus robur, Betula pendula, Populus tremula, Carpinus betulus, Sorbus intermedia,* and *Prunus avium.* During the summer of 1986 most of the stumps were marked with numbered plastic badges. The diameter and the number of annual rings were measured for each stump.

In the A2 area it was sometimes difficult to find all stumps, especially when they were dying and more or less covered by the surrounding vegetation. Therefore the A1 area was divided into squares of 10x10 m, and where the soil was thick enough, the corners of the squares were marked with iron tubes (fig. 3). The stumps were then mapped relative to the squares, so it is easy to refind them, and they can also be recognized, even if the badge has been removed. From 1986 to 1991 the development of the stump shoots was followed in the same way as in the A2 area.

In August 1986 the vegetation in a transect about 130 m long (cf. figs. 3 and 4) was analysed for the frequency of species by the Raunkiær method, with a distance of 0.5 m between the circles. The degree of cover in % (density) of each species was estimated in each of the 0.1 m^2 Raunkiær circles, and so was the degree of cover of bare soil and rocks. The level and the depth of the soil were also determined. Soil samples 0-4 cm and 7-15 cm below the surface were collected from selected localities. A perforated iron tube, whose bottom was 0.74 m below the surface, was placed in a depression in the transect. The level of free water in the tube was measured several times yearly (cf. fig. 21).

The analyses of the vegetation were repeated in August 1991. The occurrence of *Anemone nemorosa* in the transect was analysed separately in May 1992.

Special investigations of *Juniperus communis* were made in 1991 (depth of soil for young plants) and 1992 (depth of soil and time of germination for bigger plants).

2. Terrain and soil

Parts 686 and 687 are divided by the glen Ravnedalen (cf. fig. 1). Ravnedalen has steep slopes on both sides. The bottom is about 75 m above sea level, and the areas on both sides are between 80 and 95 m above sea level (cf. fig. 19).

The botanical-ecological investigations were made in two areas east of Ravnedalen (A1 and A2 in fig. 1). A1 is the area that was cleared in 1986, and A2 is placed in the northeastern part of the forest. The air photo from 1986 (fig. 2) shows that, besides forest and the cleared area, the eastern part of parts 686 and 687 also contained open grassland. In the grassland the soil is rather thin, and bare rocks (some with rock engravings) can be seen in several places. All boulders had been removed during former cultivation.

The northernmost part of the cleared area is dominated by several boulders (fig. 2). In the middle of the cleared area there are 3 depressions aligned SW-NE without large stones (cf. figs 2 and 3), while the areas between them include bare rock, boulders and areas with a thin layer of sandy moraine.

The thickness of the soil was investigated in the A1 area. In the transect (figs. 3 and 19), the thickness of the soil was measured every 0.5 m, a total of 263 measurements (table 5). In addition the soil depth was measured at the corners of the 10x10 m squares. The map fig. 20 is based on these 94 measurements. It shows areas dominated by soil depths of respectively 0-29 cm and ≥30 cm.

3. Exploitation and vegetation before about 1900

In contrast to the other parts of Borrelyngen the section of parts 686 and 687 east of Ravnedalen shows clear indications of agricultural use in antiquity. Today the traces are most obvious in the areas west of the road through part 687. During the first half of the 20th century several granite quarries were established in the area east of the road. These destroyed several of the monuments of antiquity which were described in an archaeological report from the 19th century (Petersen 1884).

The monuments in the western part include burial mounds, menhirs, and rock engravings. Along the southern side of the southernmost depression in the cleared area (cf. fig. 3) a man-made row of stones can be seen. Most likely they represent the boundary of a field. Neither historical information nor old maps bear witnesses of cultivation in historical time, so it is most likely that the fields are from antiquity. Furthermore the area contains traces reminiscent of Celtic fields (Finn Ole Nielsen, personal communication).

Rows of stones can also be seen along some of the boundaries, especially the northern one, of the big pasture in part 687 (fig. 4). There is no information about cultivation of this area earlier than the close of the 19th century, when it is marked as open land on the ordnance

Fig. 4. Row of stones (field boundary) along the limit between the pasture and the cleared A1 area. V.M. phot 30/4 1987.

map. According to local information the area was cultivated (grass and in few cases cereals) in the 1950s. Therefore it is not impossible that these stone rows may be of newer date. However, their position in relation to the monuments of antiquity indicates their dating to antiquity.

The Knægten area is now legally protected and therefore secured for the future, so no special archaeological investigations have taken place. It is assumed that the monuments originate from a period including the Young Bronze Age and the Celtic Iron Age. Therefore the first cultivation of this part of Borrelyngen may be dated to the last millennium BC.

There is no historical information on early agriculture in the historical period, but old maps (cf. Mikkelsen 1991, figs. 4, 5 and 6) give some information.

On the map of Hammer from 1746-56 the whole area is marked as a common with no indication of cultivation. Nor is any cultivation shown in the draft map of the Cadastral Register from 1784. The map from 1799-1801 made by The Royal Danish Academy of Sciences and Letters shows that heathland covered the areas on both sides of Ravnedalen.

In the period from 1750 to 1800, and most likely in the centuries before, the Knægten area has been used only as a common.

The ruined castle of Hammershus, situated about 1 km NW of the menhir Knægten can be seen in the photo from 1869 (fig. 5). It appears from the photo that the area was without forest and covered by grass and/or heather; undoubtedly the pasture was not cultivated at that time.

The eastern part of part 686, the present-day pasture and the E-W depression in the southern part of part 687 are marked as open land on the ordnance map from 1887. On the 1914 revision the pasture is marked as heath while the other parts are marked as open land. The 1945 revision shows all these areas as open land.

Fig. 5. The menhir Knægten 1869. The surrounding area is totally without forest and shrubs, so it is possible to see the ruin of the medieval castle Hammershus about 1 km NW of Knægten. Joh. Hansen phot.

The exploitation of these areas, most likely as grass fields, undoubtedly began between 1869 and 1887, which agrees well with the fact that the dispute between the government and the farmers about ownership of Højlyngen was settled in 1866 (Mikkelsen 1991, p. 10).

Apart from the small areas with grass fields, most of the Knægten area was covered by heather and grass dominated commons until about 1900. Ravnedalen was the only locality with trees and shrubs, apart from *Juniperus communis,* which undoubtedly formed a characteristic part of the grazed areas at that time.

About 1900 the utilization of Højlyngen as a common diminished markedly, which is i.a. reflected in the reduction of the total number of sheep on Bornholm. In 1871 there were about

Fig. 6. Knægten 30/4 1987. The picture is taken from a slightly lower level, because a stone quarry had replaced the hill from which fig. 5 was taken. Also today Hammershus can be seen from here, but is situated behind the menhir in the photo. To the right in the background can be seen the big burial mound overgrown with oaks and the high trees in the 0-parcel east of the A1 area. V.M. phot.

28,400 sheep, but in 1903 the number had decreased to 9,200, to 5,200 in 1920 and to 300 in 1940 (cf. Mikkelsen 1991, table 1).

This decrease in the grazing intensity was the reason for an increased overgrowing of the commons on Bornholm.

4. Overgrowing after about 1900

Trees were most likely felled in the cleared A1 area before nature conservation management started in 1974. However, because overgrowing first accelerated around 1900, only a few trees can have been suitable for felling before 1974.

Before 1967 a large stand of *Pinus sylvestris* was found in the cleared area (A1 on the map fig. 1). A gale in 1967 blew most of them over and the rest were felled by man in 1974. At the same time some deciduous trees were also felled.

In 1984 it was possible to count the annual rings on 27 stumps of pines felled in 1974 in order to determine the time of germination. The year of germination was also determined for 126 deciduous trees (mostly oak) in the A2 area and for about 200 deciduous trees and 28 *Juniperus communis* in the A1 area.

As the number of annual rings are mostly counted in the field, an uncertainty of a couple of years cannot be excluded.

TABLE 1

	A2 area				A1 area									
	Quercus robur	Populus tremula	Salix caprea	Total	Quercus robur	Betula pendula	Populus tremula	Carpinus betulus	Sorbus intermedia	Prunus avium	Total	Pinus sylvestris	Juniperus communis	Total
1974-80	–	–	–	–	–	9	–	–	–	–	9	–	2	2
1966-73	–	–	–	–	1	14	–	2	–	1	18	–	2	2
1941-65	101	6	2	109	38	21	9	2	1	2	73	6	15	21
1916-40	17	–	–	17	57	13	2	1	2	–	75	21	7	28
1891-1915	–	–	–	–	14	–	–	2	2	–	18	–	2	2
First seedling	1918	1950	1950		1894	1920	1936	1904	1897	1945		1916	1910	
Year of felling	1981 1991	1981	1981		1986	1986	1986	1986	1986	1986		1974	1986 1992	
n	118	6	2	126	110	57	11	7	5	3	192	27	28	55

Table 1. Survey of the year of germination of 373 trees and shrubs in the A1 and A2 area according to counting of year-rings of the stumps of trees felled in 1974, 1981, 1986 and 1991.

Table 1 shows the number of germinated trees in periods of 25 years from 1891 to 1965, and in the periods 1966 to 1973 and 1974 to 1980.

In the A1 area the stumps of the deciduous trees were mapped in order to draw a map of their distribution in selected years.

Since 1961, the Geodetic Institute has produced aerial photos (1:4000) of the area every 5 or 6 years. Apart from a colour photo from October 1973 all the aerial photos were taken before leafing, so they give no useful picture of the deciduous forest. The distribution of the conifers can be seen, but it is not possible to distinguish between *Pinus sylvestris* and *Juniperus communis* in the photos. Most likely pine was the dominating conifer in the period from 1961 to 1974. After that time *Juniperus* was the only conifer in the area. Until 1986 juniper covered only a small part of the area (cf. fig. 11).

In the A2 area the stumps from the thinnings in 1981 and 1991 were not mapped, and the area is still covered by forest, so it has not been possible to map the development.

a. From about 1900 to 1915

A1 AREA. The oldest stumps in the A1 area germinated shortly before 1900; two *Quercus robur* in the period 1891-95 and one *Quercus* and one *Sorbus intermedia* between 1896 and 1900.

The investigations of the reaction of the stumps and the seedlings to sheep grazing indicate that even a moderate sheep grazing every year prevents these two species from developing into trees. Therefore the reason for the developing of these four trees is most likely that sheep grazing in the area stopped during the period or at least that it was so sporadic and irregular that the trees had time to grow high enough, so that the sheep could not damage them. Possibly sheep grazing in that period took place in the enclosure in the eastern part of part 686, which is shown as open land on the map from 1887. No or very few sheep can have grazed on the common.

In the following 15 years (1901-1915) 11 *Quercus robur,* 2 *Carpinus betulus,* 1 *Sorbus intermedia,* and 2 *Juniperus communis* germinated, which indicates that there was no grazing in the area at that time.

The distribution of the deciduous trees in 1911 is shown on a map (fig. 7). The overgrowing started in the northern corner of the area, which, as can be seen in the air photo (fig. 2), is characterized by lots of boulders. Furthermore the map of the thickness of the soil (fig. 20a) shows that the area is dominated by soil ≥30 cm. The overgrowing W of the NW corner of the 0-parcel, an area characterized by thick layers of soil and several boulders, must have started later.

Boulders protect germinating trees. Today, when the sheep are not too hungry they avoid such places. However, with the present degree of grazing, no stumps, seedlings or root-suckers have developed into trees in the areas with boulders.

A2 AREA. On the ordnance map corrected in 1914 the A2 area is shown as heath with only a few indications of deciduous trees. 118 stumps were investigated in the area, but none had germinated before 1918. Since all the trees have not been felled, it is theoretically possible that there may be older trees in the A2 area. The description of part 687 by the Nature-Preservation Committee in October 1973 (cf. the map fig. 8) mentions that the area contained some big oaks estimated to be about 80 years old, i.e. they germinated before 1900. Undoubtedly the age estimate was too high, because the big oaks felled in 1986 in the area at the NW corner of the 0-parcel had germinated in 1910-15, and these oaks must have been some of those estimated to be 80 years old in 1973. There are no traces of old fences between the A1 and the A2 areas, and undoubtedly conditions in the two areas were the same. There are no oaks left in the area with a diameter bigger than the biggest of the stumps investigated, so there is no reason to believe that there are oaks older than the oldest stump.

b. 1916-1940

The overgrowing accelerated in the A1 area. 57 oaks are from this period, and 14 birches date from around 1920.

In 1916 the first of the investigated stumps of *Pinus sylvestris* germinated. It was almost contemporary with the oldest one found in part 690, which was dated to 1911. Undoubtedly the trees were self-sown. The ordnance map from 1887 shows a plantation of pine in the immediate vicinity of part 690 and a plantation in Slotslyngen, a forest district close to Hammershus.

In 1846 the government sold Slotslyngen (it returned to the government in 1906). Like the plantations W of part 690 the plantations in Slotslyngen are a result of the planting done by the farmers on the old Højlyngen, starting in the middle of the 19th century. On the forest map from 1977, the age of the pines on Slotslyngen is estimated to be about 100 years, i.e. they were sown about 1870-80. Seeds from these plantations may have germinated on Borrelyngen. On the forest map from 1977 the pine plantation in part 685 W of Ravnedalen is estimated to be 60 years old, i.e. it was established about 1917, which is in accordance with the results of the investigations of the stumps.

The overgrowing of the A1 area accelerated mostly after 1926. At the beginning oak dominated, but from 1931 pine and birch also became common. The oldest *Populus tremula* germinated in 1936.

The increasing frequency of the trees mentioned above together with 1 *Carpinus betulus* and 2 *Sorbus intermedia* from this period indicates that sheep grazing in the area was either

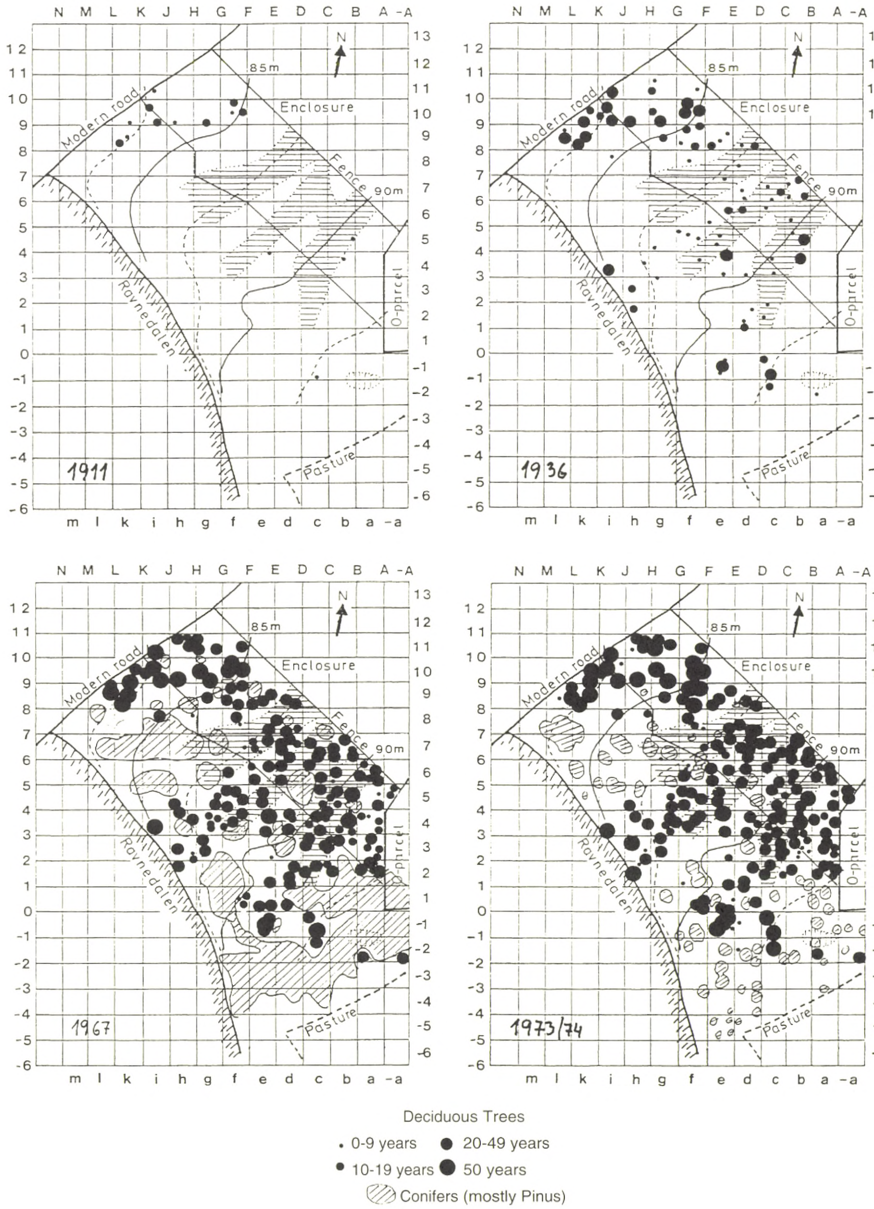

Fig. 7. Maps showing overgrowing of the A1 area from 1911 to 1973/74. The distribution of the deciduous trees is based on the dated stumps of the trees felled in 1986. The indication of conifers (mostly *Pinus sylvestris*) is based on aerial photos from 1967 and 1974. About half of the pines were already in the locality in 1936, but the stumps have not been mapped.

totally absent or was very sporadic or infrequent. This is in accordance with the fact that the number of sheep on Bornholm decreased from 5,200 in 1920 to about 300 in 1940.

The map of the distribution of deciduous trees in 1936 (fig. 7) shows that a large part of the area was covered by deciduous trees, but there were still areas without trees. A comparison with the map from 1967 (fig. 7) with the distribution of conifers shows that the open areas on the map from 1936 are almost identical with the distribution of the conifers in 1967. As more than half of the conifers had germinated before 1936, in all probability most of the A1 area was covered by trees in 1936.

A2 AREA. The oldest investigated stump in the A2 area had germinated in 1918, but the overgrowing was much slower in the A2 area than in the A1 area. 126 stumps of deciduous trees were investigated in the A2 area, and only 17 (18%) had germinated in the period 1916-1940. In the A1 area 75 (39%) of the 192 deciduous trees and 21 (78%) of the 27 pines originated from this period.

A reasonable explanation of the difference between the areas is the exploitation of the A2 area. At the beginning of the 20th century several granite quarries, both small and big, were established in part 687, especially in the eastern part (cf. fig. 8). The establishment of the quarries and the associated activity may have prevented overgrowing. The use by stone workers on Bornholm of juniper shrubs when blasting the rocks may indirectly have prevented the overgrowing.

Unfortunately there are no written sources about the history of these quarries. Some information can be found on the ordnance maps. This, together with information about the period 1948-1970 from a former quarry owner, is the background for the following. The maps from 1887 and 1914 show no quarries in the area, but they are shown on the map corrected in 1945. Some small quarries may have been overlooked in 1914, but the bigger quarries must have been established between 1914 and 1945. One of the larger quarries is located in the northern part of the A2 area. The big quarries and the necessity of a forge (cf. fig. 8) show that the exploitation was great until it stopped before 1948. Undoubtedly several of the small quarries in the northern part of the A2 area were also used in the period.

c. 1941-1973

In the A1 area overgrowing continued steadily until about 1960. After that time the number of newly germinated trees decreased appreciably. The increased number of new *Populus tremula* and the first new *Prunus avium* from 1945 indicate that the area was not grazed, which is also confirmed by local information.

The density of the overgrowing was highest in 1967 as can be seen on the map from 1967, (fig. 7). This map is based on the stumps of the deciduous trees and on an aerial photo from 12/5 1967, i.e. before the storm which blew over most of the pines.

The map from 1967 (fig. 7) shows that the area was covered by groups of conifers (*Pinus sylvestris*) and groups of deciduous trees (mostly *Quercus robur* and *Betula pendula*).

In the A2 area the overgrowing really accelerated in the 1940s and continued until about 1965. Of the 126 investigated stumps, 109 (87%) germinated between 1941 and 1965, namely 101 *Quercus robur*, 6 *Populus tremula*, and 2 *Salix caprea*.

Stumps of birch were only investigated in 1981, and at that time it was impossible to count the *Betula* annual rings in the field. However, all stumps had a diameter less than 30 cm. Most of the birch stumps in the A1 area which had an equal diameter were less than 35 years old, and the oldest one was 43 years old. It is therefore most probable that the overgrowing of birch in the A2 area first started in the 1940s like most of the other trees.

The beginning of vigorous overgrowing in the 1940s was undoubtedly caused by the fact that the use of the granite quarries in the A2 area stopped at that time. The use of the big quarry south of the area from the close of the 1940s to about 1970 had no influence on the overgrowing of the A2 area. The same must have been the case for the few small quarries in the A2 area, which were probably used in the 1950s. According to local information there was no grazing in the area.

In the A1 as well as in the A2 area the over-

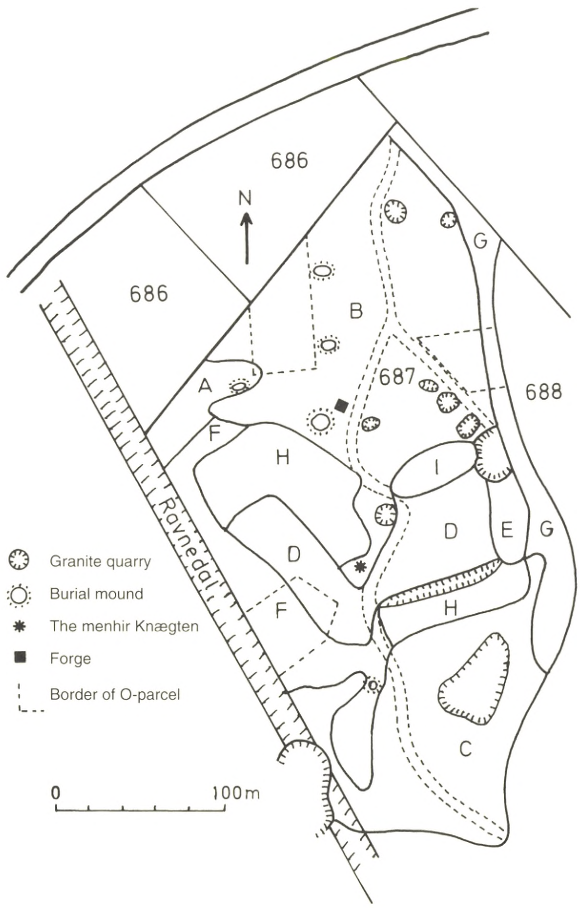

Fig. 8. Map showing vegetation in the eastern part of part 687. Simplified after the map made by Damgaard and Riisager 1973 supplied by a coloured air photo from October 1973.

A. *Pinus sylvestris* and some *Quercus, Betula* and *Juniperus.*

B. *Quercus,* some of them rather big, together with some *Betula, Populus tremula,* and *Salix caprea.* The trees were about 10-12 m high, but in the NE part they were lower and shrublike. The bottom vegetation: *Lonicera periclymenum* and *Vaccinium myrtillus,* some places *Deschampsia flexuosa.* A few suppressed *Juniperus.*

C. 8-12 m high trees of *Quercus, Betula, Salix caprea, Prunus avium,* and *Populus tremula.* Towards the SW some big oaks. Bottom vegetation: *Juniperus, Lonicera,* and *Vaccinium.*

D. *Quercus, Betula, Sorbus intermedia,* and *Prunus avium.* In the southern part some *Pinus sylvestris.* Towards the E scrub of small oaks and birches. Bottom vegetation: *Calluna, Juniperus* and *Lonicera.* No sharp limit to part E.

E. Rocky ground with *Calluna* and *Juniperus.* From W the area is invaded by *Quercus* and *Betula.*

F. *Calluna* and *Juniperus.* A few *Pinus.*

G. *Betula, Salix caprea, Sorbus intermedia,* and a few oaks up till a height of 15 m.

H. Earlier cultivated fields (last crop *Dactylis glomerata*). Self sown plants of *Betula, Salix caprea,* and *Prunus avium.* In the northern part, lots of *Prunus avium* seedlings and in the western part 8 rows of 0.5-1 m high *Picea abies.*

growing had progressed so far that, after 1965, new trees had very limited possibilities for germination and development (cf. table 1).

A heavy storm in October 1967 overturned a lot of pines in the A1 area. In the period 1971 to 1973, 12 birches germinated, most of them in areas previously covered by pines. *Juniperus communis* was also favoured in this area. 2 of the 28 junipers investigated had germinated in 1968.

In 1973 the Danish Government represented by the Nature Preservation Committee of Bornholm, acquired the area which included parts 687, 688 and 689 (cf. fig. 1). A report on the status of the vegetation was prepared by P. Damgaard and J. Riisager in 1973. Based on their map and descriptions together with an aerial photo in colour from October 1973 a simplified map (fig. 8) is made showing the vegetation in part 687 before the nature conservation management started in 1974. Part 686 is missing in the map because this area was not acquired until 1975-76 (Hansen 1979).

The map from 1973/74 in fig. 7 is based on the dated stumps of the deciduous trees in A1 and an aerial photo from the spring of 1974, i.e. the time just before the nature conservation management started. The map shows that large parts of the A1 area were densely overgrown and there were only some open places. Undoubtedly bare rocks and heath with scattered juniper shrubs on rather thin layers of soil were indicated as open places; such habitats are also common today.

5. Nature conservation management from 1974

In the 20th century, the grazing of sheep and other domestic animals has come to an end on the heath and grass-dominated common along the coast of Bornholm and on the former Højlyngen.

When nature conservation management started, the only method was mechanical clearing - a method which is still used in many places. However, mechanical clearing alone does not prevent overgrowing. Most of the deciduous trees and shrubs quickly produce lots of new shoots from the stumps or from the roots. Furthermore, seedlings of deciduous trees as well as of conifers have good chances of developing into new trees. In less than 2-3 years the cleared area changes to an almost impenetrable copse with a ground flora of blackberries, raspberries, nettles, and high perennial herbs.

After the middle of this century, mechanical clearing followed by grazing of sheep, cattle or more uncommonly goats has been used where circumstances allow.

In parts 686 and 687 of Borrelyngen, sheep grazing was chosen, and in the uninvestigated part 688, cattle grazing.

Before the start of nature conservation management in 1974 three 0-parcels were established (cf. fig. 8). In these 0-parcels, vegetation developed independently of the surrounding nature conservation management. In 1975 a fourth 0-parcel was established in the narrow E-W going earlier pasture (the southern H in Fig. 8). A comparison between grazed and ungrazed areas became possible in this way, and the influence of the sheep could be examined.

The author followed the investigations from 1974 to 1978 in the area, and his own investigations in the Knægten area started in 1981.

a. Clearing

In 1974 all exotic conifers (*Pinus sylvestris* and *Picea abies*) were felled, while most shrubs of *Juniperus communis* were preserved. Part 687 (including the A2 area) was heavily thinned partly in order to establish an open forest which could be used for grazing and partly to avoid overgrowing of the heath areas.

The thinning favoured the growth of the trees which had been left, and a new thinning took place in March 1981. The stumps of *Quercus robur, Betula pendula, Populus tremula,* and *Salix caprea* (cf. tab. 2) from that felling were used in the investigation of the influence of sheep on the development of shoots from the stumps. While a greater variety of trees was preserved in 1981, it was mostly oak which was preserved at the later thinnings in 1987 and 1991.

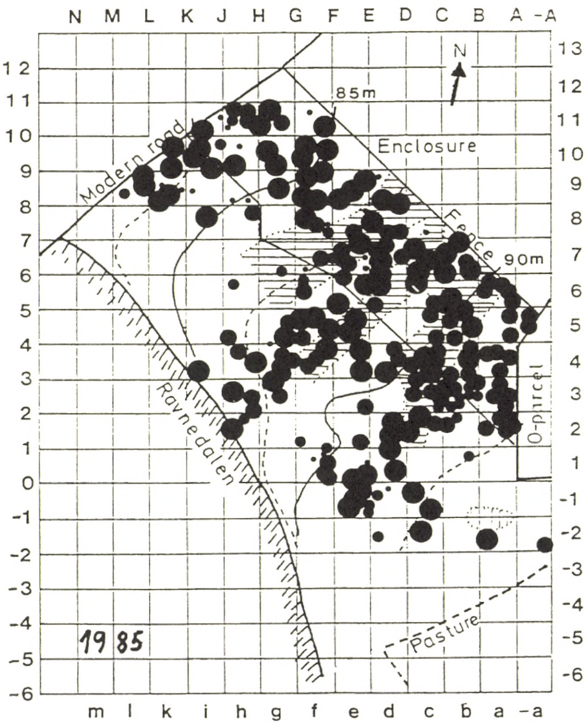

Fig. 9. Distribution of deciduous forest in the A1 area in 1985. Only trees felled in 1986 are mapped. Signatures as in fig. 7.

Fig. 10. Burial mound in the southern part of the A1 area (cf. fig. 3) shortly after clearing. Several fresh stumps of oak and stumps of pines felled in 1974 can be seen as well as several *Juniperus*. In the background the 0-parcel. V.M. phot. 29/4 1986.

In the A1 area the rest of the pines were felled in 1974, while the thinning of the deciduous forest must have been very limited. In 1986, very few stumps of deciduous trees were left from the felling in 1974, while there was a large number of stumps of *Pinus*. The relatively dense stand of deciduous trees (cf. fig. 9) caused the sheep mostly to avoid the area. In the period 1974 to 1980, 9 *Betula pendula* germinated and developed into trees (cf. tab. 2). Most of them and 2 *Juniperus* germinated in the area earlier dominated by *Pinus*.

In March 1986 the A1 area was cleared (cf fig. 10). *Juniperus* was preserved together with a couple of oaks on the border to the pasture south of the area and 4 *Sorbus intermedia* and 1 *Sorbus aucuparia,* partly near the northeastern limit and partly in a rocky area in the northwestern part of A1. The maps fig. 11 are based on air photos from 1/5 1986 and 21/5 1991 and show the distribution of *Juniperus, Sorbus* and *Quercus* during the two years.

After the felling in 1986, all stumps with a diameter of more than 6-8 cm were marked with plastic labels and mapped. The shoots from the bigger stumps were eaten by the sheep, but some dense groups of very thin stumps were avoided by them and developed into copses which were later cleared mechanically.

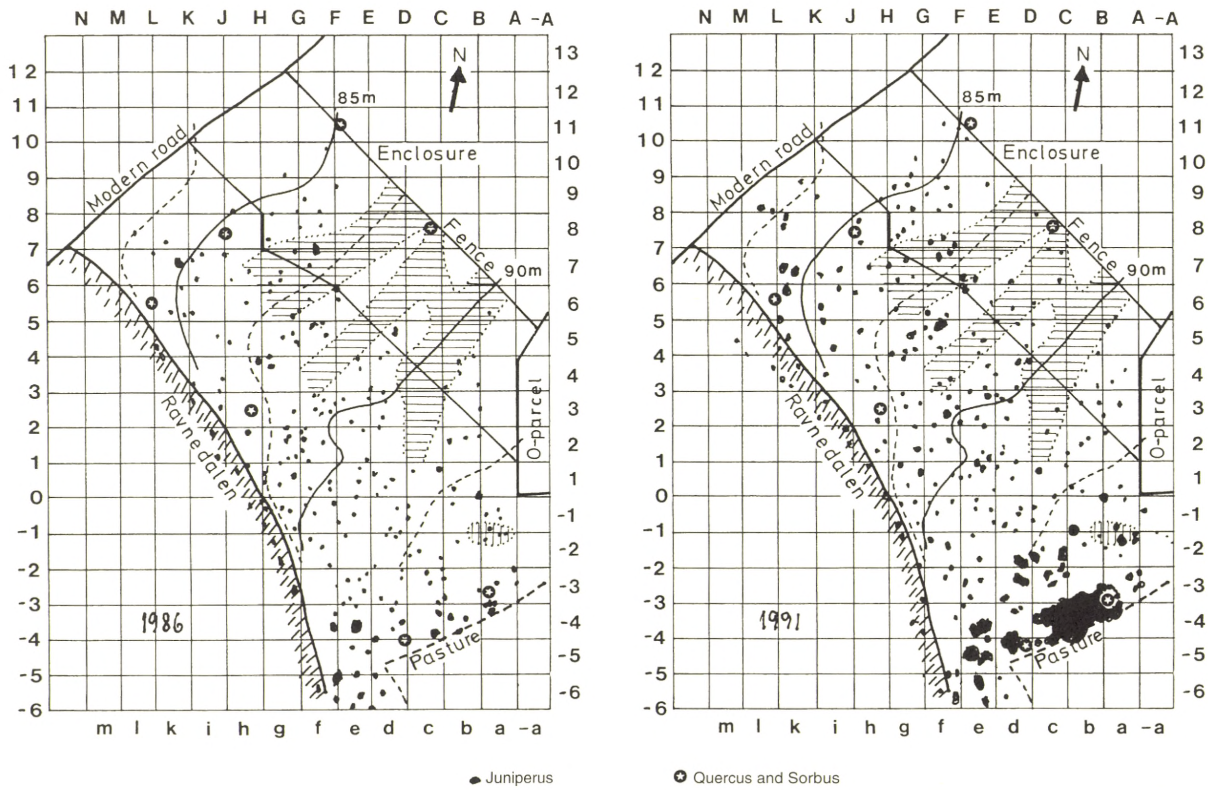

Fig. 11. The distribution of *Juniperus communis* in 1986 and 1991, based on air photos. Because the air photos are in the scale 1:4000, the accuracy is limited, but a coloured air photo from October 1986 confirms the main distribution of *Juniperus* in 1986. Other photos of the area from 1986 and 1991 also confirm the distribution.

b. Sheep grazing

From May 1974 the area was grazed by sheep. The area is about 13 ha (9 ha in part 687 and 4 ha in part 686). The sheep are from the Brogaard farm near the area. The owner is conscious of the economic aspects of sheep breeding and adjusted the number of sheep to the actual amount of food in the area. When necessary they got extra food. Therefore the sheep have never been really hungry, which has influenced the intensity of the grazing and therefore also the vegetation. The grazing intensity varies in the area and is highest E of Ravnedalen (the feeding places are in the NE corner of part 687). Dense forest, and localities with many boulders are avoided when the sheep are not really hungry.

Generally there were 20-45 adult sheep with 10-50 lambs from the end of May to the end of December. During December, the area was usually used as a gathering place for sheep from other areas, bringing the total up to 70-120 sheep.

6. The influence of the sheep on the overgrowing of natural areas

The intensity of grazing in a natural area varies very much, especially when the sheep are never really hungry as in the investigated area. This depends to some degree on the fact that the sheep are very selective concerning what they prefer to eat.

a. Ground flora

No special investigations concerning this problem were made, but many observations have provided some information during the years, especially in years when food was abundant in the area. It was for instance the case in early summer 1988. The A1 area had at that time a very vigorous growth of grass, which at the beginning of July was almost untouched, but from the main sheep path there were small paths to the stumps (especially oak) which were heavily browsed. Later in the year, *Vaccinium myrtillus* and a bit later also *Rubus idaeus* were eaten, while *Deschampsia flexuosa* and *Agrostis tenuis* were untouched. These two grasses are avoided as long as there are any other kinds of food such as *Rubus fruticosus, Holcus lanatus, Poa pratensis,* and *Platanthera chlorantha.* Even low stands of *Betula pendula* are preferred to the two grasses.

b. Seedlings and root-suckers

In the description of the area in 1973, it was mentioned that the northern pasture (fig. 8 H) contained self-sown *Betula, Salix,* and *Prunus,* and that the eastern part of the pasture contained large numbers of young *Prunus avium.* Junipers were only observed in neighbouring

Fig. 12. *Juniperus communis* on the pasture south of the A1 area in September 1990. To the right in the background are the oaks on the big burial mound and trees in the 0-parcel. In the middle of the background is the big oak on the limit of the A1 area. Compared with figs. 4 and 6 from 1987, the number and size of junipers have increased. V.M. phot. Sept. 1990.

communities. The growth was cleared in 1974, after which sheep grazing started. Neither *Salix* nor *Prunus* regenerated. Some dense groups of young *Betula* regenerated, but were later cleared mechanically, and do not exist any more. The tree species mentioned all disappeared from the pasture, because the sheep had eaten all the seedlings. On the other hand sheep grazing favoured the germination and growth of *Juniperus* very much both in the northern (fig. 12) and the southern pastures in part 687.

In the 0-parcel established in the southern pasture in 1975 there are no *Juniperus*. The same is the case in areas without grazing and with intact cover of vegetation.

In the A1 area there are also lots of young plants of *Juniperus* which the sheep have avoided. The preservation of large shrubs of *Juniperus* may produce a renewed overgrowing in the future. Since 1990 several small trees of *Betula pendula*, *Quercus robur*, and *Sorbus aucuparia*, germinated and grew up protected against the sheep by the surrounding junipers. If they are not mechanically cleared, at least the oaks will become large trees, and their shadows will be able to kill the junipers.

Several seedlings of oak and birch, together with root-suckers of *Populus tremula* were found in the A1 area at the beginning of several growing seasons, but they did not survive browsing by sheep.

Carpinus betulus is a bit different. Many places in the A1 area contained several shoots of *Carpi-*

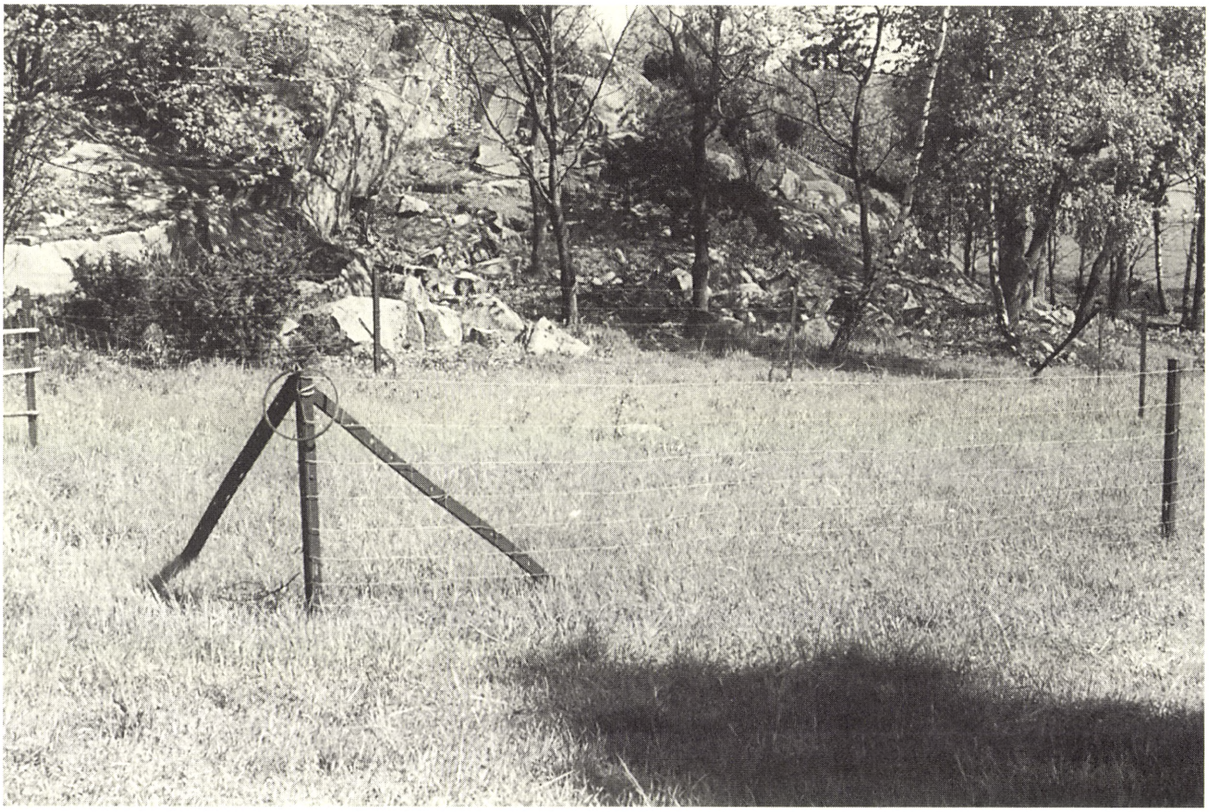

Fig. 13. 0-parcel established 1975 in the southern pasture in part 687 in June 1976. In the background is an old granite quarry. V.M. phot.

Fig. 14. The same 0-parcel in July 1987. Most of the high trees are *Prunus avium* and *Betula pendula.* G.M. phot.

nus with a diameter of 1-3 cm. Almost every year they are bitten down to a height of 10-15 cm, but unlike the other species they are still alive in the grazed area. 19 living shoots were investigated in 1993. 7 of the seedlings had survived in 9-18 years and 12 in 5-8 years. The shoots had horizontal branches just above the surface and had produced a carpet of shoots.

In the grazed areas none of the species mentioned have had an opportunity to develop into trees in the period since 1974. On the other hand in the 0-parcels there are several examples of root-suckers of *Populus* and seedlings of *Betula* and *Prunus* which have grown into trees (cf. fig. 13, 14, and 15); and in a part of the A1 area which was avoided by sheep in 1992 and 1993 a seedling af *Carpinus* from 1986 had produced a 140 cm long shoot, which is above the level of sheep browsing.

Fig. 15. The eastern part of the A1 area and the western part of the northern 0-parcel in part 687. The high trees in the 0-parcel are mostly *Quercus robur, Betula pendula,* and *Populus tremula.* All seedlings and root-suckers in the A1 area have been browsed by sheep and are dead. V.M. phot. 13/8 1987.

A conclusion is that sheep grazing prevents young plants of *Betula pendula, Carpinus betulus, Prunus avium, Populus tremula, Salix caprea, Sorbus* spp., and *Quercus robur* from developing into trees. Among the investigated species *Carpinus* is the only species which may be able to develop into a tree, if there is no grazing for some years.

Sheep grazing favours the development of *Juniperus communis,* cf. also Bülow-Olsen 1979, Vedel 1961 and Vedel and Ødum 1970.

c. Shoots from the stumps

The influence of sheep grazing on the development of shoots from stumps was recorded systematically. After the thinning of the A2 area in March 1981, 130 stumps were marked, and the development of the shoots was followed during the following 8 years. After the clearing of the A1 area in March 1986, 212 stumps were marked, and the development of shoots was followed until 1991. The survival of the stumps of each species is shown in table 2. In the A1 area (felled in 1986) all of the stumps were recorded, while in the A2 area only a part of the felled trees were recorded; relatively many of these were *Betula pendula.*

Betula pendula

According to earlier investigations by Bülow-Olsen (1979), stumps of big birches (diameter ≥10 cm) were severely browsed, and after 3 years only 7% were alive, while 46% of small birches (diameter ≤5 cm) were still alive. Several of these developed into a scrub about 2 m high during the next couple of years. Sheep

TABLE 2

		% alive									
		Populus tremula		Prunus avium	Salix caprea	Sorbus intermedia	Carpinus betula	Betula pendula		Quercus robur	
Felled		1981	1986	1986	1981	1986	1986	1981	1986	1981	1986
Growing	1.	62	36	50	100	100	100	82	78	96	92
	2.	38	–	–	88	28	71	62	6	94	79
seasons	3.	15	–	–	38	–	14	16	3	90	73
	4.	8	–	–	13	–	14	15	3	69	61
after	5.	–	–	–	–	–	14	11	–	60	45
	6.	–	–	–	–	–	–	11	–	56	26
felling	7.	–	–	–	–	–	–	7	–	31	
	8.	–	–	–	–	–	–	–	–	23	
n		13	11	6	8	7	7	61	64	48	117

Table 2. Living stumps at the end of each growing season after the felling – in percentage of trees felled. In the A2 area the forest was thinned in 1981. In the A1 area all trees were felled in 1986.

could eat only the leaves on the outskirts of the densely grown areas. The birches were mechanically cleared later and did not regenerate.

The stumps of birch investigated were divided into categories by thickness (6-10, 11-19, 20-49 cm) and age (0-24 and 25-69 years), but there was no essential difference between those categories and the results shown in table 2.

Table 2 shows that about 20% of the birches died during the first growth season. Those still living usually formed a cushion of dense new shoots which were browsed close to the stump. At the end of the third season, 16% were still alive in the A2 area but only 3% in the A1 area, which is similar to the results of Bülow-Olsen (1979).

Some birch stumps lived longer in the thinned forest (A2) than in the cleared area (A1). 2 birch stumps (7%) were still alive in the 7th season in the A2 area, while all were dead in the A1 area after 4 seasons. Another difference is that, at the end of the second season, 62% were alive in the thinned forest, but only 6% in the cleared area. However, 61% were alive at the beginning of the second season in the cleared area. Undoubtedly the difference was caused by the greater intensity of grazing in open areas compared to grazing inside the forest.

TABLE 3

	A2		A1	
Year	$\tilde{m}$ of length of shoots	n	$\tilde{m}$ of length of shoots	n
1982	37	45	–	–
1983	32	43	–	–
1984	34	33	–	–
1985	38	29	–	–
1986	26	27	8	108
1987	18	15	10	93
1988	22	11	17	82
1989	–	–	13	71
1990	–	–	11	53
1991	–	–	21	31

Table 3. Average length in cm of shoots from stumps of *Quercus robur* in the thinned forest in the A2 area and in the A1 area, where all trees were felled. For each stump the measure is taken from the longest living shoot at the end of the growing season. The A2 area was investigated 1982-1988, and the A1 area from 1986 to 1991.

Quercus robur

The sheep showed a strong preference for stumps of oak. Shortly after sheep came to the area, the cushions of dense stump shoots looked as if they had been shaved, so that shoots and stumps together formed a smooth surface (cf. fig. 16). Longer, isolated shoots from the stumps were rare.

Table 3 shows the average length of the longest shoot from each oak stump. The average length was larger in the thinned forest (A2) than in the cleared area. The reason for this is most likely that the shoots were more accessible and the intensity of grazing was greatest in the cleared area. The mortality of the oak stumps was also somewhat higher in the A1 area than in the A2 area (tab. 2).

Bülow-Olsen (l.c.) found that 3 years after felling, 66% of the oak stumps were still alive. The investigations from 1981 and 1986 show the same result at the end of the 4th season (table 2).

In the 4th and 5th seasons many of the oak stumps were attacked by fungi. Fig. 16 (from 1987) shows the oak stump marked M2 with a dense cushion of down browsed shoots. At the end of the second year after felling it was already covered by fungi (fig. 17). The stump was still alive at the beginning of the 5th season (1990), but in October of the same year it

Fig. 16. Stumps of oak (M2 in the A1 area), diameter 20 cm, germinated in 1951, felled in 1986. Cushions of browsed dense shoots can be seen in front of and to the left of the stump. V.M. phot. 13/8 1987.

Fig. 17. In December 1988 the same stump was partly covered by fungi, but still alive. The stump and the shoots died in 1990. V.M. phot. 16/12 1988.

TABLE 4

Age \ Diameter	0-19 cm n	0-19 cm 2'	0-19 cm 6'	20-39 cm n	20-39 cm 2'	20-39 cm 6'	≥ 40 cm n	≥ 40 cm 2'	≥ 40 cm 6'	n
unknown	5	100	0							5
0-24 years	14	100	43							14
25-49 years	42	95	43	42	90	43				84
50-74 years	1	100	0	36	81	22	14	57	43	51
≥ 75 years							11	27	18	11
n	62			78			25			165

Table 4. Living stumps of *Quercus robur* at the end of the 2nd and in the 6th growing season after felling – in percentage of the number of felled trees (n).
The stumps are from the A1 and A2 areas. In the A2 area the forest was thinned in 1981. In the A1 area all trees were felled in 1986.

was dead and the cushion of shoots was also dead.

An investigation of different categories by thickness and age, table 4, suggests that stumps ≥75 year old die more quickly than the other categories, which all behave almost similarly.

Table 2 shows that at the end of the 8th season about $^1/_4$ of the oak stumps were still alive. In order to get an impression of the vitality of these stumps, 4 of the most vigorous ones were surrounded by a fence in the spring of 1989. The fences (fig. 18) prevented the sheep from browsing the shoots. Three of the stumps died in the following years. In August 1993 the fourth was still thriving, although only with 30-40 cm long shoots.

The investigations showed that most of the stumps lost their ability to regenerate into trees

Fig. 18. Stump of *Quercus robur* (X15 in the A2 area), diameter 17 cm, germinated 1954, felled 1981. Stump shoots browsed by sheep 1981-1988. Fenced in the spring of 1989. Still alive in 1993, but no shoots longer than 30-40 cm. V.M. phot. 27/4 1989.

after 8 years of sheep grazing, and possibly earlier. None of the stumps from 1974, when sheep grazing started, have developed to trees.

In the A2 area there are some stumps which initially had 2 or more independent trunks, most likely shoots from the same original stump. 2 such stumps were investigated. One of them started in 1925 with 2 shoots which fused into one in 1957. The other started in 1934, also with 2 shoots becoming 2 independent trunks which grew into one in 1961. Both of these stump shoots became trees during a period without sheep grazing.

Carpinus betulus
As mentioned above, *Carpinus* is much preferred by the sheep, and early in the growth season all shoots are eaten down to the stump. As can be seen in table 2, the mortality amongst the 7 stumps investigated was rather high. Only one (81 years, diameter 55 cm) lived 5 years. On the other hand, as mentioned above, several stumps (diameter 1-3 cm) of seedlings from 1976 to 1989 were still alive in 1993.

Sorbus intermedia
According to Bülow-Olsen (1979) the sheep browsed the stump shoots. All the stumps she investigated were alive after 3 years. In the A1 area all the stumps investigated were dead in the third year (table 2). *Sorbus intermedia* does not seem able to survive intensive grazing.

Salix caprea
Salix caprea is intensively eaten by the sheep (Bülow-Olsen l.c.), but of the 16 stumps she investigated, 15 were still alive after 3 years. In the A2 area only one of 8 was alive after 4 years, and in the 5th season all were dead (table 2). Several of the stumps investigated by Bülow-Olsen were still alive in 1980 (the 6th year after felling), but they were overgrown by the fungus *Pholiota mutabilis,* and a few years later they were dead and totally decayed.

Prunus avium
Not only the seedlings, but also the shoots from the stumps are much preferred by the sheep. Bülow-Olsen investigated 44 stumps, of which only 4% were alive after 3 years. In the A1 area, there were only 6 stumps and all were dead in the second season, so it can be concluded that *Prunus avium* is very sensitive to sheep grazing.

Populus tremula
Populus tremula produces lots of root-suckers, but sheep grazing prevents them from developing into trees. There were no shoots from the upper part of the stumps, and it was difficult to see if shoots from the lower part of the stumps were from the base of the trunk or from the upper part of the root. According to table 2, one of 13 shoots was still alive in the 4th season, but this may have been a root-sucker from the upper part of the root. Generally most of the stumps of *Populus tremula* were already dead in the first season after felling. In the 0-parcels many root-suckers developed into trees.

III The development of the vegetation in the cleared area in Knægten (the A1 area) from 1986 to 1993

1. The investigations

In 1986 a transect through the cleared area was established. The map, fig. 3, shows the placing of the transect. The fixed points (A1, B2, C3, etc.) were marked in the field with iron tubes.

The first botanical-ecological investigation of the transect was made in August 1986, and the locality was visited several times during the following years. The analyses of the vegetation were repeated in August 1991. The last analysis was supplemented in May 1992 with an analysis of the frequency and density of *Anemone nemorosa* in the transect.

The transect, as shown in fig. 19, furthermore contains signatures showing trees which were located 2 m or less from the transect in 1985.

2. The soil

a. The thickness of the soil

The surface of the granite is characterized by glacial erosion and contains many "roche moutonné". The granite is more or less covered by a layer of sandy moraine. The uppermost few centimetres contain humus, while lower strata are mostly characterized by sand.

The thickness of the soil varies greatly in the area. Some areas have lots of exposed granite surfaces without soil, in others there are soil layers up to 100 cm thick. In 1986 the depth of the soil was measured in all 263 points of analysis in the transect and in the 94 corners of the squares. Table 5 shows the distribution of soil thickness in the transect. 60% of the sample

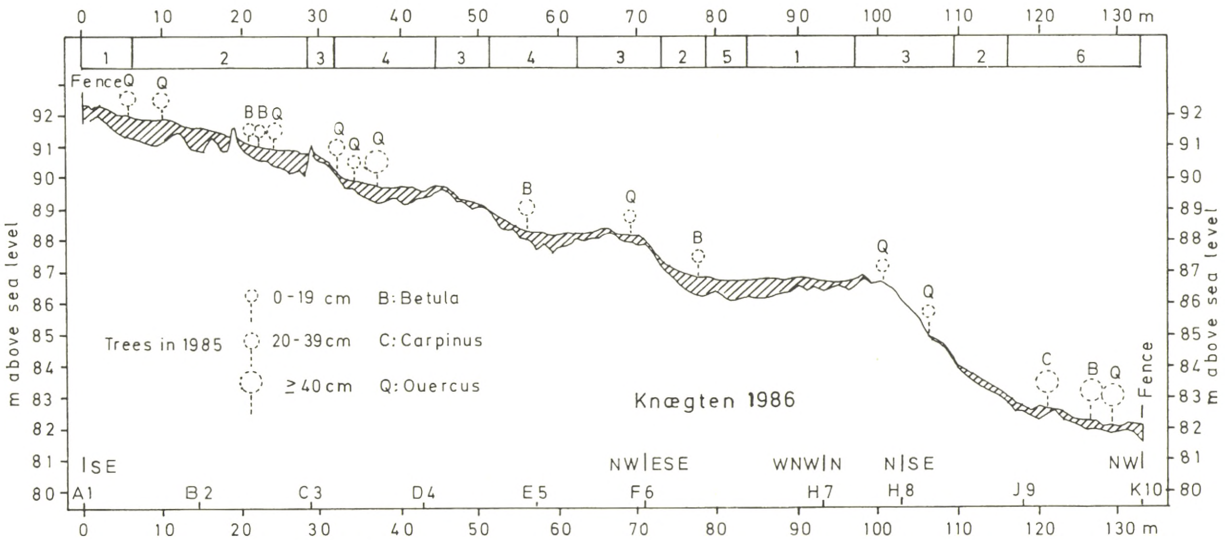

Fig. 19. Transect through the A1 area. The locations of the plant communities are marked by the numbers 1 to 6 above the transect. The soil layer is hatched. Signatures show the location of trees which were inside a distance of 2 m from the transect in 1985. Below is marked the location of the transect from square corner A1 to K10 (cf. fig. 3).

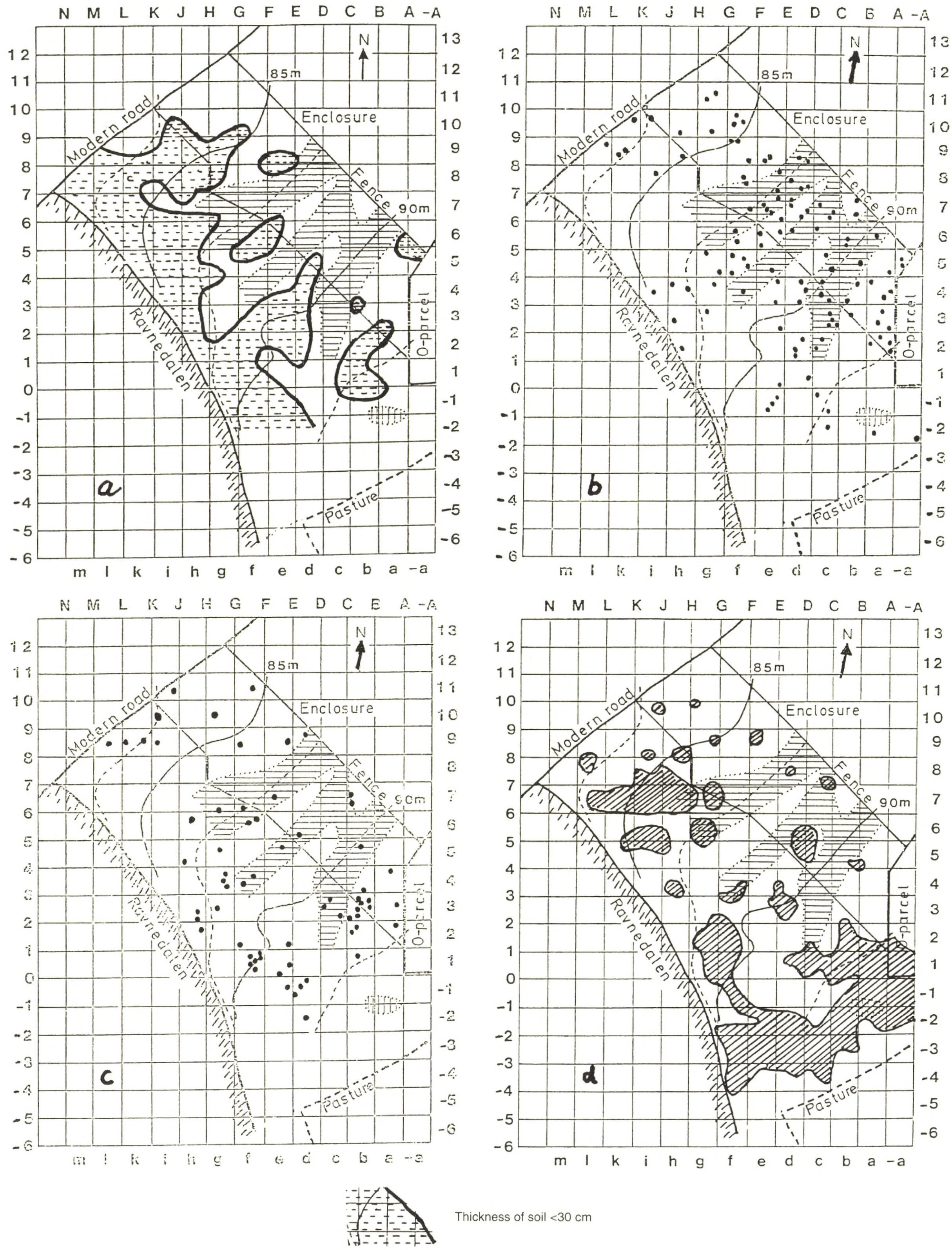
N M L K J H G F E D C B A -A
m l k i h g f e d c b a -a
N
85m
90m
Modern road
Enclosure
Fence
Ravnedalen
O-parcel
Pasture
a
b
c
d
Thickness of soil <30 cm

TABLE 5

Knægten

Depth of soil in the transect	1986 n	%
0-3 cm	31	11.8
4-9 cm	22	8.4
10-19 cm	48	18.3
20-29 cm	56	21.3
30-39 cm	28	10.6
40-49 cm	12	4.6
50-59 cm	18	6.8
60-69 cm	22	8.4
70-79 cm	17	6.5
80-89 cm	5	1.9
90-100 cm	4	1.5
$\bar{m}$ = 31.3 cm (SE 2.9)	263	100.1

Table 5. Distribution of soil thickness in the transect in the A1 area.

points had 0-29 cm soil, with about 20% to each of the three groups 0-9, 10-19, and 20-29 cm. 22% had a thickness of 30-59 cm, and in 18% of the samples the soil layers were 60-100 cm thick.

The map (fig. 20a) is based on the measurements in the corners of the squares and shows the distribution of areas with soil depths of 0-29 cm and ≥30 cm. The map must be taken with some reservations, as the variation of soil thickness is locally very great, because the granite surface is very uneven with many broad as well as narrow fissures. Detailed measurements in the transect showed that there were several local deviations. However, in broad outline the map is usable. This is confirmed by the fact that bare rocks are very common in the areas indicated as having a thin layer of soil, and they are almost missing in the other part of the map. The map is also in relatively good accordance with the depths measured for every metre along the transect (fig. 19).

Figs. 20a-d show the soil depth and the distribution of *Quercus* and *Betula* (1985) and conifers (1967). The maps show that conifers (mainly *Pinus*) were mostly found on thin layers of soil, while *Quercus* and *Betula* were found on thicker soil. The other deciduous trees (*Populus tremula, Sorbus intermedia, Carpinus betulus* and *Cerasus avium*) had also germinated in areas with thicker layers of soil.

◄ Fig. 20.
a. The thickness of the soil in the A1 area based on measurements at the square corners. Because of the local variation in soil thickness the map must be taken with some reservations. In both categories of thickness there are small areas which should have been indicated by the other signature.
b. The maximal distribution of *Quercus robur*, based on stumps from trees felled in 1986.
c. The same for *Betula pendula*.
d. The maximal distribution of *Pinus sylvestris* based on the airphoto from 1967.

b. Chemical conditions

In 1986 soil samples were taken at 10 different places in the transect and analysed chemically.

Table 6 shows the results. 5 of the 6 plant communities in the transect are represented. Furthermore the results from comparative investigations are shown, namely from an earlier investigation in part 687 (Bülow-Olsen 1975) and from part 690 in 1984 and 1986 (Mikkelsen 1991).

The measurements from 1975 were entirely or partly from areas which had been cultivated as fields as late as the 1950s. This may possibly explain the differences between this grassland and the results for the communities in the transect from 1986. The possible supply of lime to the cultivated field may explain the higher pH and the higher content of Ca and P in the samples from 1975. That this may be so is indicated by the content of nutrients of a limed common at Tjørnestykket on Sealand (Mikkelsen 1989,

TABLE 6

		pH	lt	Ca	Mg	K	Na	P	n
Knægten A1 area 1986									
1. Calluna heath	0-4 cm	3.5	494	6.9	3.5	1.0	0.7	15	2
–	7-15 cm	3.7	204	0.9	0.6	0.2	0.3	9	2
2. Vaccinium com.	0-4 cm	3.9	338	6.7	2.6	1.1	0.4	13	4
–	7-15 cm	3.4	90	1.3	0.6	0.2	0.3	8	4
4. Grassland, thick soil	0-4 cm	4.0	289	4.6	2.2	0.8	0.5	9	2
–	7-15 cm	4.1	76	0.8	0.5	0.1	0.3	10	2
5. Carex nigra com.	0-4 cm	3.6	285	2.7	1.2	0.5	0.6	14	1
–	7-15 cm	3.8	95	1.1	0.6	0.1	0.4	17	1
6. Poa nemoralis com.	0-4 cm	4.6	181	6.7	1.4	0.3	0.4	8	1
–	7-15 cm	4.6	138	4.4	1.1	0.2	0.4	7	1
Knægten 1975									
Grassland	0-10 cm	6.1	-	6.5	0.6	0.2	0.1	24	-
Habbedam 1984 and 1986									
Calluna heath,	mor	3.9	471	3.1	1.5	0.6	0.6	11	16
–	sand	4.5	128	0.4	0.2	0.1	0.4	7	16
Vaccinium com.,	mor	4.0	497	3.2	1.7	0.5	0.6	4	1
–	sand	4.7	108	0.3	0.2	0.0	0.5	6	1
Calluna-Molinia com.,	mor	3.5	577	1.4	1.0	0.8	0.5	5	2
–	sand	3.9	52	0.4	0.6	0.1	0.4	5	2

Table 6. Chemical analyses of soil samples from Knægten 1986 compared to analyses from Knægten 1975 (Bülow-Olsen 1975) and Habbedam (Mikkelsen 1991). Ca, Mg, K, Na, and Mn in meq/100 g soil. P in ppm. Conductivity (lt) in µmho.

tab. 3) being almost identical with the results from 1975.

Regarding Mg, K, and Na the results from 1986 in the 0-4 cm layer were higher than the results from 1975, which were more equal to the values from 7-15 cm. This may be due to the fact that the samples from 1975 include the upper 10 cm. However, it cannot be excluded that the nutrients in the former lime fertiliser could have been removed from the fields by the harvesting of the former crops.

The communities on dry ground (communities 1, 2, and 4) in the higher part of the transect were all characterized by relatively high values for Ca, Mg, and K. The lower situated *Poa nemoralis* community (community 6) had an equally high value for Ca but less Mg and K.

The content of Ca and Mg was lower in the *Carex nigra* community on wet ground (community 5), but the value for P was relatively high.

A comparison between the *Calluna* and *Vaccinium* communities in the Knægten area (the A1 area) and the Habbedam area (the B area) showed that the values for Ca, Mg, and K were almost twice as high at Knægten as those from Habbedam. The content of Ca in the *Carex nigra* community at Knægten was also twice as high as in the *Calluna-Molinia* community at Habbedam. The content of P was mostly higher at Knægten than at Habbedam.

c. Humidity of the soil

The humidity of the soil varies much during the year. In the period from November 1986 to October 1991 the level of ground water was measured several times every year in a perforated iron tube placed in a depression dominated by *Carex nigra* (community 5 in the transect fig. 19). Most of the measurements took place from spring to autumn. Fig. 21 shows

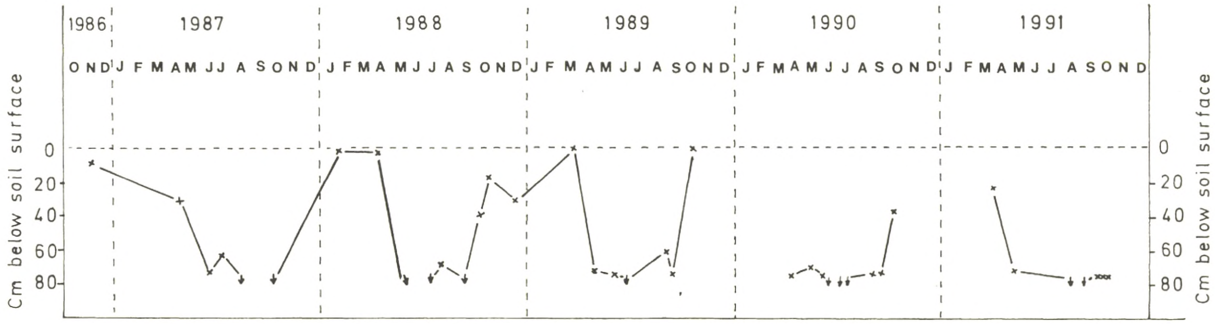

Fig. 21. Variation from November 1986 to October 1991 of the water level measured in a perforated iron tube placed in a depression in the transect dominated by *Carex nigra* (cf. fig. 19, community 5).

that from the end of October to the beginning of spring the level of the water was close to the surface of the soil, i.e. the soil was very wet. From April/May to the beginning of October, i.e. in the growing season, the level of the water was 70-80 cm below the surface, i.e. the upper layers of the soil were dried up.

The thin soil layers in the area are most exposed to drying up, and in warm summers they are in danger of erosion due to the grazing sheep. Since 1986 this has resulted in many rock surfaces becoming bare.

3. Distribution of species according to thickness of the soil

In table 7 the analyses of the vegetation in the transect have been divided into 4 categories according to the thickness of the soil, namely: ≥20, 14-10, 9-4, and 3-0 cm.

The degree of cover of the whole vegetation was highest on the thickest layer of soil, where it was 78.7%, and decreased evenly to the thinnest soil layers with 35.0% on soil of 0-3 cm. On the other hand the degree of cover for areas without vegetation (bare rocks and bare soil) increased from 4.4% on soil ≥20 cm to 48.8% on layers 0-3 cm.

The layers of soil which cover the surface of the granite are the only places where water from wetter periods can be preserved for drier periods. Thick soil layers are able to contain much more water than thin layers. The soil materials are rather uniform. Therefore soil thickness undoubtedly reflects greater or smaller water retention capability. As the ability of the species to stand drying out is different, most likely competitive power and distribution depend on the water retention of the soil.

Most of the investigated species were found on all thicknesses of the soil, but they were only abundant within certain soil thicknesses.

The plant species can be divided approximately into 3 groups: a. species with the greatest cover on soil ≥10 cm, b. species preferring soil ≥4 cm, and c. species on all thicknesses of soil.

a. Species with the greatest cover on soil ≥10 cm

TREES. All deciduous trees are unified in one group in table 7. In the area the trees were represented by seedlings, root-suckers and shoots from stumps with a maximum diameter of a couple of cm. The species represented are: *Betula pendula* (n=16), *Carpinus betulus* (n=20), *Populus tremula* (n=20), *Quercus robur* (n=19), *Salix* sp. (n=5), and *Sorbus intermedia* (n=2). Among those 82 individuals only 1 *Carpinus* and 1 *Populus* were found on soil layers thinner than 10 cm.

TABLE 7

Knægten 1986 % cover

Soil in cm	≥ 20	19-10	9-4	3-0	n of indiv.
n of samples	165	46	21	31	
1 Trees	3.6	1.4	0.2	–	82
Juniperus communis	2.6	–	1.8	–	11
Carex nigra	3.7	1.9	–	–	11
Hypochoeris radicata	1.0	0.3	0.1	0.1	30
Luzula multiflora	1.2	0.7	–	0.1	36
Poa pratensis	0.6	0.9	–	–	13
2 Calluna vulgaris	4.6	5.0	1.3	0.1	27
Agrostis tenuis	1.7	4.9	3.9	0.2	44
Anthoxanthum odoratum	1.0	0.9	0.6	0.1	43
Poa nemoralis	2.9	4.5	5.0	0.1	35
Viola canina	0.4	1.2	0.9	–	23
3 Lonicera periclymenum	1.6	2.5	2.0	0.6	83
Rubus idaeus + fruticosus	3.4	6.3	2.8	1.6	102
Vaccinium myrtillus	12.9	5.1	0.1	4.2	74
Carex pilulifera	1.8	2.9	0.4	0.4	38
Deschampsia flexuosa	29.2	21.0	30.1	21.8	234
Festuca ovina	1.0	3.1	2.4	2.0	17
Holcus lanatus	0.8	1.8	0.3	0.6	18
Rumex acetosella	1.4	3.4	1.6	1.1	44
Other herbs	2.1	2.5	1.3	1.4	
Bryophytes and Lichens	1.2	0.3	–	0.6	
Σ Vegetation	78.7	70.6	54.8	35.0	
Bare rock and soil	4.4	6.8	12.8	48.8	

Table 7. Distribution of species by soil thickness. Trees include the following species with similar distribution: *Betula pendula, Carpinus betulus, Populus tremula, Quercus robur, Salix sp.*, and *Sorbus intermedia*.

The distribution of the stumps of *Quercus* and *Betula* felled in 1986 is shown on figs. 20b and 20c. A comparison with the map of soil thickness, fig. 20a, indicates that most of these trees had germinated and developed on thick layers of soil.

The distribution of *Betula* and *Quercus* according to depth of soil was also investigated in part 690, the Habbedam area (Mikkelsen 1991, tab. 15). Most of the individuals were found on thicker soil in this area as well.

Juniperus communis. Only 11 of the Raunkiær-circles in the transect contained this species, and in many cases the density recorded was measured on shoots from larger shrubs in the neighbouring area. So table 7 does not yield reliable information for *Juniperus.* In April 1991 the depth of the soil was measured for 51 small juniper plants, most of which had germinated between 1986 and 1990 in the A1 area (table 8). The table shows that 45 plants (88%) had germinated on soil ≥20 cm, while only 1 (2%) on soil ≤9 cm and 5 (10%) on soil 10-19 cm. In September 1992 27 older junipers were felled (tab. 8). Among these 19 (71%) were found on soil ≥20 cm and 8 (30%) on soil 10-19 cm.

The maps, fig. 11, show the distribution of *Juniperus communis* in 1986 and 1991. A com-

TABLE 8

	Young Junipers (1-5 years)					Old Junipers (18-82 years)				
	Height in cm			n	%	Diameter in cm			n	%
Soil	10-19	20-39	40-60			≤ 5	6-9	10-15		
4-9 cm	–	1		1	2	–	–	–	–	–
10-19 cm	1	4		5	10	3	2	3	8	30
20-39 cm	4	16	8	28	55	2	5	4	11	41
40-70 cm	2	6	9	17	33	2	3	3	8	30
n	7	27	17	51		7	10	10	27	

Table 8. Distribution of *Juniperus communis* germinated in the A1 area by thickness of the soil.

parison between the distribution of juniper in 1986 and the map of the thickness of the soil (fig. 20a) shows that *Juniperus* was mostly found in areas with thinner soil. However, thicker layers of soil are also found in these areas, and very often the old junipers were found in fissures in the rock filled with earth.

While numerous young junipers germinated in a period with sheep grazing, most of the older junipers germinated in a period without sheep grazing (cf. table 1). However, especially in areas with bare rocks, natural erosion can produce bare soil, which like sheep grazing favours the germination of junipers. Undoubtedly the heavy storm in October 1967 also favoured the germination of junipers in this area.

The distribution of trees and shrubs in the A1 area according to depth of soil shows that the overgrowing of the former common started on thick layers of soil. The same was the case in part 690, where the overgrowing started in depressions with thick layers of soil and formed shelter belts which in turn helped further overgrowing (Mikkelsen 1991, fig. 7 and p. 47).

Trees and shrubs have good possibilities of germinating and competing with dwarf shrubs and herbs and developing on thick layers of soil. This undoubtedly is the reason why most of the valleys in the heaths on Bornholm are covered with shrubs and forest.

Carex nigra. In the transect this species is found only in a depression with a 50-60 cm thick layer of soil in most places. During winter the depression is very often inundated. The species dominates in the centre of the depression.

The three other species in group 1: *Hypochoeris radicata, Luzula multiflora,* and *Poa pratensis* seem to be unable to manage competition on soil layers ≤10 cm.

b. Species preferring soil ≥4 cm

Calluna vulgaris had the highest degree of cover on soil ≥10 cm in the A1 area, but the cover was also relatively high on soil of 9-4 cm, as was the case in the heath in part 690. On soil layers of 3-0 cm there was some difference between Knægten (the A1 area) and Habbedam (part 690). On thin soil layers, *Calluna* is very sensitive to drying out in warm and dry periods (cf. Mikkelsen 1991, p. 31 and tab. 10). Therefore, in Habbedam the density varied according to the fluctuations in the weather, but was still higher than in Knægten. This may be connected with the fact that there are many more competing species on thin layers of soil in Knægten than in Habbedam.

Anthoxanthum odoratum behaved in the same manner as *Calluna* in the A1 area.

Agrostis tenuis, Poa nemoralis, and *Viola canina* were most abundant on soil of 19-4 cm. The degree of cover was less on soil ≥20 cm, and very small on soil 3-0 cm.

c. Species on all thicknesses of soil

Deschampsia flexuosa was the most common species in the area. The degree of cover in the four categories of soil thickness varied between 21 and 30. So the distribution seems not to be dependent on the soil thickness. Conditions in the heath on rocky ground are almost the same, but it seems that the species managed better on soil ≤10 m than on thicker soil (Mikkelsen 1991, tab. 10)

Festuca ovina, Holcus lanatus, and *Rumex acetosella* showed no real differences in the degree of cover in the four categories of soil thickness.

Lonicera periclymenum, Rubus idaeus, and *R. fruticosus* all have fair degrees of cover on the thin layers of soil, but the degree of cover was greater on the thicker soil, where they seemed to thrive better, but they also managed to survive on the thinnest soil layers.

Vaccinium myrtillus was found in places on thick as well as on thin layers of soil, like the results from part 690 (Mikkelsen 1991, tab. 15).

Carex pilulifera thrived best in the A1 area on soil ≥ 10 cm, but was also found on the thinner soil layers. In part 690 55% of the tufts were found on soil 9-4 cm, while the rest were almost equally distributed on the three other categories (Mikkelsen 1991, tab. 16).

4. The plant communities

The plant communities investigated in 1986 to 1992 in the A1 area are part of the previous succession which is still going on in the area.

a. History

The A1 area has been a grazed heath from about AD 1200. But at the end of the 19th century the grazing decreased or stopped entirely, and the overgrowing started in the beginning with scattered groups of deciduous trees. Later self-sown *Pinus sylvestris* appeared. After 1967 most of the A1 area was covered by forest, which was felled in March 1986, so the forest period lasted less than 100 years.

Of course the ground flora changed during the forest period, but remains of the heath vegetation perpetuated together with the ground flora of the forest. The felling in 1986 and the nature conservation management started a new succession. The investigations in 1986-1992 give some suggestions as to future development, but the final result of the conservation management will not be seen for several years.

b. The influence of the season on the results of the vegetation analyses

In 1986 and 1991 the vegetation analyses were made in August and should be comparable. In a grazed area the vegetation at a fixed date (here the month of August) may vary somewhat from year to year. A wet and warm spring and early summer may produce better growth, so it takes a longer time for the sheep to graze down the vegetation. When there is abundant food, the sheep are highly selective in their choice of which plants they eat first. Because of that the aspect of the area at a given time of year (e.g. August) can be somewhat different from year to year. This is of importance for the evaluation of the two kinds of vegetation analyses which were made, namely analyses of frequency and degree of cover.

The frequency analyses are based on the presence or absence of species represented by shoots with renewal buds inside the Raunkiær circles. Therefore, the frequencies found were not dependent on the grazing intensity. On the other hand the analyses of degree of cover were dependent on the grazing. Grazing reduces the degree of cover, and in a period with plenty of food, the species not preferred by the sheep will get a higher degree of cover than in

TABLE 9

Plant communities	1		2		3		4		5		6	
	1986	1991	1986	1991	1986	1991	1986	1991	1986	1991	1986	1991
Trees and shrubs	10.9	17.1	3.4	8.7	3.3	3.1	3.3	0.2	1.2	–	10.1	7.6
Rubus spp.	0.1	0.1	4.4	6.1	1.3	1.9	1.8	2.1	–	–	13.4	13.7
Calluna vulgaris	24.5	17.6	0.3	0.1	0.4	0.3	–	–	1.2	0.9	–	–
Vaccinium myrtillus	0.2	0.1	36,3	14.5	+	0.2	–	–	0.6	0.6	1.2	0.7
Grasses	34.9	36.5	27.5	66.5	40.1	43.8	49.6	66.9	13.3	12.0	34.5[1]	52.9[2]
Other herbs	12.1	10.4	4.1	10.3	4.1	5.1	8.0	14.0	67.4[3]	81.6[4]	10.8	10.2
Bryophytes	2.4	2.4	+	0.2	0.3	0.1	0.1	–	–	–	–	–
Lichens	1.8	0.6	–	+	0.2	0.6	–	0.1	–	–	–	–
Total of vegetation	88.1	90.0	76.0	106.4	49.7	55.1	62.8	83.3	83.7	91.1	70.0	85.1
Bare soil and rock	1.5	5.9	8.7	3.3	25.8	35.8	3.1	0.7	1.2	–	9.7	2.9
Thickness of soil $\bar{m}$	39		45		8		45		47		21	
n	40		66		69		45		10		33	34

1) Poa nemoralis 24.2, 2) P. nemoralis 18.9, 3) Carex nigra 66.2, 4) Carex nigra 78.6

Table 9. Survey of the plant communities in the transect based on the degree of cover (in %) for the important elements of the vegetation in 1991.

periods with less food. So it is not possible to demonstrate all the changes in vegetation from 1986 to 1991 by changes in the degree of cover alone. Only if changes in cover and frequency are parallel do they indicate changes in the vegetation during the period.

The analyses gave an impression of the influence sheep grazing had on some species. Species with a high degree of cover will have better chances the following year than species with a low degree of cover.

c. The plant communities in the transect

In some periods during the year, such as just before grazing started, the vegetation in the A1 area looked rather uniform, but a closer investigation showed that the area contained a mosaic of communities.

The analyses of the vegetation showed that terrain, thickness of soil and the occurrence of some characteristic species formed a basis for a grouping of the different mosaic sections in the transect into 6 different plant communities.

Table 9 gives in broad outline a survey of the degree of cover for some species, groups of species, and areas without vegetation in these 6 plant communities.

Grass species dominated all the communities, except community 5, which is dominated by *Carex nigra*. In communities 1-4 *Deschampsia flexuosa* and *Agrostis tenuis* are the dominating grasses, and in community 6 it is *Poa nemoralis*. In community 1 *Calluna vulgaris* is also very common, and in community 2 *Vaccinium myrtillus* is dominating together with the grasses. Communities 3 and 4 are both dominated by grasses, but differ from each other because community 3 is found on thin layers of soil and has several places with bare rock and soil, while community 4 has thicker layers of soil and very few areas without vegetation.

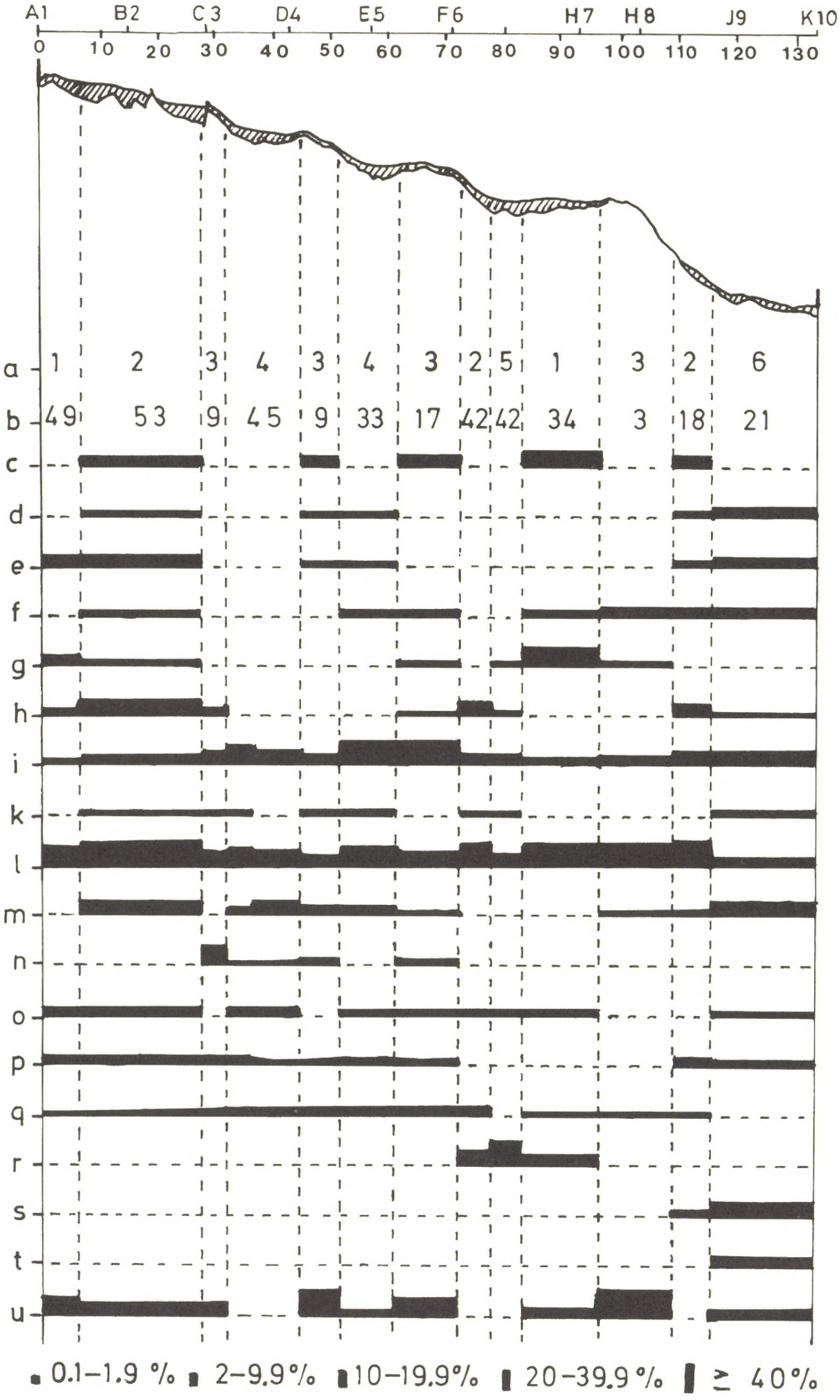

Fig. 22. The distribution of the most common species in the transect indicated by their density percentage in the different plant communities (1-6) measured in 1991. 1. *Calluna*-heath, 2. *Vaccinium*-com., 3. Grassland on thin soil, 4. Grassland on thicker soil (ancient fields?), 5. *Carex nigra*-com., 6. *Poa nemoralis*-com.
a. plant communities, b soil thickness (m̄), c. *Juniperus communis*, d. *Lonicera periclymenum*, e. *Rubus idaeus*, f. *Rubus fruticosus*, g. *Calluna vulgaris*, h. *Vaccinium myrtillus*, i. *Agrostis tenuis*, k. *Anthoxanthum odoratum*, l. *Deschampsia flexuosa*, m. *Holcus lanatus*, n. *Festuca ovina*, o. *Luzula multiflora*, p. *Hypochoeris radicata*, q. *Rumex acetosella*, r. *Carex nigra*, s. *Poa nemoralis*, t. *Hypericum perforatum*, u. area without vegetation.

Fig. 22 shows the degree of cover of some of the species in the different sections of the 6 communities in the transect.

Only very few species, e.g. *Hypericum perforatum,* were found only in a single community. Some species, e.g. *Agrostis tenuis* and *Deschampsia flexuosa,* were found in all communities, but with highly variable frequency and degree of cover. Species with a high frequency in one community, e.g. *Calluna vulgaris* and *Vaccinium myrtillus,* were also found in the neighbouring community. *Anemone nemorosa* was mostly missing in the August analyses, but in May 1992 it was rather common partly in the southern and partly in the northern part of the transect, while it was very rare in the middle part of the transect (42 to 110 m from the southern end of the transect, fig. 19).

The reason for this rather disorderly condition was probably that the vegetation in the transect was still unstable in the period 1986-1991. The succession heath-forest-open land may not yet have reached a stable level. Even if the nature conservation management is continued in the same way, it will most likely be several years before we have stable vegetation for some time.

The plant communities were not mapped, but the limits between the different communities along the transect are shown on the map fig. 23.

d. Survey of the plant communities

The 6 characteristic plant communities along the transect (cf. fig. 23) are: 1. *Calluna* heath, 2. *Vaccinium* community, 3. Grassland on thin layers of soil, 4. Grassland on thicker layers of soil, 5. *Carex nigra* community, and 6. *Poa nemoralis* community.

Calluna heat (community 1)

The community is found in areas with relatively thick layers of soil. The maps of the distribution of the forest from about 1900 to 1986 (figs. 7 and 9) show that along the transect (fig.

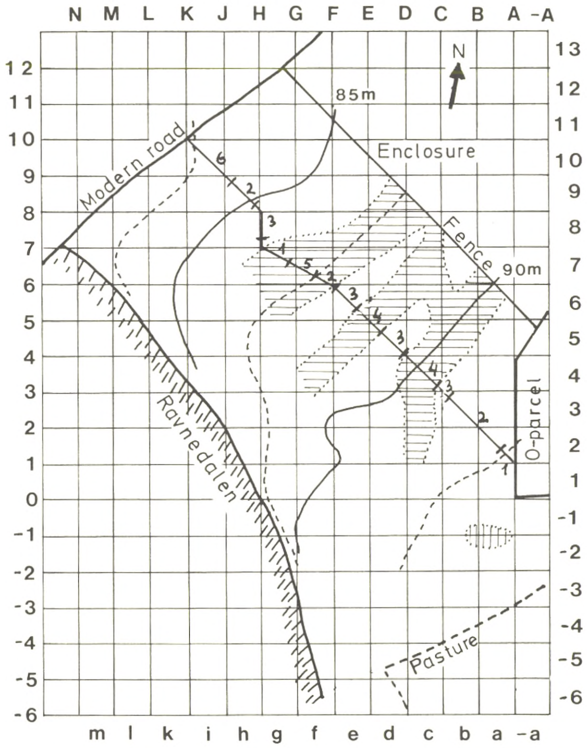

Fig. 23. The location of the plant communities along the transect in the A1 area. The plant communities have the same numbers as in fig. 22.

23) the *Calluna* heath was found in areas originally without deciduous trees, but from about 1916 (cf. tab. 1) the former *Calluna* heath was overgrown by *Pinus sylvestris,* which dominated the areas until most of the pines were overturned in 1967.

Two sections in the transect, fig. 19, are characterized by *Calluna* vulgaris, namely: a. an area close to the 0-parcel and b. the northernmost part of the high plateau. The average soil thickness was 39 cm.

The contents of the nutrients Ca, Mg, and K in the soil were large compared with the contents in the soil of the *Calluna* heath in part 690 (cf. table 6) and other heaths both on Bornholm and in Jutland (cf. K. Hansen 1976, tabs. 13-15.)

TABLE 10

1. Calluna heath	Frequency 1986	Frequency 1991	Cover (%) 1986	Cover (%) 1991
Betula pendula	23	30	3.0	8.0
Populus tremula	8	10	0.5	0.4
Quercus robur	13	–	0.4	–
Juniperus communis	10	10	7.0	8.7
Rubus idaeus	20	–	0.7	–
Rubus fruticosus	5	3	0.3	0.1
Calluna vulgaris	48	75	25.4	17.6
Vaccinium myrtillus	5	3	0.2	0.1
Aira praecox	–	8	–	0.2
Agrostis tenuis	5	28	0.2	1.4
Anthoxanthum odoratum	30	–	0.3	–
Campanula rotundifolia	–	3	–	0.1
Carex nigra	3	10	1.6	6.4
Carex pilulifera	28	45	6.6	4.3
Deschampsia flexuosa	100	95	34.4	34.1
Hieracium umbellatum	–	5	–	0.2
Hypochoeris radicata	25	20	2.1	1.8
Juncus squarrosus	3	5	0.1	0.9
Luzula multiflora	18	25	1.4	1.4
Melampyrum pratense	–	5	–	0.2
Poa annua	–	5	–	0.6
Poa pratensis	–	5	–	0.2
Polypodium vulgare	3	–	0.2	–
Rumex acetosella	3	15	0.1	0.5
Dicranum scoparium	13	25	0.9	1.7
Hypnum cupressiforme	5	15	0.5	0.5
Polytrichum formosum	–	5	–	0.2
Polytrichum piliferum	18	–	1.2	–
Pseudoscleropodium purum	3	–	0.1	–
Cladonia cf. rangiferina	–	10	–	0.5
Cladonia spp.	28	3	1.8	0.1
Bare soil	8	20	1.5	5.9
n	40			
Thickness of soil, $\bar{m}$	39 cm			

Table 10. *Calluna* heath, A1 area, Knægten. Frequency (Raunkiær analyses) and degree of cover (in %).

Table 10 shows the results of the vegetation analyses in 1986 and 1991. The most dominating species was *Deschampsia flexuosa,* which also dominated in several of the other communities (cf. tabs. 10, 11, and 12). The characteristic species was *Calluna vulgaris,* which had relative high frequencies and percentages of cover both in 1986 and 1991. While the frequency of *Calluna* increased from 1986 to 1991, the degree of cover decreased. Undoubtedly this shift is due to grazing and the result of the fact that young shoots of heather are preferred by the sheep, while *Deschampsia flexuosa* is only eaten when there is no other food.

Like *Deschampsia, Agrostis tenuis* belongs to those species which the sheep delay eating, and in most of the A1 area *Agrostis tenuis* increased in the period 1986 to 1991. However, in the *Calluna* heath the increase was low compared to the other communities.

Another remarkable change was the increase of naked soil. This was caused by the much used sheep paths (cf. fig. 24). The whole A1 area is crossed by sheep paths, both main roads and less used paths. In those which are most used there are periods with naked soil, and they are also the localities for species new to the community in 1991, e.g. *Aira praecox* and *Poa annua.*

The degree of cover for *Juniperus communis* increased. The reason for this was mainly a couple of old shrubs with vigorous growth in the transect. Furthermore, these shrubs had protected a couple of birches from the sheep, so *Betula pendula* also increased its degree of cover.

In the southern section of the *Calluna* heath (close to the 0-parcel) *Anemone nemorosa* is rather common in May and June. In May 1992 the frequency in this section was 50 and the degree of cover 3%, while the species was not found in the northern section.

In the A1 area the *Calluna* heath from the period of the Højlyngen was preserved until in the period between about 1936 and 1974 it was overgrown by *Pinus sylvestris.* However, the ground flora in the forest was still characterized by *Calluna.* The southern section was close to areas with deciduous forest, from which *Anemo-*

ne nemorosa has spread. The northern section had a greater distance to deciduous forest, which may explain the absence of *Anemone.*

Vaccinium community (community 2)
The community was found partly in relatively even terrain, which before 1986 was covered by deciduous forest, and partly on north-facing slopes. The northernmost of these slopes was situated close to the deciduous forest to the north of J9 while the other placed NW of F6 on the map had no trees during the forest period (cf. fig. 7 and 9).

Three sections of the transect are classified as belonging to this community (cf. figs. 22 and 23). The terrain and to some degree the soil thickness are somewhat different in the sections, but the results of the vegetation analyses from August 1986 and 1991 showed no real differences between the vegetation in the three sections. On the other hand the May-June aspects did show some difference (cf. figs. 24 and 25). *Anemone nemorosa* is very common in the southern section (May 1992, frequency 67 and degree of cover 11.0%) as well as in the northern section (May 1992, frequency 86 and degree of cover 9.3%). In the middle section *Anemone* was not found.

The contents of nutrients (cf. tab. 6) and the thickness of the soil (average 45 cm) in the *Vac-*

Fig. 24. Part of the transect seen from the SE. The first stick is placed at B2 and the second at C3. In the foreground *Calluna* heath with a sheep path to the right. Beyond that is the *Vaccinium* community with scattered shrubs of *Juniperus* and stumps from felled trees. The limit between the *Vaccinium* community and the next (grassland on thin layer of soil) is close to C3, cf. fig. 26. V.M. phot. August 1986.

Fig. 25. The same locality as in fig. 24 photographed 30/4 1987. *Anemone nemorosa* is very common in the *Vaccinium* community. V.M. phot.

cinium community were not much different from the conditions in the *Calluna* heath. Until 1985 the southern section especially was covered by dense deciduous forest, and the two other sections also had some tree cover. They are located on north-facing slopes, which indicates a higher humidity in the soil than in the *Calluna* heath. The location of the southern section on a lower level than the *Calluna* heath in the sloping terrains also means that this area has a higher humidity than the *Calluna* heath. Undoubtedly the somewhat higher humidity favoured *Vaccinium* rather than *Calluna*.

Table 11 shows the results of the vegetation analyses in 1986 and 1991. In both years *Vaccinium myrtillus* had a frequency of 100, but the degree of cover decreased from 36.3% in 1986 to 14.5% in 1991. Undoubtedly this is connected with the fact that *Vaccinium myrtillus* is a species preferred by the sheep. In sheep-grazed areas the species is very often eaten down to a height of 10 cm. Most likely this is the reason for the increase of species such as *Deschampsia flexuosa* and *Agrostis tenuis* which are only eaten by hungry sheep.

Deschampsia flexuosa had a frequency of 100 in both years but the degree of cover increased from 26.9% in 1986 to 56.5% in 1991.

Agrostis tenuis also belongs to the last eaten species. In 1986 the frequency was 9 and the degree of cover 1.1%, and in 1991 the frequency was 44 and the degree of cover 4.7%.

TABLE 11

2. Vaccinium-com.	Frequency		Cover (%)	
	1986	1991	1986	1991
Betula pendula	3	3	0.3	0.1
Populus tremula	6	2	0.2	+
Quercus robur	5	2	0.3	+
Sorbus aucuparia	–	3	–	0.1
Juniperus communis	2	9	1.3	4.3
Lonicera periclymenum	42	18	2.3	0.6
Rubus idaeus	36	30	4.0	6.0
Rubus fruticosus	5	6	0.4	0.1
Calluna vulgaris	5	5	0.3	0.1
Vaccinium myrtillus	100	100	36.3	14.5
Agrostis tenuis	9	44	1.1	4.7
Anemone nemorosa	2	–	+	–
Anthoxanthum odoratum	2	8	+	0.3
Carex nigra	–	5	–	1.7
Carex pilulifera	20	5	2.5	1.4
Cerastium fontanum	–	15	–	0.5
Dactylis glomerata	+	–	+	–
Deschampsia flexuosa	97	100	26.9	56.5
Dryopteris felix-mas	–	2	–	+
Festuca rubra	–	5	–	0.1
Holcus lanatus	6	24	0.4	4.8
Hypochoeris radicata	5	50	0.1	2.9
Lactuca muralis	2	–	+	–
Luzula multiflora	24	55	1.1	2.7
Melampyrum pratense	6	2	0.2	+
Poa nemoralis	3	–	0.1	–
Poa pratensis	6	6	0.1	0.1
Potentilla erecta	2	8	0.2	0.1
Ranunculus acris	–	2	–	+
Rumex acetosella	2	33	+	1.2
Solidago virg-aurea	–	2	–	+
Taraxacum sp.	2	–	+	–
Thymus serpyllum	–	2	–	+
Veronica chamaedrys	–	3	–	0.1
Viola canina	+	2	+	+
Dicranum scoparium	3	3	+	0.2
Cladonia spp.	–	3	–	+
Bare soil	23	3	6.8	0.1
Bare rock	3	5	1.9	3.2
n	66			
Thickness of soil, $\bar{m}$	45 cm			

Table 11. *Vaccinium* community, A1 area, Knægten. Frequency (Raunkiær analyses) and degree of cover (in %).

Juniperus communis is also avoided by the sheep, and the old shrubs in the community grew perceptibly, and the degree of cover had increased from 1.5 to 4.3%. Furthermore, several seedlings were established, so the frequency increased too.

Both frequency and degree of cover had increased for the following species: *Holcus lanatus, Hypochoeris radicata, Luzula multiflora,* and *Rumex acetosella.* These species are eaten by the sheep before *Deschampsia* and *Agrostis,* but do not belong to the most preferred species.

The increase of *Carex nigra* was caused by the spreading of the species from the *Carex nigra* community to the neighbouring areas of the *Vaccinium* community.

A real decrease in frequency and degree of cover was also found for the species *Lonicera periclymenum* and *Carex pilulifera.* The tufts of *Carex pilulifera* are very often eaten down early in the season. *Lonicera* also decreased in other communities in the transect (cf. tab. 12 and 13).

Another result of the conservation management was most likely the increase in the number of new species of phanerogams in the community from 26 to 30.

Areas without vegetation covered 8.7% in 1986 and 3.3% in 1991. In 1986 they were mostly naked soil, but in 1991 they were mostly bare rock. Most places in the community have a thick layer of soil ($\bar{m}$ = 45 cm), but there are some places with a thin layer of soil. On thicker soil sheep grazing hardly prevents a new cover of vegetation in places where the clearing produced naked soil, while thin layers of soil may be eroded by the combined effects of drying out in the summer and of traffic of the grazing sheep.

Grassland on thin layers of soil (community 3)
This community differs from the next by a more open vegetation, boulders and the occurrence of several drought-resistant species. The

Fig. 26. Part of the transect seen from the NW in August 1991. In the foreground is a section of the southernmost of the three depressions in the A1 area. The vegetation belongs to community 4 (grassland on thicker layers of soil). Between the depression and the stick (C3) is community 3 (grassland on thin layer of soil) with nude rocks and soil without vegetation. The part between the stick and the fence around the 0-parcel with high trees is covered by the *Vaccinium* community with shrubs of *Juniperus* and the grass *Deschampsia flexuosa,* which is still not eaten. V.M. phot.

maps in figs. 7 and 9 show that the area of community 3 contained very few trees during the forest period.

In the transect (fig. 19) the community is found along the limits of the three depressions (fig. 23). The layers of soil are usually very thin (average 8 cm), and there are many areas of bare rock (fig. 26).

Table 12 gives the results of the vegetation analyses in 1986 and 1991. The most obvious species were *Deschampsia flexuosa, Agrostis tenuis,* and *Festuca ovina.* In 1986 *Deschampsia* was the most dominant species with a degree of cover of 27.9% as against 5.7% and 4% for *Agrostis* and *Festuca.* In 1991 the degree of cover for *Deschampsia* had decreased to 15.7%, while *Agrostis* covered 20.2% in 1991. The cover of *Festuca* was almost equal in the two years.

The dominance of *Deschampsia* in 1986 was most likely caused by the fact that it had been established in areas which were open, while their neighbouring areas were covered by forest. *Anemone nemorosa* is absent from community 3.

Characteristic of the community is the abundant occurrence of areas without vegetation. In 1986 naked soil and bare rocks had a degree of cover of 13.0 and 12.8%, respectively. These degrees of cover increased in 1991 to 19.5%

TABLE 12

3. Grassland on thin layer of soil	Frequency		Cover (%)	
	1986	1991	1986	1991
Carpinus betulus	+	–	+	–
Populus tremula	6	–	0.2	–
Quercus robur	6	1	0.4	0.3
Juniperus communis	4	6	1.6	2.8
Lonicera periclymenum	17	1	1.1	+
Rubus idaeus	19	7	1.1	0.8
Rubus fruticosus	7	12	0.2	1.1
Calluna vulgaris	4	3	0.4	0.3
Vaccinium myrtillus	1	4	+	0.2
Aira praecox	–	6	–	0.7
Agrostis stricta	–	9	–	1.0
Agrostis tenuis	30	58	5.7	20.2
Anthoxanthum odoratum	4	3	0.4	0.3
Carex pilulifera	4	12	0.2	0.2
Cerastium fontanum	1	9	+	1.1
Dactylis glomerata	1	–	0.1	–
Deschampsia flexuosa	96	87	27.9	15.7
Festuca ovina	13	16	4.0	4.4
Festuca rubra	–	4	–	0.1
Holcus lanatus	7	13	1.7	1.0
Hypochoeris radicata	7	16	0.3	0.7
Juncus effusus	–	1	–	1.0
Luzula multiflora	1	4	0.3	0.1
Poa pratensis	4	9	0.3	0.4
Polypodium vulgare	4	–	0.1	–
Rumex acetosella	32	35	3.2	1.5
Spergularia rubra	–	1	–	+
Stellaria media	–	3	–	0.2
Taraxacum sp.	1	–	+	–
Veronica officinalis	1	3	+	0.3
Dicranum scoparium	1	1	+	0.1
Pseudoscleropodium purum	4	–	0.3	–
Cladonia cf. rangiferina	1	–	+	–
Cladonia spp.	3	17	0.2	0.6
Bare soil	57	61	13.0	19.5
Bare rock	28	38	12.8	16.3
n	69			
Thickness of soil, $\bar{m}$	8 cm			

Table 12. Grassland on thin layer of soil, A1 area, Knægten. Frequency (Raunkiær analyses) and degree of cover (in %).

and 16.3%, respectively. The combination of dry summers and sheep grazing caused the protruding rocks to become bare at the top and produced naked soil at the base of the rocks.

The increase in naked areas favoured the establishment of newly introduced species in the area: *Aira praecox, Agrostis stricta, Spergularia rubra,* and *Stellaria media,* all of which thrive well on thin soil or in rock fissures.

Cerastium fontanum is also favoured by grazing, but was mostly found on somewhat thicker layers of soil.

The continuous growth of *Juniperus* has produced, as in most other places, a moderate increase of the degree of cover.

Grassland on thicker layer of soil
(community 4)

The community covers the two southern depressions in the A1 area. They are characterized by a rather thick layer of soil ($\bar{m}$ = 39 cm) without big stones on the surface, because these were collected and placed in rows on the limits between communities 4 and 3. The areas of community 4 were probably used as fields in the last centuries BC, and the stone rows were placed along the boundaries of the fields. The southern border of the southernmost depression especially has the character of a field boundary.

About 1916 the overgrowing started in the areas, and in 1985 they were covered by deciduous trees. This is most likely the reason why *Anemone nemorosa* was still very common in the community in 1992.

The content of nutrients in the top soil in community 4 (table 6) differs from both the *Calluna* heath and the *Vaccinium* communities by having lower values for Ca, Mg, and K. However, the values are much higher than those of the common at Borup Gade (Mikkelsen 1989, tab. 3). The content of P is almost the same for community 4 and Borup Gade. However, if community 4 is compared with the artificially limed common at Tjørnestykket (l.c.), it is seen

TABLE 13

4. Grassland on thicker layer of soil (ancient fields?)	Frequency		Cover (%)	
	1986	1991	1986	1991
Populus tremula	22	–	1.3	–
Sorbus aucuparia	–	2	–	0.1
Juniperus communis	+	–	0.1	–
Lonicera periclymenum	40	4	1.9	0.1
Rubus idaeus	31	27	1.7	2.0
Rubus fruticosus	4	2	0.1	0.1
Agrostis tenuis	24	84	3.8	26.1
Anthoxanthum odoratum	51	20	4.0	0.9
Carex pilulifera	18	11	2.8	1.2
Cerastium fontanum	9	67	0.3	2.9
Deschampsia flexuosa	93	91	35.6	26.5
Festuca ovina	18	4	3.1	0.3
Festuca rubra	11	38	0.6	3.0
Hieracium umbellatum	4	2	0.1	0.1
Holcus lanatus	2	47	0.1	5.8
Holcus mollis	–	7	–	0.5
Hypochoeris radicata	22	56	0.8	2.9
Luzula multiflora	27	36	1.3	1.3
Poa annua	2	2	0.2	0.4
Poa pratensis	11	18	2.2	3.4
Rumex acetosella	38	78	2.6	4.8
Taraxacum sp.	2	2	0.1	0.1
Veronica officinalis	–	18	–	0.7
Pseudoscleropodium purum	2	–	0.1	–
Cladonia spp.	–	4	–	0.1
Bare soil	13	7	3.1	0.7
n	45			
Thickness of soil, $\bar{m}$	39 cm			

Table 13. Grassland on thicker layer of soil, A1 area, Knægten. Frequency (Raunkiær analyses) and degree of cover (in %).

that on this common the values for Ca and P are much higher, while the contents of Mg and K are less. As part of a common community 4 can be noted as rather rich in nutrients.

Table 13 shows the results of the analyses of the vegetation in 1986 and 1991. The vegetation was dominated by grasses. In 1986 *Deschampsia flexuosa* had a frequency of 93 and covered 35.6%. *Agrostis tenuis, Anthoxanthum odoratum, Festuca ovina,* and *Poa pratensis* had degrees of cover between 4 and 2%. Other common species were *Carex pilulifera, Hypochoeris radicata, Luzula multiflora,* and *Rumex acetosella* together with *Populus tremula* (root suckers), *Lonicera periclymenum,* and *Rubus idaeus.*

In 1991 the grasses still dominated, but the species composition had changed. *Deschampsia* preserved its high frequency (91), but its degree of cover had decreased to 26.5%, while *Agrostis tenuis* had increased to a frequency of 84 as against 24 in 1986 and the degree of cover had increased from 3.8% to 26.1%, i.e. similar to *Deschampsia. Anthoxanthum* and *Festuca ovina* had decreased, while *Poa pratensis* had increased somewhat. In 1986 *Festuca rubra* and *Holcus lanatus* covered rather little, but in 1991 their degree of cover had increased to 3.0% and 5.8%, respectively.

Cerastium fontanum was not common in 1986, but it increased to a frequency of 67 and a degree of cover of 2.9% in 1991. *Hypochoeris radicata* also increased and in 1991 had a frequency of 56 and a degree of cover of 2.9%. *Rumex acetosella* increased to a frequency of 78 and a degree of cover of 4.8%.

Carex pilulifera possibly decreased slightly, while the occurrence of *Luzula multiflora* had not changed.

As in the other sheep-grazed areas, the root-suckers of *Populus tremula* died out during the period.

Lonicera periclymenum decreased, while the occurrence of *Rubus idaeus* stayed almost constant.

As in other areas with thicker layers of soil, the degree of cover for naked areas decreased. One of the reasons for this may be the spreading of *Cerastium fontanum.*

In the period 1936 to 1985 the depressions were overgrown by deciduous trees. The many *Anemone nemorosa* in the spring aspect of community 4 (May 1992: frequency 52, degree of cover 4.6%) undoubtedly originate from this period.

The changes in the vegetation from 1986 to

1991 indicate a succession from a ground flora of a forest dominated by *Deschampsia flexuosa* and a rich occurrence of *Lonicera periclymenum* and *Anemone nemorosa* to an open, grazed common characterized by *Agrostis tenuis, Festuca rubra,* and *Poa pratensis.*

Carex nigra community (community 5)

This community is located where the transect crosses the western part of the northern depression. This area is somewhat lower than the other part of the depression. There is no outlet from the depression, and during autumn and winter the water level rises to about the surface of the soil (cf. fig. 21). During several winters there was a free water surface in the lowest part of the depression. The area contained no trees in the period before 1986.

The *Carex nigra* community grew on a relatively thick layer of soil ($\bar{m}$ = 47 cm). Regarding the content of nutrients (table 6) the values for Ca, Mg, and K were lower than in the former 3 communities, while the content of P was the same. Compared with the community on wet ground in part 690, the contents of Ca and P were much higher in the *Carex nigra* community, while the contents of Mg and K were the same in the two areas.

The community (table 14) was dominated by *Carex nigra* with a frequency of 100 in 1986 as well as in 1991. The degree of cover was very high: 66.2% in 1986 and 78.6% in 1991.

The increase of *Carex nigra* was found not only in this community, but from 1986 to 1991 this species had also spread into the neighbouring communities; the *Calluna* heath to the north and the *Vaccinium* community to the south. The reason for the increased growth of *Carex nigra* was probably that the clearings of trees and shrubs in the depression had reduced evaporation, so that the humidity of the soil had increased.

Only *Deschampsia flexuosa* also had a high frequency (90) and degree of cover (12.7%) in

TABLE 14

	Frequency		Cover (%)	
5. Carex nigra-com	1986	1991	1986	1991
Betula pendula	20	–	0.6	–
Quercus robur	10	–	0.6	–
Calluna vulgaris	20	10	1.2	0.9
Vaccinium myrtillus	10	20	0.6	0.6
Agrostis tenuis	20	70	0.6	2.7
Anthoxanthum odoratum	–	10	–	0.3
Carex nigra	100	100	66.2	78.6
Deschampsia flexuosa	90	100	12.7	9.0
Luzula multiflora	–	20	–	1.2
Potentilla erecta	–	10	–	0.9
Rumex acetosella	20	–	1.2	–
Bare soil	20	–	1.2	–
n	10			
Thickness of soil, $\bar{m}$	47 cm			

Table 14. *Carex nigra* community, A1 area, Knægten. Frequency (Raunkiær analyses) and degree of cover (in %).

1986. *Agrostis tenuis* had a frequency of 20 and a degree of cover of 0.6% in 1986, but increased in the period to a frequency of 70 and a degree of cover of 2.7% in 1991; possibly at the expense of *Deschampsia,* whose degree of cover decreased from 12.7% in 1986 to 9.0% in 1991.

In 1986 some seedlings of *Quercus* and *Betula* were found in the community, but they did not survive during the following years. No seedling established itself as a tree in this depression (cf. fig. 9) in the period when the A1 area mostly was covered with trees. *Anemone nemorosa* was not found in the *Carex nigra* community.

The naked soil found in 1986 became covered by vegetation, and the total cover of the vegetation increased from 87.7% in 1986 to 94.2% in 1991.

The *Poa nemoralis* community (community 6)

The community covers the northern part of the transect. The level of the area is 5 m lower than the plateau containing the 5 other communities (cf. fig. 19). The community is located in a depression close to the spot where the two glens, Ravnedalen and Buggedal, cross the third glen Finnedalen. The depression in the A1 area has never been cultivated, as the many boulders bear witness (cf. fig. 27). The low-lying area N of the community which slopes towards the northeastern part of the glen Finnedalen has been cultivated at least from the end of the 19th century.

The overgrowing started already in the 1890's, and about 1936 the area had a relatively dense forest. The characteristic grass *Poa nemoralis* was found only in this community and in the neighbouring part of community 2. This grass and the great numbers of *Anemone nemorosa* undoubtedly have their origin from the forest period.

The soil in the *Poa nemoralis* community (tab. 6) has a content of Ca like the other communities on dry soil, while the rather low contents of Mg and K were more like the values from the mor layers in the heath on rocky ground in part 690.

The map from 1887 indicates a combination of heath and shrubs in the area, and as can be seen in fig. 7, the overgrowing was already advanced in 1911.

After the felling in 1986 the ground flora of the former forest still characterized the vegetation. As table 15 shows, *Poa nemoralis* was the dominant species, frequency 100, degree of cover 24.2%.

In the August aspect *Anemone nemorosa* was very rare, but in May 1992 it was very common (frequency 91, degree of cover 10.9%).

The reason why *Poa nemoralis* and not *Deschampsia flexuosa* dominated in the forest is undoubtedly connected with the narrow area of forest (cf. fig. 9) which caused it to be affected by wind.

Hedera helix and *Lonicera periclymenum* were also common in 1986. *Hedera* decreased rather much, while the decrease of *Poa nemoralis* and *Lonicera periclymenum* was rather small.

Table 15

	Frequency		Cover (%)	
6. Poa nemoralis com.	1986	1991	1986	1991
Betula pendula	6	12	0.2	0.4
Carpinus betulus	58	29	3.2	2.2
Quercus robur	9	–	0.1	–
Salix sp.	15	–	0.6	–
Sorbus intermedia	6	–	0.2	–
Crataegus monogyna	–	3	–	0.3
Euonymus europaeus	–	6	–	0.5
Rosa canina	–	9	–	0.4
Viburnum opulus	–	3	–	0.3
Hedera helix	27	3	1.0	0.1
Lonicera periclymenum	79	59	4.8	3.4
Rubus idaeus	91	79	11.2	9.9
Rubus fruticosus	15	38	2.2	3.8
Vaccinium myrtillus	12	9	1.2	0.7
Agrostis tenuis	6	59	0.1	16.9
Anemone nemorosa	3	–	0.1	–
Anthoxanthum odoratum	3	6	0.1	0.2
Carex panicea	46	6	3.4	0.2
Carex pilulifera	9	3	0.5	0.1
Cerastium fontanum	–	6	–	0.4
Chrysosplenium alternifolium	6	–	0.2	–
Cirsium arvense	–	24	–	2.2
Cirsium palustre	–	6	–	0.2
Crepis capillaris	–	3	–	0.1
Dactylis glomerata	27	68	2.7	4.9
Deschampsia caespitosa	3	15	0.6	3.3
Deschampsia flexuosa	39	24	4.2	6.3
Dryopteris felix–mas	+	–	+	–
Festuca rubra	–	24	–	4.9
Holcus lanatus	24	59	2.6	10.3
Hypericum perforatum	12	35	0.5	2.4
Hypochoeris radicata	6	15	0.9	0.5
Lactuca muralis	3	–	0.1	–
Luzula multiflora	–	6	–	0.2
Melampyrum pratense	+	–	+	–
Poa nemoralis	100	65	24.2	18.9
Rumex acetosella	+	–	+	–
Taraxacum sp.	–	35	–	1.1
Veronica chamaedrys	6	18	0.4	0.7
Veronica officinalis	9	3	0.5	0.1
Viola canina	70	50	4.2	2.0
Bare soil	18	6	9.7	2.8
Bare rock	–	3	–	0.1
n	33	34	33	34
Tickness of soil, $\bar{m}$	21 cm			

Table 15. *Poa nemoralis* community, A1 area, Knægten. Frequency (Raunkiær analyses) and degree of cover (in %).

Fig. 27. Northern part of the transect in August 1986. In the foreground to the left is a part of the *Vaccinium* community (community 2). Between this and the road is the *Poa nemoralis* community (community 6) with many boulders. On the other side of the road is a depression which is a continuation of the glen Finnedalen. V.M. phot.

The clearing favoured *Rubus idaeus,* which in 1986 had a frequency of 19 and a degree of cover of 11.2%. Even if *Rubus idaeus* belongs to the species favoured by the sheep, its decrease was very small.

Carex panicea was undoubtedly favoured by the higher humidity in the low-lying area and was rather frequent in 1986 (frequency 46, degree of cover 3.4%). It decreased much and was rare in 1991.

Areas of bare soil without vegetation decreased in this community as in other communities with a relatively thick layer of soil ($\bar{m}$ = 21 cm).

Several species were favoured by the clearing and the grazing, and became more frequent, in particular grasses found on open land. As in many of the other communities, *Agrostis tenuis* especially became much more frequent. It covered 0.1% in 1986 and increased to 16.9% in 1991. The following grasses also increased considerably in the period: *Dactylis glomerata, Deschampsia caespitosa, Festuca rubra,* and *Holcus lanatus.*

Hypericum perforatum and *Cirsium arvense* also increased and mark the community when seen from some distance.

The grazing provided possibilities for the growth of the following species: *Cerastium fontanum, Cirsium palustre, Crepis capillaris,* and *Ta-*

Fig. 28. The same area as in fig. 27 in August 1991. Because of the many boulders the area is among the latest localities to be grazed by sheep, and in 1991 the sheep first began grazing in the area at the end of October. The influence of the sheep can be seen in the difference between the overgrowing of the area between the fence and the road and the area inside the fence. V.M. phot.

raxacum sp., which were found for the first time in 1991.

Among the woody plants some newly invading shrubs are especially notable. These species all have some kind of protection against grazing animals; namely *Rosa canina* and *Crataegus monogyna* with spines, together with *Euonymus europaeus* and *Viburnum opulus*, both poisonous. These species may possibly form the basis for a new overgrowing in the grazed area as *Juniperus* is in the other communities. Juniperus was not recorded in the *Poa nemoralis* community.

The many boulders in the area cause the sheep to avoid the area for as long as possible. In 1991 and 1992 the sheep grazed only very little in the area (cf. fig. 28), and in the summer of 1992 the overgrowing was so advanced that mechanical clearing was necessary in order to preserve the scenery.

5. Survey of the changes in vegetation from 1986 to 1991

In the spring of 1967 most of the A1 area was covered by a forest of deciduous trees and conifers. The heavy storm in October 1967 overturned most of the conifers (pines), and some areas in the northwestern and southern part became open (cf. fig. 7). The open areas increased after the felling of the rest of the pines in 1974. However, most of the communities in the transect were characterized by a rather dense forest during the period 1974-1986 (cf. the map fig. 9). Sheep grazing was undoubtedly rather sparse in this period.

The ground flora in the forest was most likely the remains of the vegetation from the period before the area was overgrown. In the same way, the ground flora from the forest period partly remained in the vegetation after the felling in 1986.

The fact that *Calluna* and *Vaccinium* are found in most of the communities today indicates that before the overgrowing most of the area was covered by a heath with *Calluna* and *Vaccinium*. This agrees with the signatures on the map made by the Royal Danish Academy of Sciences and Letters in 1799-1801 and the ordnance map from 1887.

In community 4 (grassland on a thicker layer of soil) there are neither *Calluna* or *Vaccinium*. This may indicate that this community represents the grass-dominated commons on Højlyngen.

The major changes in the A1 area happened when all the big and small trees were felled in 1986 and more intense sheep grazing started in the area. Only the continued presence of shrubs of *Juniperus* prevented the grazing of the sheep everywhere.

a. Woody plants

The sheep-grazing prevents the reestablishment of the forest from stump shoots. Reestablishment from stump shoots is common in areas where the only conservation management is mechanical clearing. The sheep eat all the shoots they can reach and most of the stumps die after some years' sheep-browsing. Shoots from very thin stumps of *Carpinus betulus* may form an exception. Several of these were still alive 9-18 years after germination. Another exception can be found where a dense growth of small birches is cleared and the thin stumps prevent the access of sheep, so the stumps in the middle of the group may develop into trees.

The sheep also eat all seedlings and rootsuckers of deciduous trees. Among the investigated species only *Carpinus* has a possibility of becoming a tree after 6-8 years grazing.

Juniperus communis is avoided by sheep. They eat neither shrubs nor seedlings of juniper, and because they often disturb the vegetation, seeds of juniper get the possibility of germination. Therefore junipers very often spread in grazed areas and form scrubs. In some of these scrubs in the area seedlings of *Betula* and *Quercus* have developed into trees.

If such trees are not cleared mechanically, the area will soon be overgrown. A similar tendency may be found in the *Poa nemoralis* community, where some of the new shrubs are protected against sheep-grazing by spines or a content of poison.

In 1986, *Lonicera periclymenum* was common in several of the communities. However, the species had decreased much in 1991. Only in the *Poa nemoralis* community, which was avoided by the sheep as long as there was food enough in other places, did *Lonicera* not decrease much.

Rubus idaeus was most likely favoured by the clearing. It is browsed severely by the sheep, but nevertheless it had still almost the same percentage of cover in the area.

The frequency of *Calluna vulgaris* was higher in 1991 than in 1986, but its degree of cover decreased. The higher frequency was partly a result of new plants and partly of new shoots from heavily grazed old plants. The lower percentage of cover was a result of sheep-grazing.

Vaccinium myrtillus had a frequency of 100 in its community during the period, but its degree of cover decreased because the sheep also liked the species.

b. Grasses

Grasses formed a major part of the vegetation in all communities of the transect apart from the *Carex nigra* community.

In 1986, *Deschampsia flexuosa* was the dominant grass in the *Calluna* heath, the *Vaccinium* community, and in the two grassland communities, undoubtedly favoured by partly having been very common in the former ground flora of the forest, and partly because it was avoided by not very hungry sheep. In 1991 *Deschampsia flexuosa* had the same percentage of cover in the *Calluna* heath as in 1986, while its cover in the *Vaccinium* community had increased. However, in the two grassland communities it had got a competitor on the open land, namely *Agrostis tenuis,* which is avoided by the not very hungry sheep. In 1991 *Agrostis tenuis* had a similar degree of cover as *Deschampsia* in those two communities. In 1991 *Agrostis tenuis* had a much higher degree of cover in all communities than it had in 1986.

In 1986 *Poa nemoralis* was only found in the community characterized by it. In the following period it decreased most likely because of competitive grasses, namely *Dactylis glomerata, Deschampsia caespitosa, Festuca rubra* and *Holcus lanatus.* These grasses are preferred by the sheep, but they undoubtedly grow better in open land than the forest grass *Poa nemoralis.*

Holcus lanatus increased also in the *Vaccinium* community as well as in the grassland community on thicker soil. In the latter community *Festuca rubra* and *Poa pratensis* also increased.

Festuca ovina was found only in the two grassland communities. In 1986 its occurrence in the two communities was almost equal. In 1991 its percentage of cover was almost the same on the thinner soil, but on the thicker soil it had decreased relatively much, possibly because its competitive ability was relatively less on thick layers of soil.

The erosion in the grassland on thin layers of soil, which had produced increased areas of naked soil and rocks, had favoured two grass species. The annual species *Aira praecox* on thin naked soil, and the perennial *Agrostis stricta* which are mostly found in fissures filled with soil in otherwise bare rocks.

All the communities in the transect had an increase of cover for the whole vegetation apart from the *Calluna* heath (community 1) and the grassland on thin layers of soil (community 3) (cf. tab. 9). In the *Carex nigra* community this was caused by the characteristic species, while it was caused by grasses in the other communities. In the *Vaccinium* community it was *Deschampsia flexuosa,* but in the other it is partly *Agrostis tenuis,* which is more or less avoided by the sheep, and partly species the sheep like, namely *Festuca rubra, Holcus lanatus,* and *Poa pratensis.* At least on thicker layers of soil the competitive power of these species seems to be equal to what is found on grazed meadows and commons.

c. Other herbs

Cerastium fontanum was found only in the grassland community on thicker soil in 1986. Here it increased and was also found in some of the other communities in 1991.

Luzula multiflora was rather common in some communities in 1986. In 1991 it was found in all communities and had become more common in the *Vaccinium* community.

Hypochoeris radicata and *Rumex acetosella* were not only more common in 1991 than in 1986 in the *Vaccinium* community but also in the grassland on thicker soil.

Hypericum perforatum, Cirsium arvense, and *Taraxacum* sp. had increased much in the *Poa nemoralis* community in 1991.

Some less common species in the transect were found in more places in 1991. Among these can be mentioned: *Crepis capillaris, Hieracium umbellatum, Holcus mollis, Ranunculus acris, Solidago virg-aurea, Spergularia rubra, Stellaria media, Thymus serpyllum, Veronica chamaed-*

rys, and *V. officinalis.* All these species are common in grazed pastures.

The southernmost part of the A1 area is a new locality for *Scorzonera humilis,* which in 1986 and earlier was only found in the SW corner of the 0-parcel.

Cirsium acaule is a new species in the pasture S of the A1 area.

The development of the A1 area seems to indicate that the area will become a mixture of *Calluna* heath and grazed commons. Both communities will contain many more species than before grazing started. However, this depends on the fact that the continuous conservation management can limit the growth of *Juniperus,* otherwise the area will develop into a dense scrub of juniper with good possibilities for the establishment of a new oak-birch forest.

IV. Habbedam. The area dominated by heath in part 690

1. The investigations 1979-1989

The area was investigated from 1979 to 1984 (Mikkelsen 1991). As a supplement to this investigation a new investigation was made in August 1989. The N-S transect (cf. fig. 1 and 29) was investigated in the same way as in 1981 and 1984. Raunkiær analyses, analyses of degree of cover and the depth of the soil were recorded for every metre. Locally the soil was very dry in 1989, and in many places it was impossible to measure depths of more than 35-50 cm. So it is not possible to calculate the average depth of the thicker layers of soil.

For measuring the transect in all three years a 50 m long tape measure of steel was used, placed along a tight string between marked points. Because of the uneven terrain and vegetation the placing of the single points of the analyses may be slightly different in the three years, but mostly the differences are only a few decimeters. As an example it can be mentioned that the total length of the transect was measured as 198.3 m in 1981, 199.8 m in 1984, and 197.6 m in 1989.

2. Survey of the plant communities

Most of the N-S transect is covered by *Calluna* heath. In 1981 there was also a small part covered by dense forest before the felling in 1979.

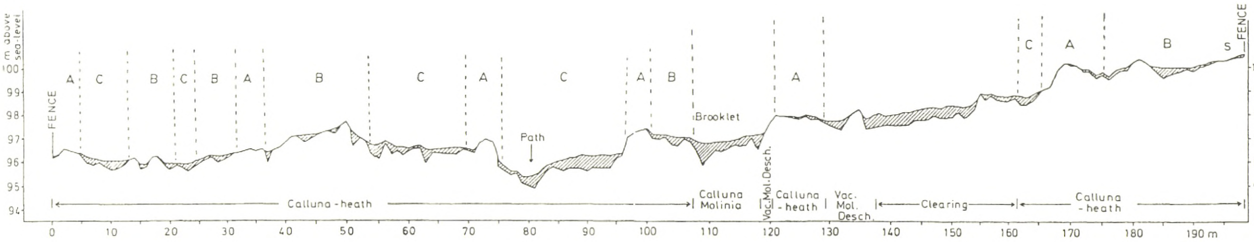

Fig. 29. The distribution of the 3 categories of *Calluna* heath in the N-S transect from part. 690, Habbedam, cfr. Mikkelsen 1991 fig. 12.
A: Mainly thin layers of soil. B: Mainly medium layers of soil. C: Mainly thick layers of soil.

In this clearing, the *Calluna* heath was almost totally reestablished in 1989, but in the survey it is regarded as a special community. An area dominated by *Molinia coerulea,* other herbs from wet ground, and *Calluna* is also regarded as a special community. A fourth community covers a small area characterized by *Deschampsia flexuosa* and *Vaccinium myrtillus* in 1981.

3. The Calluna heath

In 1981 and 1984 the *Calluna* heath was analysed both in the N-S transect and in two other transects, and the analyses were placed in 4 categories depending on the thickness of the soil, namely 0-3 cm, 4-9 cm, 10-19 cm and ≥20 cm. All species are shown in the tables with frequency and degree of cover.

In this paper only the averages of the analyses of degree of cover from the N-S transect are used for the three years (tables 17 and 18). All woody plants are collected in one group. Because most herbs had a very low degree of cover, only *Calluna vulgaris* and *Deschampsia flexuosa* have their own degrees of cover, all the other herbs are collected in one group. Bryophytes and lichens are also shown as groups, not as single species.

a. The thickness of the soil

The *Calluna* heath is presented in two tables. In table 17 the analyses are divided according to the thickness of the soil measured in 1989 as in Mikkelsen 1991.

While the location of a single analysis and therefore also the thickness of the soil may vary somewhat between the three years, the location of the analysis may be placed in one year in one category and in the neighbouring category in another. So the groups may contain somewhat different analyses in the three years.

In order to be able to compare the same groups of analyses from the three years, the analyses from the *Calluna* heath were divided into three sections in table 18, namely: A. analyses of areas dominated by thin layers of soil, B. of medium thick soil layers, and C. of areas dominated by thick layers of soil (cf. fig. 29). The distribution is made based on the measurements of soil thickness in all the three years, while the thicknesses of the soil shown in fig. 29 are based only on the measurements

TABLE 16

	A. Thin (n = 50)			B. Middle (n = 56)			C. Thick (n = 48)		
	1981	1984	1989	1981	1984	1989	1981	1984	1989
0	32.0	28.0	40.0	8.9	10.7	3.6	–	2.1	–
1-3	28.0	38.0	44.0	28.6	12.5	21.4	4.2	2.1	2.1
4-9	28.0	28.0	10.0	21.4	30.4	25.0	8.3	2.1	12.5
10-19	10.0	4.0	4.0	19.6	23.2	17.9	16.7	10.4	18.8
≥ 20	2.0	2.0	2.0	21.4	23.2	32.1	70.8	83.3	66.7
$\bar{m}$	3,4	3.0	2.6	11.0	11.7	12.9	29.6	35.8	
Variation in soil thickness	0-20	0-20	0-35	0-54	0-45	0-50	3-65	0-70	2->60

Table 16. *Calluna* heath in the NS-transect in part 690. Distribution in % of thickness of soil in: A. Areas dominated by thin layers of soil, B. Areas mostly with medium layers of soil, and C. Areas dominated by thicker layers of soil, cf. fig. 29. The same areas are used in each of the three years. In 1989 the absolute thickness was not measured for all of the samples with more than 35 cm soil.

TABLE 17

	0-3			4-9			10-19			≥ 20			All layers		
Calluna heath	1981	1984	1989	1981	1984	1989	1981	1984	1989	1981	1984	1989	1981	1984	1989
Trees and shrubs	0.3	0.5	-	0.5	2.0	1.7	0.3	+	1.9	2.8	2.1	4.9	1.1	1.1	2.0
Dwarf shrubs and herbs															
Calluna vulgaris	23.4	9.0	16.0	45.1	38.3	69.0	61.7	70.9	77.3	71.3	74.3	73.7	48.2	46.1	52.6
Deschampsia flexuosa	0.3	4.4	6.2	0.6	11.8	9.3	0.8	0.8	4.8	2.3	4.2	3.9	1.0	5.5	5.8
Others	0.8	1.4	0.2	0.8	0.5	0.1	0.9	-	0.2	0.4	1.5	0.5	0.6	0.9	0.2
total	24.5	14.8	22.4	46.5	50.6	78.4	63.4	71.7	82.3	74.0	80.0	78.1	49.8	52.5	58.6
Ground layer															
Bryophytes	1.6	4.6	2.2	2.5	7.6	2.6	2.0	4.6	0.4	1.9	6.4	4.8	1.9	5.7	2.5
Lichens	0.7	2.1	1.3	1.1	2.0	0.4	-	-	-	0.1	0.1	-	0.4	1.1	0.6
total	2.3	6.7	3.5	3.6	9.6	3.0	2.0	4.6	0.4	2.0	6.5	4.8	2.3	6.8	3.1
Areas without vegetation	48.8	58.1	59.3	17.6	14.5	3.4	10.3	6.8	1.9	0.1	1.3	2.1	21.9	22.2	21.5
n	54	48	57	30	34	25	24	20	21	48	55	51	156	157	154

Table 17. Cover in % for the different parts of the vegetation in 1981, 1984, and 1989, distributed by the thickness of the soil measured in the year in question.

made in 1981, when the levelling was also made.

Table 16 shows the distribution of soil thickness in the three sections of the *Calluna* heath in the three years. In group A (thin layer of soil) about 90% of the analyses have a thickness of less than 10 cm, and in group C (thick layer of soil) about 90% of the analyses have a thickness of 10 cm or more. On the other hand the variation in group B (middle thickness) is greater with almost the same amount in each of the categories 0-3, 4-9, 10-19 and ≥20 cm.

The distribution of soil thickness and the average for each of the three groups show no reliable changes from 1981 to 1989. There may possibly be an increase in the number of analyses with soil depth 0 or 1-3 cm in group A from 1981 to 1989 (cf. table 16). This may have been caused by the fact that the warm and dry summers in 1982 and 1983 caused erosion of the thin soil layers where the heather died. The eroded soil was transported to the neighbouring depressions, where usually thick layers of soil became thicker (cf. Mikkelsen 1991, fig. 19). In groups B and C with thicker layers of soil the possibilities for heather death and erosion were very few.

b. The vegetation

Tables 17 and 18 show the percentage of cover for the different groups of vegetation in each of the categories of soil thickness. The categories of soil thickness in table 17 are based on the depth of soil measured during the actual year, while in table 18 they are based on the location in the different groups of soil thickness in the *Calluna* heath.

The tree and shrub layer. Most trees and shrubs were felled in 1979; only *Juniperus* was spared. Later, mechanical clearings kept the trees and shrubs down. Both tables show that trees and shrubs play an insignificant role in the *Calluna* heath under nature conservation management during the whole period. Both tables show that it is mostly on thicker soil that trees and shrubs are found.

The layer of dwarf shrubs and herbs. This layer of vegetation consisted mostly of *Calluna vulgaris* and *Deschampsia flexuosa*. Herbs other than *Calluna* and *Deschampsia* covered about

TABLE 18

	Thin layers of soil n = 50			Middle layers of soil n = 56			Thick layers of soil n = 48		
Calluna heath	1981	1984	1989	1981	1984	1989	1981	1984	1989
Trees and shrubs	0.1	–	–	1.6	4.2	3.2	4.9	2.7	3.0
Dwarf shrubs and herbs									
Calluna vulgaris	27.0	17.4	25.3	47.5	47.6	54.7	74.8	78.5	78.8
Deschampsia flexuosa	0.5	8.8	6.8	1.9	8.1	8.1	0.6	1.9	2.2
Others	0.2	0.8	0.4	1.5	0.6	0.2	0.7	1.8	0.3
total	27.9	25.0	32.5	50.9	56.3	63.0	76.1	82.2	81.3
Ground layer									
Bryophytes	1.3	2.7	1.1	1.3	9.2	2.3	3.5	4.8	3.4
Lichens	0.3	2.0	1.8	0.5	1.6	0.7	0.4	0.1	–
total	1.6	4.7	2.9	1.8	10.8	3.0	3.9	4.9	3.4
Areas without vegetation	44.8	52.0	56.5	18.1	16.6	15.7	1.3	3.7	1.0
Soil layer in cm $\bar{m}$	3.4	3.0	2.6	11.0	11.7	12.9	29.6	35.8	

Table 18. Cover in % for the different parts of the vegetation in 1981, 1984, and 1989 in the three groups of soil thickness, cf. fig. 29 and table 16.

1%, and none of these herbs showed significant changes in the period.

In the *Calluna* heath as a whole (table 17, all layers) the degree of cover for *Calluna* did not change much during the period, but varied around 50%. There may have been a small decrease from 1981 to 1984 and an increase to a higher value in 1989 than in 1981. In 1992 the heather seems to have continued its increase after 1989, but this was not investigated.

On the other hand the development of vegetation in each of the different categories of soil thickness was very different. Table 17 shows that on soil layers of 0-3 cm, *Calluna* covered 23% in 1981, decreased to 9% in 1984 and after that increased again to 16% in 1989. On 4-9 cm soil there was also a decline from 45.1% in 1981 to 38.3% in 1984 and then an increase to 69% in 1989. On soil of 10-19 cm there was a steady increase from 61.7% in 1981 to 77.3% in 1989, while the degree of cover on soil ≥20 cm in all three years was somewhat more than 70%. This shows that only on the thinner soil did the dryness of 1982 and 1983 have an influence on *Calluna*.

The degree cover for *Deschampsia flexuosa* on soil of 0-3 cm increased from 0.3% in 1981, to 4.4% in 1984 and 6.2% in 1989. On soil of 4-9 cm there was also a considerable increase from 0.6% in 1981, to 11.8% in 1984 and 9.3% in 1989. On soil layers of 10-19 cm the degree of cover was 0.8% in both 1981 and 1984, but increased to 4.8% in 1989. On the thicker layers of soil (≥20 cm) the degree of cover was between 2.3% and 4.3% in all three years.

Cover of the dwarf-shrubs and herbs growing on soil layers of 0-3 cm decreased from 24.5% in 1981 to 14.8% in 1984 and recovered to 22.4% in 1989. On soils of 4-9 cm and 10-19 cm the degree of cover increased steadily from 1981 to 1989. In 1989, both soil categories had a degree of cover of about 80%. On soil ≥20 cm the degree of cover varied between 74% and 80% in the three years.

Bryophytes had a slightly higher cover in 1984 than in the other years. On soil ≤9 cm lichens also had a higher degree of cover in 1984.

Areas without vegetation were most prominent on thin layers of soil (table 17). On soil layers of 0-3 cm the degree of cover was 48.8% in 1981, increased to 58.1% in 1984 and 59.3% in 1989. On soil of 4-9 cm cover decreased from 17.6% in 1981 to 14.5% and 3.4% in 1984 and 1989, and on soil 10-19 cm thick from 10.3% in 1981 to 6.8% and 1.9% in 1984 and 1989. On thick layers of soil (≥20 cm) the degree of cover for bare soil and rock was small, between 0.1% and 2.1% in the three years.

On layers of soil of 0-3 cm the areas without vegetation had almost the same degree of cover in 1989 as in 1984. However, the number of analyses with thin layers increased during the period from 1981 to 1989. Table 16 shows that in areas with a thin layer of soil the frequency of analyses with 0 cm and 1-3 cm together was 60% in 1981, 66% in 1984 and 84% in 1989. This indicates that the process of erosion continued after the death of the heather in the warm and dry summers of 1982 and 1983. The upper part of the "roche moutonné" in the area became more and more bare, and the material from the erosion was collected in the flat areas below.

Table 18 shows the conditions when all the analyses were made of the same localities in all years. Most of the results are the same as in table 17, but it gives supplementary information regarding *Deschampsia flexuosa*. In unbroken areas where the layer of soil either is very thin or medium thick, the degree of cover of *Deschampsia* increased from 1981 to 1984 and remained at the same size in 1989. On thicker layers of soil the development was equal, but the degree of cover was rather low.

4. The clearing

Table 19 shows the different degrees of cover in the clearing in the years 1981, 1984 and 1989. In 1981 the area was marked by naked soil, which covered 55.7%.

TABLE 19

Clearing	1981	1984	1989
Trees and shrubs	2.0	1.7	3.7
Dwarf shrubs and herbs			
Calluna vulgaris	16.3	47.4	67.0
Deschampsia flexuosa	–	12.2	14.7
Rumex acetosella	–	5.6	–
Others	0.1	1.4	0.7
total	16.4	66.6	82.4
Ground layer			
Bryophytes	0.1	0.9	0.7
Lichens	–	0.1	0.4
total	0.1	1.0	1.1
Bare soil	55.7	10.3	6.7
Bare rock	–	0.4	6.7
total	55.7	10.7	13.4
n	23	23	23
Soil layer in cm $\bar{m}$	32	34	31

Table 19. Cover in % for the different parts of the vegetation in the clearing in 1981, 1984, and 1989.

Calluna vulgaris formed the only important vegetation. It consisted mostly of young plants, and the degree of cover was only 16.3%. By 1984 the heather plants had grown bigger and they covered 47.4% at that time. Furthermore *Deschampsia flexuosa* had spread and covered 12.2%. The naked soil in the period between 1981 and 1984 created germination possibilities for *Rumex acetosella,* which covered 5.6% in 1984. The naked soil was reduced to slightly more than 10% in 1984. In 1989 *Rumex acetosella* had almost disappeared (it was not found in the localities for the analyses), while *Deschampsia flexuosa* still had a rather high degree of cover (14.7%). On the other hand *Calluna* had increased to a degree of cover of 67%.

In 1989 *Calluna* and *Deschampsia* formed together a cover like that found on layers of the same thickness (average about 30 cm) in the

Calluna heath. However, there was a difference in the cover of *Deschampsia*, which was 14.7% in the clearing as against about 2% in the *Calluna* heath on a thick layer of soil (tab. 18) or about 4% in analyses with a soil thickness ≥20 cm (tab. 17).

5. The Calluna-Molinia-Juncus community

The community covers an E-W trending depression with a small brook (cf. fig. 29).

The northern border of the community (table 20) is characterized by a low growth of *Betula pendula* and *Frangula alnus*, which regenerated soon after both the sheep-browsing in the first years and the mechanical clearings the following years. In all three years the shrubs had a relatively high degree of cover, namely 10.9%, 11.8% and 17.8%.

The community is also characterized by hillocks surrounded by flat areas and traversed by a small brook.

In 1981 the following species grew on the hillocks: *Calluna vulgaris* (degree of cover in the community 6.1%), *Carex echinata* (7.0%), *C. pilulifera* (2.7%), and *Juncus effusus* (0.3%). The flat areas contained naked soil (cover 12.2%) and a low growth of *Juncus bulbosus* (14.2%). Furthermore, the community contained *Deschampsia flexuosa* (2.3%), *Molinia coerulea* (1.3%) and *Agrostis canina* (0.7%). The total degree of cover of dwarf-shrubs and herbs was 34.9%.

In 1984 most of the naked soil was covered by vegetation. The degree of cover for *Calluna vulgaris* had increased to 13.4% and for *Deschampsia flexuosa* to 3.1%, while it had decreased to 0.9% for *Carex pilulifera*. The degree of cover for the species which preferred wet soil had increased from 23.5% in 1981 to 47.3% in 1984. The degree of cover for *Molinia coerulea, Agrostis canina, Carex echinata, Juncus effusus,* and *J. squarrosus* had all increased much,

TABLE 20

Cal.-Mol.-Junc.		1981	1984	1989
Trees and shrubs		10.9	11.8	17.8
Dwarf shrubs and herbs				
Calluna vulgaris		6.1	13.4	13.8
Deschampsia flexuosa		2.3	3.1	–
Carex pilulifera		2.7	0.9	–
Vaccinium myrtillus		–	0.3	0.3
	total	11.1	17.7	14.1
Molinia coerulea		1.3	5.9	26.9
Agrostis canina		0.7	9.1	–
Carex echinata		7.0	11.5	5.0
Juncus bulbosus		14.2	11.9	0.3
Juncus effusus		0.3	3.3	0.6
Juncus squarrosus		+	5.6	0.3
Others		0.3	0.9	–
	total	23.8	48.2	33.1
Vegetation	total	45.8	77.7	65.3
Bare soil		12.2	–	–
n		9	10	10
Soil layer in cm	$\bar{m}$		42	41

Table 20. Cover in % for the different parts of the vegetation in the *Calluna-Molinia-Juncus* community in 1981, 1984, and 1989.

while *Juncus bulbosus* had decreased slightly. An increased humidity in the area was undoubtedly caused by the felling of many birch trees in the big depression close to the central 0-parcel which is drained off by the brook.

In 1989 the degree of cover for *Calluna vulgaris* was the same as in 1984, while *Deschampsia* had disappeared from the localities of the analyses. Among the species preferring wet soil *Molinia coerulea* was the most dominant with a degree of cover of 26.9%. *Carex echinata* had decreased to 5.0% from 11.5% in 1984. The other herbs from wet soil (*Agrostis canina, Juncus bulbosus, J. effusus,* and *J. squarrosus*) all decreased very much, undoubtedly because they were not able to compete with *Molinia coerulea*. In 1989 *Molinia* and *Calluna* were the characteristic species of the community.

6. The Vaccinium-Molinia-Deschampsia community

This community is rather inhomogeneous. It covers a couple of N facing slopes on each side of a section of the *Calluna* heath on thin layers of soil (cf. fig. 29). The *Calluna-Molinia-Juncus* community is situated north of the northern slope, and south of the southern slope we have the clearing. The thickness of the soil is very variable (0-70 cm). *Vaccinium myrtillus* was found on the N facing slopes both in analyses with thin and thick layers of soil, while *Molinia coerulea* was found mostly on the thicker layers of soil.

The woody plants usually have their roots in thicker layers of soil. During the period 1981 to 1989 *Juniperus communis* increased very much from a degree of cover of 0.8% in 1981 to 18.4% in 1989 (cf. tab. 21). The changes were insignificant for *Betula pendula, Quercus robur,* and *Frangula alnus.* This was the result of the mechanical clearings, where only *Juniperus* was spared.

Calluna vulgaris, Deschampsia flexuosa, Vaccinium myrtillus, and *Molinia coerulea* all increased from 1981 to 1984. The degree of cover for all of them increased from 26.9% in 1981 to 65.1% in 1984. In the same period the degree of cover for areas without vegetation decreased from 15.8% in 1981 to 3.1% in 1984.

Together, dwarf shrubs and herbs had an unchanged degree of cover in 1984 and 1989 (65.1% and 63.5%), but the composition changed. *Vaccinium myrtillus* decreased much, especially in analyses of thicker layers of soil and covered only 5.9% in 1989 against 27.6% in 1984. This decrease was compensated by a high increase in the cover of *Calluna vulgaris* from 12.8% in 1984 to 26.5% in 1989 and a lesser increase in cover of *Deschampsia* and *Molinia.* In 1989 there was no naked soil or rock in the community.

TABLE 21

Vac.-Mol.-Desh.	1981	1984	1989
Trees and shrubs			
Juniperus communis	0.8	2.2	18.4
Others	4.1	1.2	3.5
total	4.9	3.4	21.9
Dwarf shrubs and herbs			
Calluna vulgaris	6.3	12.8	26.5
Deschampsia flexuosa	6.8	16.0	19.2
Vaccinium myrtillus	12.4	27.6	5.9
Carex pilulifera	0.3	–	–
Molinia coerulea	1.1	8.7	11.9
total	26.9	65.1	63.5
Areas without vegetation			
Bare soil	7.9	2.2	–
Bare rock	7.9	0.9	–
total	15.8	3.1	–
n	11	10	12
Soil layer in cm $\bar{m}$		29	27

Table 21. Cover in % for the different parts of the vegetation in the *Vaccinium-Molinia-Deschampsia* community in 1981, 1984, and 1989.

7. Survey of change in the vegetation from 1979 to 1989

Just before the clearing in 1979, only a few areas were still open and covered by heather. The forest contained *Quercus robur* and *Betula pendula.* Both undoubtedly survived the grazing period in the glens on both sides of the area. *Frangula alnus, Salix aurita, Populus tremula,* and *Juniperus communis* most likely had survived in the same localities and were a part of the forest and scrub vegetation in 1979.

Another important part of the forest was self-grown trees of *Pinus sylvestris,* undoubtedly spread from the neighbouring plantations established at the end of the 19th century. Many parts of the forest were so open that *Calluna* was a dominant part of the ground flora, which was otherwise poor in species. Except on the slopes towards Ravnedalen *Vaccinium myrtillus* and *Deschampsia flexuosa* played a minor role in the ground flora.

a. Trees and shrubs

In 1979 the trees were felled, juniper was spared both in 1979 and in the following mechanical clearings. However, trees and shrubs were not eradicated. Both shoots from stumps and new seedlings produced new trees and shrubs because of the scarce or absent sheep-grazing.

Trees and shrubs were not distributed evenly in the different communities. In the *Calluna* heath (tables 17 and 18) they play a very small role. There were very few on thin layers of soil, but more occurred on thicker layers of soil.

In the period 1981 to 1989 the clearing (table 19) developed into a *Calluna-Deschampsia* heath. The cover of the woody plants was small, and of the same size as in the *Calluna* heath on thicker layers of soil which is equal to the thickness of the soil in the clearing.

The trees and shrubs prefer the thicker layers of soil. In the *Vaccinium-Deschampsia-Molinia* community (average soil thickness 27-29 cm) the degree of cover for trees and shrubs was relatively low both in 1981 and 1984, but increased much to more than 20% in 1989 (tab. 21). In this case it was mostly the spared junipers which increased.

The trees and shrubs had a high degree of cover in the depression with the *Calluna-Molinia-Juncus* community (average soil thickness 41-42 cm). In 1981 the degree of cover was 10.9%, and it increased to 17.8% in 1989.

The fact that trees and shrubs thrive best in depressions with a thick layer of soil is in good accordance with the development of the natural overgrowing of the area between 1961 and 1974 as recorded in Mikkelsen 1991, fig. 7. The narrow depressions which traversed the area developed into shelter belts favouring the following overgrowing.

b. Calluna vulgaris

On the thinner layers of soil the dry summers of 1982 and 1983 caused the death of heather and a decrease of *Calluna* in the period 1981 to 1984. In the following 5-year-period *Calluna* re-established itself on the thinner soil and in 1989 had a degree of cover corresponding to that in 1981 (about 20%). On soil between 4 and 19 cm the degree of cover of *Calluna* increased during the period 1981 to 1989 to about 70%. The very high degree of cover on soil ≥20 cm was almost unchanged during the period (table 18).

In the clearing (table 19) the degree of cover of *Calluna* increased from 16.5% in 1981 to 67% in 1989, and the community developed into a *Calluna-Deschampsia* heath with a total degree of cover of the two species to a bit more than 80%.

In the *Vaccinium-Molinia-Deschampsia* community (table 21) *Calluna* increased from 6.3% in 1981 to 26.5% in 1989.

The increase of *Calluna* was less in the community on wet soil (table 20), namely from 6.1% in 1981 to 13.8% in 1989.

Since the nature conservation management started in 1979, *Calluna* has increased very much in most of the area, and in 1992 the increase seemed to have continued. The increase of *Calluna* was most likely caused by the increased light after the clearing.

c. Deschampsia flexuosa

In 1981 *Deschampsia* had a very small degree of cover in the area, except in the *Vaccinium-Molinia-Deschampsia* community (table 21). In this community and in the *Calluna* heath on thinner and middle soil (table 18), *Deschampsia* increased in the 10-year-period. On the other hand in the community on wet soil (table 20) the species remained unimportant, most likely because it could not manage the competition with *Molinia coerulea*.

In the *Calluna* heath on thicker layers of soil (table 17 and 18) with a large degree of cover for *Calluna, Deschampsia* also remained with a small degree of cover during the period. On the other hand in the clearing (table 19) with an average soil thickness of 31-34 cm, *Deschampsia* increased from not found in 1981 to a degree of cover of 14.7% in 1989.

The investigations indicate that *Deschampsia flexuosa* usually increased in areas where the total cover was small, where the competition with *Calluna* or *Molinia* was not too severe. So the species showed no increases in the sections of the *Calluna* heath where the dominant species had a high degree of cover.

Most likely *Deschampsia* is favoured somewhat by the absence of grazing at the end of the period. This may be the reason for the continued high degree of cover in the clearing in 1989.

d. Molinia coerulea

In the wet community (table 20) *Molinia coerulea* increased very much in the 10-year-period. Except for *Calluna* and *Carex echinata,* the other species lost in the competition with Molinia. On the thicker soil layers in the *Vaccinium-Molinia-Deschampsia* community (table 21) *Molinia* also increased from 1.1% in 1981 to 11.9% in 1989.

e. Vaccinium myrtillus

The only community where *Vaccinium myrtillus* had some importance is shown in table 21. In this inhomogeneous community *Vaccinium* was found mostly on a couple of N facing slopes, and in the community as a whole it covered 12.4%. In 1984 *Vaccinium* was also found in the rest of the area and covered 27.6%. However, during the following 5 years the species decreased to 5.9%, most likely because it could not manage the competition with *Calluna, Molini,* and *Deschampsia,* all of which increased.

f. Other herbs

In the community on wet soil (table 20) species preferring wet soil such as *Agrostis canina, Juncus effusus* and *Juncus squarrosus* all increased from 1981 to 1984. Undoubtedly they were favoured by the bare soil and maybe also by the increased humidity, which was also indicated by the decrease of *Carex pilulifera. Juncus bulbosus,* which also prefers wet areas, was already common in 1981 and kept a rather high degree of cover in 1984. All these species decreased in the period 1984 to 1989, most likely because of the increase of *Molinia coerulea.*

g. Bryophytes and lichens

Bryophytes and lichens were of some importance only in the *Calluna* heath. They may have increased somewhat from 1981 to 1984, but decreased during the following 5 years to values equal to those of 1981. This was most distinct in areas with soil of middle thickness, table 18. The increase after the clearing in 1979 may have been caused by the increased amount of light, which, however, after 1984 diminished at the ground layer, because of the increased degree of cover of *Calluna* and *Deschampsia.*

h. Areas without vegetation

In 1981 many areas without vegetation were found in all the communities. During the period 1981-1989 much of the bare soil became overgrown. On the other hand, in the section of the *Calluna* heath on thin layers of soil, the areas without vegetation increased and had a degree of cover of more than 50% in 1989.

Table 16 shows that the number of analyses of soil of 0 and 1-3 cm together amount to 60% of the analyses in 1981, 66% in 1984 and 84% in 1989.

The change towards many more analyses in the category with the thinnest layers of soil from 1981 to 1989 was undoubtedly caused by the death of the heather on thin layers of soil in the dry summers of 1982 and 1983. The erosion during the following years caused many of the protruding rocks to become bare, and the eroded material ended up in the depressions below and on the flat bare rocks, which in 1989 were covered by 1-3 cm of bare soil. In the future some of the areas with bare, thin soil in flat terrain may be the locality where seedlings of *Calluna* establish themselves and cause a regrowth of heather unless new dry summers prevent it.

V. Differences between the two areas in Borrelyngen

The vegetation in the two parts of Borrelyngen, Knægten and Habbedam, is very different today (1992). In antiquity there had also been differences. In the last millennium BC, parts of Knægten were used by farmers, indicated by the occurrence of many monuments of antiquity. On the other hand the Habbedam area contains no monuments.

This difference is determined by the fact that Knægten contains areas suitable for cultivation and is located much nearer to and is more accessible from localities which have been inhabited since early periods of antiquity.

The differences between the two areas are specially marked by the development of the vegetation after the start of the nature conservation management in the 1970s. In some areas, all trees and shrubs other than *Juniperus* were felled. In other areas, the forest was thinned in order to favour grazing. In the investigated areas sheep were put to graze.

The thinned, grazed forest (A2 in fig. 1) was only studied for the influence of sheep-grazing on stump shoots. Today the forest is open and dominated by *Quercus robur.* The dominant species in the ground flora are *Deschampsia flexuosa, Anemone nemorosa,* and *Vaccinium myrtillus* in 1992.

The investigations were concentrated on the two areas which were totally cleared in 1979 (the B area) and in 1986 (the A1 area).

1. The vegetation

In 1979 the vegetation was very different in the two localities.

The B area (Habbedam, part 690) was dominated by a *Calluna* heath containing only a few species and many bare, protruding rocks and bare soil without vegetation (cf. table 17, all layers).

Furthermore there are depressions dominated by *Calluna* and *Molinia* (cf. Mikkelsen 1991, tab. 20). The depressions also contain species preferring acid soil such as *Trichophorum caespitosum, Eriophorum angustifolium* and *Sphagnum* spp.

Only small areas of the heath in Habbedam are dominated by *Vaccinium myrtillus.*

In the A1 area (Knægten) there are also areas dominated by heather. However, the *Calluna* heath (community 1 in the transect fig. 19) differs from the *Calluna* heath in Habbedam. It contains many more species, and because the layer of soil is thicker there are not so many bare, protruding rocks (cf. table 10).

Vaccinium myrtillus is more common in the A1 area and is found either in N facing slopes or in flat areas which until 1986 were covered by deciduous forest (community 2 in the transect, and table 11).

The only community on wet soil in the A1 area is community 5 in the transect. It is dominated by *Carex nigra* (tab. 14) and grasses, while the species from acid soil, which characterize the *Molinia* community in Habbedam, are not found in the A1 area.

The most prominent communities in the A1 area are dominated by grasses (communities 3, 4 and 6, tables 12, 13 and 15). Grasses are also prominent in most of the other communities, cf. table 9.

The communities on dry soil in the A1 area (tables 10-13 and 15) contain many more species than in the B area. Among species from the A1 area which are not found in the B area the following species from neighbouring plant communities can be mentioned:

Forest: *Anemone nemoralis, Anthoxanthum odoratum, Lactuca muralis, Poa nemoralis,* and *Veronica officinalis.*

Commons and heath: *Campanula rotundifolia, Cerastium fontanum, Cirsium acaule, Crepis capillaris, Dactylis glomerata, Festuca rubra, F. ovina, Hieracium umbellatum, Hypericum perforatum, Poa pratensis, Scorzonera humilis, Solidago virg-aurea, Taraxacum* spp., *Veronica chamaedrys,* and *Viola canina.*

Meadows: *Cirsium palustre, Potentilla erecta,* and *Ranunculus acris.*

Fields (weeds): *Cirsium arvense, Poa annua,* and *Stellaria media.*

2. Content of nutrients dependent on the degree of leaching of the soil

The difference of the vegetation in the two areas is most probably caused by the fact that the soil in Knægten contains more nutrients than the soil in Habbedam. Table 6 shows that the contents of especially Ca, Mg and K are different.

Investigations of the common of Rejnstrup (Mikkelsen 1989, tab. 6 part E) showed that a supply of Ca had changed an area which in 1941 was dominated by *Calluna vulgaris* and *Deschampsia flexuosa* to an area dominated by other grasses in 1986. The lower content of Ca in Habbedam undoubtedly favoured the competitive power of *Calluna* against the different grasses.

The question therefore is what was the reason for this difference. The most probable reason is the difference in the leaching of nutrients in the two areas. In about 600 years (from about AD 1200 to AD 1800) both areas had been open commons and were therefore exposed to considerable leaching.

Leaching depends on the amount of precipitation, the composition of the soil, and the terrain. The amount of precipitation cannot have been much different in the two neighbouring areas, and both have a soil of sandy moraine.

Both areas are placed on plateaus which are limited both towards E and W by glens (cf. fig. 1). Regarding the *Calluna* heath in Habbedam and the communities on dry soil in Knægten, the only difference in the terrain is that there are some higher areas between the A1 area and the glen (Buggedalen) towards the E, which means that the drainage runs mostly towards the W.

Regarding the communities on wet, thick soil there are several differences in the terrain. Most of the wet areas in Habbedam, which are dominated by *Molinia coerulea,* have an outlet as a brooklet at least in winter time. On the other hand the *Carex nigra* community in Knægten does not have any outlet on the surface.

The better possibilities for leaching in the wet areas in Habbedam may be the explanation why there are species preferring acid soil such as *Molinia coerulea, Trichophorum caespitosum, Eriophorum angustifolium* and *Sphagnum* spp. These are not found at Knægten.

Regarding the communities on dry soil the essential difference between the two areas is the thickness of the soil. It varies much in both localities, but the distribution on the different categories of soil thickness is very different.

Table 22 shows the distribution of soil thickness in the two areas, based on the measure-

TABLE 22

Depth of soil cm	Knægten part 686 + 687	Habbedam part 690
0-3	11.8	30.5
4-9	8.4	15.1
10-19	18.3	16.1
20-100	61.6	38.3
n	263	939
$\bar{m}$	31,3	18.5

Table 22. Distribution in % of the different categories of soil thickness in the transects in the Knægten area and the Habbedam area.

ments in the two investigated transects. Layers of soil ≥20 cm are more common in Knægten (61,6%) than in Habbedam (38.8%). More significant is the difference regarding the thinner layers of soil (0-3 cm and 4-9 cm). In Habbedam there are 30.5% and 15.1% respectively as against 11.8% and 8.4% in Knægten.

As leaching is greater in thinner than in thicker layers of soil, the most probable reason for the difference in the content of nutrients and vegetation in the dry soils of the two areas is the differences in the soil thicknesses.

VI. Survey of the influence of sheep in nature conservation

1. The selectivity of sheep grazing

Sheep are very selective in their the choice of food. The selection is dependent on how much food there is and how accessible it is. As long as there is plenty of food, only the most preferred and most easily accessible plants will be eaten. Hungry sheep give a more effective grazing.

In the period before about 1850, farmers on Bornholm had no other food for their sheep than what could be grazed on Højlyngen and the other commons. In unfavourable years it could not be avoided that the sheep became hungry and the grazing became very intensive. Today substitute feeds are available, and because of economic reasons and animal welfare farmers make sure that their sheep do not become really hungry. If hungry sheep have to walk too much to find food, the farmer might suffer a loss of meat production and income.

In Borrelyngen the sheep avoided the areas with many boulders as long as possible. Areas with dense groups of thin stumps (e.g. after felling a copse of young birches) were also avoided.

The traffic of sheep in the A1 area looks very well regulated. A couple of very much used paths, often with bare soil, lead from the pasture south of the A1 area towards the northern part. Bigger and smaller secondary paths lead to localities with attractive food.

The area was marked by selective grazing. When the sheep arrived in May at the area, they started with food they preferred. When the first stump shoots of e.g. oak appeared, secondary paths to the stumps were found through uneaten vegetation. This activity continued until only the least favoured or least accessible food was left. Most often that kind of food was also used before the end of the grazing season.

2. The influence of sheep on the vegetation

The following results of the influence of sheep on the different species are based on the investigations in Borrelyngen. Only species from this area are mentioned, and it cannot be excluded that the never really hungry sheep of Borrelyngen may have behaved somewhat differently from others.

a. Trees and shrubs

There are only a few tall deciduous trees in the area, e.g. some 2-3 m high *Betula pendula*. The sheep eat leaves and thin twigs of the deciduous trees to a height of about 1 m. The only conifer is *Juniperus communis,* which is totally avoided by the sheep. The deciduous trees in the area are represented mostly by seedlings, root-suckers and stump shoots.

b. Seedlings and root-suckers

Seedlings of the following deciduous trees and shrubs were found: *Betula pendula, Carpinus betulus, Prunus avium, Quercus robur, Salix caprea, Sorbus aucuparia,* and *S. intermedia*. All these together with root-suckers of *Populus tremula* were eaten early in the grazing season. At Habbedam, seedlings of *Pinus sylvestris* were found, and they were also eaten.

The only seedlings not eaten by sheep were *Juniperus communis.* The sheep also avoided bigger junipers, resulting in a spread of juniper. Under shelter of the juniper, deciduous trees such as *Quercus, Betula,* and *Sorbus* may have the possibility of developing into trees.

In the period 1986-1991, certain shrubs had developed in the *Poa nemoralis* community, a community which belongs to areas grazed latest in the season. The species which were avoided by grazing livestock were *Crataegus monogyna* and *Rosa canina* with spines, together with the poisonous *Euonymus europaeus* and *Viburnum opulus.* However, not all species known to be poisonous were avoided by the sheep. When the first sheep reached the Habbedam area in 1979, their food was stump shoots of oak and birch together with shoots of *Frangula alnus.* However, the excrements of the sheep did not indicate any poisonous effect of *Frangula.*

c. Stump shoots

Young buds of deciduous trees are very much preferred by the sheep, and they are among the first food selected.

The early stump shoots are eaten as close to the stump as possible, so the stump shoots usually form a cushion which fills up all uneveness in the stump and the nearest surroundings. The surface looks densely cut (cf. fig. 16). If the stump shoots had the possibility of growing longer, usually only the outermost part with fresh buds and leaves was eaten. If the stump shoots are fully developed before the sheep arrive in the area, they are no longer preferred and often totally avoided.

Neither *Pinus sylvestris* nor *Picea abies* made stump shoots in Borrelyngen. On the other hand most of the deciduous trees did so (cf. table 2).

In an area grazed by sheep, the time during which the stumps live on is dependent on the intensity of grazing, which again is dependent on the accessibility of the stumps. The accessibility was less in the thinned forest in the A2 area than in the cleared A1 area. Therefore the stumps stayed alive longer in the A2 area. For example, 56% of the stumps of oak were alive in the A2 area in the sixth year after the felling as against 26% in the A1 area.

The stump shoots of species such as *Betula pendula, Populus tremula, Prunus avium, Salix caprea,* and *Sorbus intermedia* only lived a short time, most of them being dead after 2 years. Stumps of *Carpinus betulus* with a diameter ≥10 cm were only alive for a short time, while stumps of seedlings with a diameter of 1-3 cm seemed to survive yearly browsing for at last 18 years, and produce long shoots, when grazing stopped.

Several shoots of *Quercus robur* were alive for a relatively long period. In the A2 area 23% were alive after 8 years, and in the A1 area 26% were alive in the sixth year. However, much indicates that old stumps do not develop into trees. 4 stumps, which were alive after 8 years' grazing were fenced and protected against sheep. None of them produced shoots longer than 40 cm, 2 died in the course of 2 years, and at least one of the others seemed to be dying in 1992 and was dead in 1993.

Furthermore it must be noted that none of the stumps from the first fellings in 1974 in the A2 area were alive in 1992. So sheep grazing is an effective way of preventing overgrowing of a cleared area except with *Juniperus communis.*

d. Dwarf shrubs, etc.

Young shoots of *Vaccinium myrtillus* are very much preferred by sheep, and early in the grazing season a great part of the *Vaccinium* are eaten down to a low height.

The sheep also prefer young shoots of *Calluna vulgaris.*

Rubus idaeus also belongs to the plants eaten early in the season, and very few fresh shoots reach the flowering phase. However, due to many new shoots from the rootstock the species after all preserved an almost unchanged frequency in the A1 area.

Rubus fruticosus is possibly slightly less preferred by the sheep, and it did not change frequency during the grazing period.

The frequency of *Lonicera periclymenum* generally decreased in the grazed A1 area, but an early browsing of this species was not noted in the period.

e. Grasses

According to the present study the sheep showed a considerable preference for some species of grasses as opposed to others.

The following grasses belong to those eaten earliest: *Dactylis glomerata, Festuca rubra, Holcus lanatus,* and *Poa pratensis. Deschampsia caespitosa* seems to be somewhat less preferred. Most of these grasses were not damaged by sheep grazing which, for most of them, seemed to increase their ability to compete against other species.

Festuca rubra was not found in 1986, but became rather common during the grazing period, especially in the grass-dominated communities on thick soil (communities 4 and 6). In these communities and in the *Vaccinium* community, *Holcus lanatus* increased rather much. *Poa pratensis* increased in community 4, and *Dactylis glomerata* and *Deschampsia caespitosa* increased most in the *Poa nemoralis* community (community 6).

Species such as *Deschampsia flexuosa, Agrostis tenuis,* and *Festuca ovina* were only eaten by sheep when better food was absent.

Deschampsia flexuosa decreased in most of the communities, most likely because it could not manage the competition in the open land with *Agrostis tenuis,* which increased in most of the area. However, in the *Vaccinium* community *Deschampsia flexuosa* increased. This may have been caused by early grazing of the competitor *Vaccinium myrtillus.*

Festuca ovina was found in the two grass-dominated communities (communities 3 and 4) upon the plateau in 1986. In 1991 the frequency was unchanged on the thin soil (community 3), while it had decreased on the thicker layers of soil (community 4), possibly because of competition with other grasses.

Grasses such as *Aira praecox* and *Agrostis stricta* increased during the grazing period, undoubtedly because of the traffic of the sheep on thin layers of soil. This caused erosion, which produced bare soil close to the protruding rocks (*Aira*) and in the fissures (*Agrostis*). *Poa annua* was also found in these localities and on the bare soil in the sheep paths.

f. Other herbs

The open land and the low vegetation caused by the grazing have favoured some species in the area.

Species such as *Cerastium fontanum, Taraxacum* spp., and *Veronica chamaedrys* increased during the grazing period, even though they were eaten by the sheep. On the other hand, the increase of *Hypericum perforatum* may be partly caused by the fact that the species is avoided by sheep because of the noxious influence *Hypericum* has at least on white lambs.

g. Newly established species

The low, grazed vegetation and the frequent occurrence of small holes with bare soil made germination of species new to the A1 area possible. So the number of species increased due to grazing.

These species are partly weeds such as *Cirsium arvense, Crepis capillaris,* and *Stellaria media,* and partly species from commons, heaths, and meadows such as *Campanula rotundifolia, Ranunculus acris, Solidago virg-aurea, Thymus serpyllum, Holcus mollis, Potentilla erecta,* and *Cirsium palustre.*

Eroded areas on thin soil had the following newly established species: *Aira praecox, Agrostis stricta,* and *Spergularia rubra.*

Earlier the species *Scorzonera humilis* was found only in the 0-parcel, but during the latest years new plants were found in the SW part of the A1 ara. On the pasture S of the area, *Cirsium acaule* has occurred in most recent years.

Undoubtedly sheep have had great influence on the spreading of species from other localities.

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