# Coastal heath vegetation in central Norway; recent past, present state and future possibilities

Liv S. Nilsen

Dr. scient. thesis

Department of Biology
Faculty of Natural Sciences and Technology
Norwegian University of Science and Technology
Trondheim, Norway
April 2004

**Preface**

My first job after finishing my Master thesis in 1995 was registering valuable cultural landscapes in Nord-Trøndelag. This was quite a challenge, and it opened my eyes to the values of the coastal landscape, the history and the people who had lived and live in the area. Through a network of people from local communities, the management authorities (local, regional and national) and the scientific community, I have had the opportunity to continue working in the coastal areas, initially, financed by the County Governors of Sør- and Nord-Trøndelag and the Directorate for Nature Management to prepare management plans for areas registered as specially valuable, and lately through my doctoral work financed by the Research Council of Norway. This work is based on my earlier studies and has been stimulated by my astonishment concerning the similarities and dissimilarities with coastal areas further south.

My supervisors have been Asbjørn Moen, Museum of Natural History and Archaeology, and Bård Pedersen, Department of Biology, both in the Norwegian University of Science and Technology. I want to thank you both for guiding me through this work, your cooperation and your vitality.

This work has been carried out at the Museum of Natural History and Archaeology and I want to thank the entire staff on the "Botany floor" for a good working environment. Writing a doctoral thesis requires teamwork and, in addition to my supervisors, I specially want to thank my cultural landscape colleges Anders Lyngstad and Dag-Inge Øien and the Master degree students Anne Aasmundsen, Hubertina Doeven, Line Johansen, Lotte Skoglund and Liv Guri Velle, who have been associated with this project. Thanks also to Inger Marie Growen and Else Johanne Svorkås at the section office for all kinds of help and thoughtfulness.

To understand the processes taking place in the cultural landscape, it is important to have knowledge of the former use of an area. Thank you Aud Mikkelsen Tretvik (Institute of History) for opening my eyes for new contexts. Thanks also to Kristin Floa and Asbjørn Tingstad – fortunately people like you work in the County Governor' office!

This work is based on field research and many days have been spent in the coastal heathlands of central Norway, often with Eli Munkebye. I want to thank you for your contribution and consideration during fieldwork and for our conversations and friendship over the years. Thanks also to the inhabitants of Tarva and Borgan for all your help during my stays on the islands.

Finally, I wish to thank my husband Terje and my two marvellous children Elisif and Askild. You made me remember the main thing in life!

Liv S. Nilsen
Trondheim, April 2004

**Contents**



Photographs: Asbjørn Moen (Paper I, upper), Anne Aasmundsen (Paper IV, bottom), the others by Liv S. Nilsen.

**List of papers**

The thesis is based on the following individual papers

I Nilsen, L.S. & Moen, A. Coastal heath vegetation types in Trøndelag, central Norway. (submitted)

II Nilsen, L.S. & Pedersen, B. Effects of burning and grazing on coastal heath vegetation in central Norway: an experimental study. (manuscript)

III Nilsen, L.S., Johansen, L. & Velle, L.G. Early stages of *Calluna vulgaris* regeneration after burning of coastal heaths on Tarva, central Norway. (submitted)

IV Nilsen, L.S., Aasmundsen, A., Moen, A. & Oterholm, A.I. Woodland regeneration in a coastal heathland area in central Norway. (submitted)

The papers are referred to by their roman numerals in the text.

## Introduction

The coastal heathland in Norway is part of a European landscape along the Atlantic coast from Portugal to northern Norway (Figure 1). These heathlands give rise to a distinctive, open type of landscape, which is often of great beauty.

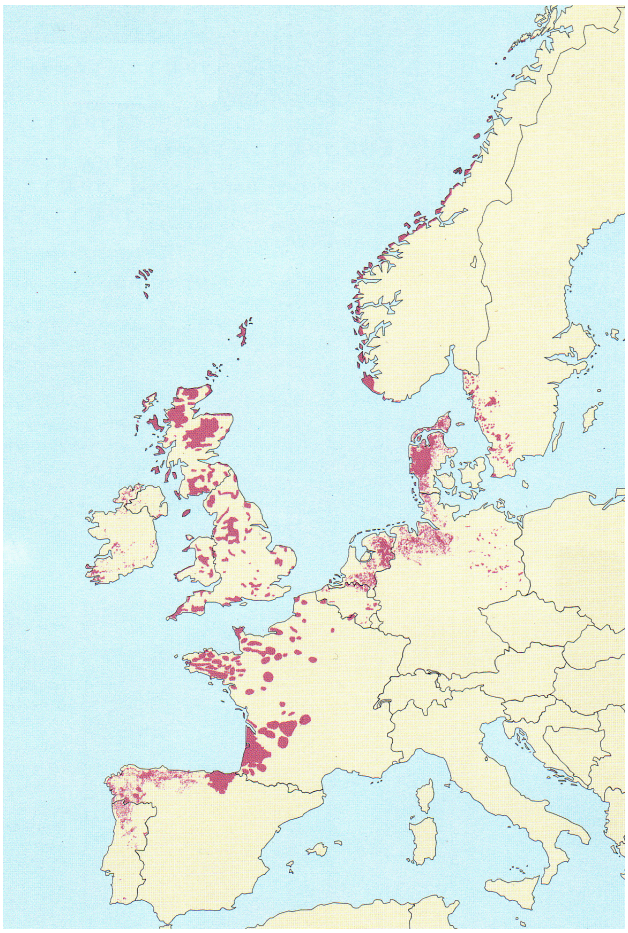


**Figure 1.** The distribution of coastal heathland in Europe (from Haaland 2002).

*The origin and the traditional use of the heathland*

Heathland is usually confined to places where a humid oceanic climate is combined with a cool temperature regime and a freely drained soil (Gimingham 1972, Specht 1979). In some areas, like the outermost islands of western Norway, heath vegetation may be natural (Kaland 1986), but most of these western European heathlands below the forest limit are secondary vegetation, derived from former woodlands (e.g. Gimingham 1972, de Smidt 1979, Prøsch-Danielsen & Simonsen 2000). Human-induced deforestation, followed by the establishment of open heath, goes back to 4000 BC in southernmost Norway (Prøsch-Danielsen & Simonsen 2000), about the same time as in Jutland, Denmark (Odgaard 1994) and Shetland (Bennet et al. 1992). This process started somewhat later and lasted longer

further north, from about 2800 BC to about AD 1000 in central Norway (Ramfjord 1979, Paus 1982, Solem 1989, Sageidet 1999, Tveraabak 2004).

Until recent times, the heathlands traditionally have been used for grazing and harvesting (Kaland 1979). In Norway, cattle were kept in byres in winter, whereas sheep mostly grazed outdoors all the year round. With only a sparse snow cover, the evergreen *Calluna vulgaris* (hereafter called *Calluna*) plants were grazed in winter. Small areas of heath were burned from time to time to remove old nutrient-poor woody *Calluna* plants and keep the vegetation young and rich in nutrients to provide good forage. For the first few years after burning, herbs and graminoids usually dominate before *Calluna* again takes over. The burning also fertilises the soil and hinders shrub and tree colonisation (Gimingham 1972, 1981). To avoid severe fires, which may destroy the stem bases and seed bank, the burning was done in winter and early spring when the soil was either wet or frozen. Due to the regeneration cycle of *Calluna*, the burning intervals have been every 10-12 years in Scotland and every 25-40 or 50 years in western Norway (Gimingham 1972, Fremstad et al. 1991). At Vikna, Tveraabak (2004) found regular burning intervals of about 22 years after AD 1500. Heather was also cut to provide winter fodder.

*Composition and variation on European heathland*

Heathland is a characteristic type of landscape and may be composed of various nature types, like heath, mire, salt marsh and grassland, in addition to areas of barren rock. The chief plants of heaths are dwarf shrubs, tall shrubs and trees being either completely absent or sparse and scattered. *Calluna* usually dominates on heath, but other dwarf shrubs may also be important.

In Norway, the coastal heathlands are limited to the most oceanic areas, mainly the highly oceanic vegetation section (O3, Moen 1999). They occur along the coast in a belt of varying width, earlier mostly about 25 km (up to 40 km) in southern Norway, but narrower further north (Dahl et al. 1986, Skogen 1987).

The vegetation of the European heathlands varies greatly, regionally due to climate and locally due to differences in geology, topography and soil type (Böcher 1943, Gimingham et al. 1979, Rodwell et al. 1991). In Britain, it is common to differentiate between lowland heath and upland heath and moorland (Rodwell et al. 1991, Gimingham 1992). The term

moorland is often used for the heathlands in the uplands, and often includes heath and blanket bogs in a mosaic (Ward et al. 1995). The lowland heaths of Norway are regarded as upland heaths (Thompson et al. 1995). It may be easier to compare heaths on the basis of vegetation zones. The coastal (lowland) heaths of central Norway mainly belong to the southern boreal vegetation zone (Moen 1999). Boreal heaths are also found in the uplands of Britain and the islands north of Scotland. However, the lowlands of Scotland and the Orkneys have boreonemoral heaths, and further south nemoral and submeridional heaths cover the lowlands. In Britain, sub-montane heath types represent parallel zonal vegetation to boreal heath types; the montane types are mainly alpine (Ratcliffe & Thompson 1988, Rodwell et al. 1991).

The main heath types of north-western Europe are described and classified in papers like Böcher (1940, 1943), Gimingham (1961, 1972), de Smidt (1967) and Gimingham et al. (1979); Norwegian vegetation types are often included or mentioned, but only as regards the south-western (boreonemoral) part of the country. The vegetation types found in Norwegian heaths are described in the surveys of Norwegian vegetation types by Fremstad (1997).

Fremstad et al. (1991) separated the coastal heathlands of Norway into four main regions, from south to north: the Jæren area, western Norway north to Sunnmøre, Stad to Trondheimsfjord, and north of Trondheimsfjord. Our study area mainly belongs to the last-mentioned region, and in Trøndelag our results support the view of this being a separate region. However, Tveraabak (2004) found some important differences in the vegetation from Vikna to Lofoten and associated these with climatic differences. Hence, it seems reasonable to divide the last-mentioned region of Fremstad et al. (1991) into southern boreal (including our study area) and middle boreal (from Helgeland northwards) regions, as was practised by Moen (1999). The boreal heaths contain less dry heath, have comparatively more *Empetrum nigrum* coll., alpine/northern boreal species are common while species common further south such as *Erica cinerea* is absent (Fremstad et al. 1991).

*Threats on the European heaths*

Agricultural practices have changed over the last century, resulting in a dramatic decrease in the utilisation of the extensive areas of outlying land. The heaths are being colonised by shrubs and trees (Miles 1981, Thompson et al. 1995, Mitchell et al. 1999). Figure 2

illustrates the situation where the ball will move towards the right. Excessive burning (Clémet & Touffet 1981, Maltby et al. 1990), excessive grazing (Hester & Baillie 1998, Hulme et al. 2002, Pakeman et al. 2003) and the use of artificial fertilisers (Aerts & Heil 1993) change heath vegetation into grassland (moving towards the left in Figure 2). The rise in atmospheric nitrogen deposition also affects heaths, reducing the abundance of *Calluna* and increasing that of grasses (Aerts & Heil 1993, de Smidt 1995). Only small areas lacking substantial nitrogen deposition are now safe refugia for heathland and the area north of Bergen can be characterised as such an area (de Smidt 1995).

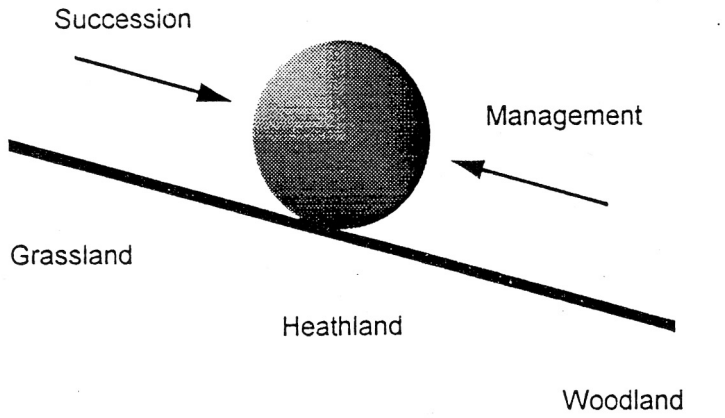



**Figure 2.** Heath vegetation can be considered as a transitional stage in the succession from grassland to woodland. While successional forces tend to drive this change in one direction towards scrub and woodland, management by grazing and burning tends to reverse the trend. Excessive burning and grazing may change heath vegetation into grassland. (From Legg 1995)

Heaths once covered several million hectares, but their extent has so drastically decreased that such vegetation is now classified as greatly endangered (EC Habitats Directive 92/43/EEC, Webb 1998, Aarrestad et al. 2001). Due to the wide distribution of this nature type and its importance for conservation, several recent studies in different regions have focused on heathland management and conservation (e.g. Hobbs & Gimingham 1987, Gimingham 1992, Sedlakova & Chytry 1999, Bokdam & Gleichman 2000, Britton et al. 2000, Aarrestad & Vandvik 2000, Christensen & Johansen 2001, Calvo et al. 2002). Because the threats vary, different means of protecting the heathlands and the heath vegetation must be found.

More needs to be known about the variations present throughout the heathland area in central Norway. Utilisation of the outlying land has decreased during the 20th century

(Tretvik 2003), and the vegetation is changing, particularly due to the rapid invasion of trees and shrubs. Few studies of these northern heaths have been carried out. It is therefore essential to study the patterns and processes in these types of heath, and consider how the heaths should be managed and conserved.

**The aims of this thesis**

This thesis aims to describe the types of coastal heath vegetation occurring in Trøndelag, central Norway. Further, it aims to study the vegetational changes taking place in the central Norwegian heathlands due to decreased or abandoned utilisation and the successions in heaths managed by burning and grazing. This will reveal the similarities and dissimilarities with heaths further south and provide a basis for discussing how these systems may be conserved in the future.

These topics are dealt with in four papers which:

- describe the vegetation types in the coastal heaths of central Norway, interpret the most important gradients and compare these to types of heath vegetation found in other areas, especially in Great Britain (Paper I)
- study, through experiments, the early succession in burned and grazed heath vegetation (Paper II), and especially the dominant heath species, *Calluna* (Paper III)
- quantify, at one site, the invasion of coastal heathland by woodland and scrub during the last 40 years, and relate this to biotic and abiotic factors (Paper IV)
- increase our knowledge about boreal coastal heath vegetation which will create a basis for the conservation and management of these heath types (Papers I, II, III, IV)

**Nomenclature**

Names of vascular plants follow Lid & Lid (1994) and bryophytes follow Frisvoll et al. (1995).

## Study areas

The two main study areas are Tarva in Bjugn and Kalvøya in Vikna. Paper II considers both areas, Paper III Tarva and Paper IV Kalvøya. Paper I presents sample plots from Hitra, Frøya, Ørland, Bjugn, Roan, Osen, Flatanger, Fosnes, Nærøy, Vikna and Leka. All these areas are shown in Figure 3.

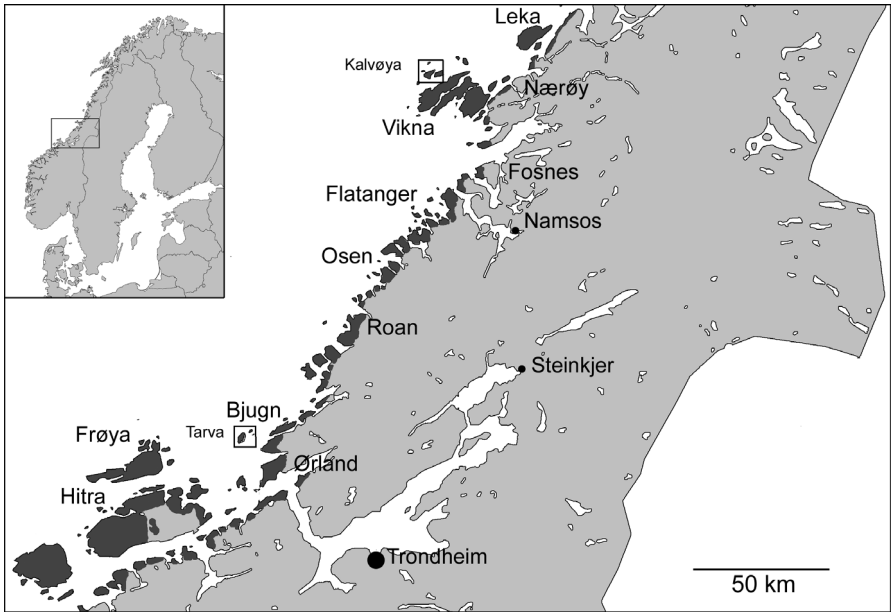



**Figure 3.** The coastal heathland area of Trøndelag, central Norway (after Dahl et al. 1986), showing the location of the localities studied and the islands of Tarva and Kalvøya.

All the areas studied are situated lower than 100 m a.s.l. and less than 3 km from the sea. The localities studied have a yearly precipitation of about 800-1200 mm, and 0.1 mm or more of this precipitation falls on more than 200 days (Førland 1993). The mean annual temperature is approximately 6 $^{o}$C, the mean January (and February) temperature is about 0.5 $^{o}$C and the mean July (and August) temperature is about 12.5 $^{o}$C (Aune 1993). There is a general fall in temperature from south to north, but this difference is small in Trøndelag, and local variations in climate are more important than the regional gradient. All the localities studied are situated in the southern boreal vegetation zone and the humid sub-section of the highly oceanic vegetation section (Moen 1999).

Gneiss is the major rock type in coastal parts of central Norway (Dahl et al. 1997), but more calcareous bedrock occurs here and there (Wolff 1976, Solli et al. 1997). Peat (including raw humus) is the typical soil type on the coastal heaths of central Norway; its

thickness varies up to a few dm and patches of bare rock are frequently present (Fremstad & Nilsen 2000, Nilsen & Moen 2003).

Tretvik (2003) has mapped the former and present-day utilisation of the heathland in the two main study areas, Tarva and Kalvøya. Tarva has had stable grazing pressure by sheep (mostly Norwegian short-tailed sheep (*Ovis brachyura borealis*)) both summer and winter, and cows mostly in summer. The landscape is still open, with almost no invasion of shrubs and trees. Summer dairy farming took place on Kalvøya until 1896. Afterwards, around 300 sheep grazed in summer, but the grazing pressure eventually decreased and almost no stock grazing occurred for 20-30 years until the 1990s when it increased again. Today, 300 sheep graze the island from May to October. In addition, a small flock of Norwegian short-tailed sheep has grazed Kalvøya the whole year round since 2001. Heath burning has been practised on both islands, but rarely after the 1950s.

## Summary of papers

### Paper I

*Coastal heath vegetation types in Trøndelag, central Norway*

Multivariate analyses (DCA and TWINSPAN) were used to analyse a data set of 354 sample plots (1-5 $m^2$) on heath on the coast of Trøndelag, containing 243 taxa. A phytosociological classification of the open coastal heath vegetation was also performed to determine the main floristic gradients. The results were compared with similar vegetation in other parts of Europe, especially Britain (Rodwell et al. 1991, 1992).

The main findings were:

- Four main community types were described: Community type I: Poor Racomitrium heath (34 samples), Community type II: Poor, wet heath (247 samples), Community type III: Herb- and grass-rich dry heath (63 samples) and Community type IV: Extremely rich heath (10 samples)
- In the European hierarchical phytosociological system, the vegetation concerned was classified in five alliances: Erico-Sphagnion (II p.p.), Ericion tetralicis (II p.p.), Myrtillion boreale (II p.p.), Loiseleurio-Vaccinion (I, II p.p., III) and Kobresio-Dryadion (IV)

- The main floristic gradient (DCA1) was a base rich - base poor gradient. DCA2 displayed a tendency for a wet to dry gradient, but also a productive and competitive to low-productive and stagnant gradient
- The vegetation studied was rather poor in species, with a mean of 13-25 species per sample plot in the majority of clusters, and 38 species in the extremely rich heath
- Calluna vulgaris, Empetrum nigrum, Vaccinium myrtillus, V. uliginosum and V. vitis-idaea were among the most frequent and abundant vascular species, and Hylocomium splendens, Hypnum jutlandicum and Pleurozium schreberi the most frequent and abundant mosses. Lichens were most common in the poor communities. The opposite was the case for herbs and graminoids
- The heaths in central Norway lacked a number of typical species from further south, while some other species were common that are absent or only occasionally present in coastal heath vegetation in nemoral and boreonemoral zones. A large number of western species occasionally occurred in the heaths. Carex binervis was an exclusive characteristic species for the heaths.

**Paper II**

*Effects of burning and grazing on boreal heath vegetation in central Norway: an experimental study*

The vegetation dynamics over a period of four years (one year before burning and three years after burning) in coastal heath on Kalvøya and Tarva (two sites on each island) were studied in an experiment based on a repeated measures design. Half of the sample plots were fenced in to exclude domestic animals grazing the study sites. The peat depth, soil pH, loss on ignition and % water contents were recorded in all 48 sample plots. The 192 records of floristic composition were analysed using multifactorial MANOVA. A variance partitioning approach was used to evaluate the influence of measured soil variables.

The main findings were:

- Fire dramatically reduced the cover of dwarf shrubs, bryophytes and lichens
- More than 50 % of the total floristic variance in the data was among sites and plots
- Soil variables explained most of the variation among sites
- In subsequent years, the vegetation recovered towards its pre-treatment floristic composition

- Pioneer species were virtually absent at all sites during the secondary succession in burned plots
- All dwarf shrubs decreased drastically as a consequence of burning. The greatest difference before and after burning was in the amount of *Calluna,* which covered around 80 % before burning and less than 1 % three months after burning. *Calluna* regenerated only from seeds. The other dwarf shrub species also regenerated during the first summer after burning, but vegetatively. *Calluna, Empetrum nigrum* and *Vaccinium vitis-idaea* only partly recovered during the study period, whereas *Vaccinium uliginosum* more than recovered and *Vaccinium myrtillus* returned to pre-treatment levels. Two years after burning, *Calluna* covered 10-30 %
- Other species which decreased after burning were, in particular, the mosses *Dicranum scoparium, Hylocomium splendens, Hypnum jutlandicum* and *Pleurozium schreberi*
- Some species were not affected by the burning (e.g. *Rubus chamaemorus* and *Eriophorum vaginatum*), whereas other species (e.g. *Carex nigra* and *Eriophorum angustifolium*) increased during the study period
- No establishment of tree and shrub species occurred
- No effect of fencing (grazing) was detected, not even in burned plots

**Paper III**

*Early stages of Calluna vulgaris regeneration after burning of coastal heaths on Tarva, central Norway*

The early regeneration of *Calluna* after burning was studied in a series of experiments in wet and dry *Calluna*-dominated heath sites on Tarva. Old and young, wet heath and old, dry heath plots were burned. Data on cover, frequency, height and number of seedlings of *Calluna* were collected in 1 $m^2$ plots for up to three years after burning. Fire temperatures were also measured. Differences in *Calluna* regeneration among treatments and sites were tested in a nested analysis of variance (ANOVA).

The main findings were:

- The mean burning temperature was 680-740 ºC, highest in wet heath with a long burning interval and lowest in wet heath with a short burning interval

- *Calluna* regenerated already the same year it was burned, but only from seeds. Vegetative regeneration was even absent in heath with a short burning interval
- The *Calluna* cover increased yearly and passed 50 % three years after burning. The frequency was high already the year after burning and highest in heath with a short burning interval. The height increased regularly in all sites, but most in dry heath
- The number of seedlings was highest in heath with a short burning interval. Even though only seed germination occurred; the *Calluna* density increased fast, which is positive for conservation and management of boreal coastal heaths

**Paper IV**

*Woodland regeneration in a coastal heathland area in central Norway*

Woodland regeneration was studied on Kalvøya. The areas covered with woodland and scrub in 1961 and 1981 were estimated in a study area of 1.3 $km^2$ using stereo pairs of aerial photos dating from those years. In 2001, the woodland (trees >2 m) and scrub cover was estimated by field studies, using orthophotos from 1981. The species composition was recorded, and the age of the tallest trees in each polygon was measured using an increment corer at their base. The slope, aspect, form, geology, vegetation types and former utilisation were factors used to understand more about the woodland regeneration taking place on the island. GIS were extensively used in this study for data input, analysis and presentation.

The main findings were:

- The coverage of woodland and scrub increased from 3.0 % in 1961 to 4.3 % in 1981 and to 11.6 % in 2001. *Betula pubescens* was the most common tree species, thereafter *Populus tremula, Salix aurita, S. caprea* and *Sorbus aucuparia*
- Woodland was most common where the slope angle exceeded 13º, whereas scrub was most common on more gentle slopes. Aspect gave no clear explanation for the woodland and scrub establishment. Concave and moderately convex forms had the highest woodland coverage
- Most woodland and scrub was found on mica schist, even though marble (metalimestone) is the dominant rock type
- Old trees (150-175 years) were found in the whole area, but their frequency increased with the distance from the former summer farm area

## Discussion

*Changes in the ecology of heaths in central Norway over time*

In the narrow heathland section of Norway woodland was always close by (Skogen 1987). Studies in Vikna (Hoffstad 1899, Tveraabak 2004) confirm this. A land reallocation document from 1831 reported some small wooded areas on Kalvøya (Tretvik 2003) and trees that were up to 175 years old in 2001 may indicate such areas (Paper IV). The well-developed woodland vegetation on Kalvøya, which includes species characteristic of old, continuous forests (most important *Epipogium aphyllum,* (Nilsen & Moen 2003)), also supports this. There may be a number of explanations for why these woodlands were not destroyed: (i) the district has a very scattered population, resulting in little utilisation of the outlying land (Fjær 1983), (ii) the long distance from the farms out to Kalvøya and the fairly long distance from the summer farm area there to the old woodlands, (iii) the farmers owned Kalvøya jointly, which complicated its utilisation (Tretvik 2003), (iiii) perhaps the farmers "protected" some of the woodland to provide shelter for grazing animals.

On Kalvøya (Paper IV) and elsewhere along the coast of central Norway, the vegetation is now changing from open heathland to woodland (Fremstad et al. 1991, Nilsen 1998, 2000, Nilsen & Fremstad 2000). The successional trajectory that occurs on heath will depend on many factors. Proximity to a seed source for the successional species influences which species invade. In central Norway, *Betula pubescens* is the most aggressive invasion species. Establishment occurs in *Calluna* heath gaps (Gimingham 1978), either through seed germination or vegetatively. According to Paper II, no establishment of *Betula pubescens* or other tree and shrub species was found in the burned plots. However, in other areas where woody species already were established in the heath, they sprouted vegetatively and rapidly increased their coverage after burning (L.S. Nilsen pers. obs.). Seed germination of *Betula pubescens* most often takes place near the propagating plant (Harper 1977, Legg 1995). Doeven (2003) found less than 4 % of *Betula* and *Salix* seeds in the seed bank of open heaths (about 10 m from shrubs and trees) on Kalvøya. This indicates that few seeds are available for germination in the open heaths when no shrubs or trees stand near by. Early aerial photos of Kalvøya showed single trees in open heath areas, and dispersal presumably occurred from these individuals. The standing trees produce seeds and spread vegetatively into the open heath. They also form shelter for the new trees, giving the species the chance to expand into less suitable areas. This was the situation

described in Paper IV, and the invasion rate was found to be accelerating. The oldest and largest areas of woodland are on moderate to steep slopes, i.e. in fairly dry areas. The shelter from strong winds provided by steep slopes may also be important. As woodland and scrub are often linked to concave and gentle terrain, the first colonisation often occurs in sheltered places, such as below the crest of a ridge. The grazing pressure is vital in determining the rate of woodland colonisation. Even though Kalvøya is grazed today, the period of 20-30 years with almost no grazing pressure gave woody species the opportunity to establish. The grazing pressure is not high enough for sheep to graze the woody species.

*Heath types in central Norway*

Wet, poor heaths (Community type II, Paper I) are most common in central Norway, due to the humid climate. Typical wet heath species are *Rubus chamaemorus, Carex nigra* and *Eriophorum vaginatum. Calluna* most often dominates and other common species include *Empetrum nigrum, Vaccinium uliginosum, V. vitis-idaea*, *Dicranum scoparium, Hylocomium splendens* and *Pleurozium schreberi*. The community type is heterogeneous and includes types of vegetation that are transitional to mire and dry heath. Mire and wet heath communities are classified in the Erico-Sphagnion and Ericion tetralicis alliances and are close to types M16 (*Erica tetralix-Sphagnum compactum* wet heath) and M19 (*Calluna vulgaris-Eriophorum vaginatum* blanket mire) in the system published by Rodwell et al. (1991). The majority are included in Myrtillion boreale, close to H12 (*Calluna vulgaris-Vaccinium myrtillus* heath) in the British system. When *Arctostaphylos alpinus* and *Racomitrium lanuginosum* are typical species, such heaths classify close to the montane community H17 (*Calluna vulgaris-Arctostaphylos alpinus* heath) in the Loiseleurio-Vaccinion alliance.

Racomitrium heath (Community type I, Paper I) dominates in some drier or stagnant, poor heath areas. The lack or rarity of such species as *Vaccinium myrtillus, Pleurozium schreberi* and *Cornus suecica*, and the lack of wet heath species like *Eriophorum* spp. and *Rubus chamaemorus* characterise this community. *Racomitrium lanuginosum* mainly has a boreal and oceanic distribution, and *Calluna-Racomitrium* heath has its main geographical range in the Scottish mountains and along the coast of central and northern Norway. It is classified in the Loiseleurio-Vaccinion alliance. Rodwell et al. (1991) included *Calluna vulgaris-Racomitrium lanuginosum* heath in their (H14) Montane heaths with lichens and mosses.

Dry heath vegetation (Community type III, Paper I) contains a large number of grasses and herbs, and sometimes some basiphilous species. These are classified in Loiseleurio-Vaccinion. In the British system, the community seems to most closely resemble the H15 (*Calluna vulgaris*-*Juniperus communis* ssp. *nana* heath) community of Rodwell et al. (1991). However, since this British community has no basiphilous species, the "richer part" does not match well with the sub-montane/montane communities of the British system. On the other hand, the lowland (nemoral/boreonemoral) heath communities of the British system include some that contain many herbs and grasses, and some basiphilous species (e.g. H7 (*Calluna vulgaris*-*Scilla verna* heath)).

The extremely rich heath (Community type IV, Paper I) includes a number of basiphilous species which grow together with species regarded as basifugous, like *Calluna*. However, although *Calluna* can grow on soils rich in minerals and nutrients, it may require acid soil to germinate and/or develop (Grubb et al. 1969, Ellenberg 1996). In the study area, where there is high humidity and extensive oligotrophication and humidification, basiphilous and basifugous species can occur together in the same community when the former are deep-rooted (growing in mineral soil) and the latter shallow-rooted and thus growing in the acid layers above. Rodwell et al. (1992) included the extremely rich heath vegetation in the "Calcareous grasslands". It seems most similar to the *Dryas octopetala*-*Carex flacca* heath (CG13), a sub-alpine/montane community classified in the Kobresio-Dryadion alliance (Rodwell et al. 2000).

*Comments on floristic phytogeography*

The strongly western species (frost-sensitive species), *Erica cinerea, Hymenophyllum wilsonii, Luzula multiflora* ssp. *congesta, Scilla verna* and *Vicia orobus*, are common in western Norway as far north as central Norway (Fægri 1960). They are exclusive differential species for the boreonemoral coastal heaths and are lacking (or very rare) in Trøndelag. A large number of additional species with a rather wide western distribution occur (e.g. *Blechnum spicant, Erica tetralix*, *Narthecium ossifragum, Trichophorum cespitosum* ssp. *germanicum, Mnium hornum* and *Plagiothecium undulatum*). The western species, *Carex pulicaris, Juncus squarrosus, Luzula sylvatica*, *Pedicularis sylvatica*, *Mylia taylorii*, *Sphagnum quinquefarium* and *S. strictum*, are rare in the data set used in Paper I. All these western species occur occasionally or frequently in coastal heaths in Europe (e.g. Böcher 1940, Fægri 1960, Gimingham 1961, 1972, de Smidt 1967, Rodwell et al. 1991).

A number of southern thermophilous (nemoral and boreonemoral) heath species are lacking in central Norway (e.g. *Gentiana pneumonanthe*). Of the species that do occur, *Carex flacca* and *Pseudoscleropodium purum* are regarded as weakly southern species in Norway (i.e. species which usually do not occur further north or higher above sea level than the southern boreal vegetation zone, Moen 1999). Species with a southern tendency in their distribution (not occurring above the middle boreal zone) are *Galium verum*, *Linum catharticum, Myrica gale, Pimpinellia saxifraga, Polygala vulgaris* and *Salix aurita*.

The most common species with an upper boreal (and alpine) distribution are *Arctostaphylos alpinus, Betula nana, Rubus chamaemorus* and *Thalictrum alpinum.* Both *Betula nana* and *Rubus chamaemorus* are much more common in central Norway than in the similar communities in Britain. There are also a number of additional species with the same tendencies (e.g. *Trientalis europaeus*, *Vaccinium uliginosum* and *Carex nigra*). *Carex nigra* is common in heath vegetation in central Norway and occurs in mire vegetation all over Europe, but is quite rare in boreonemoral and nemoral heaths and is lacking in the sub-montane and montane heath types in Britain (Rodwell et al. 1991). *Vaccinium uliginosum* is also a frequent and abundant species in central Norwegian heaths compared to nemoral and boreonemoral heaths (Øvstedal 1985), and is much rarer in Britain than in central Norway.

Native *Picea abies* (an eastern species) is very rare in the coastal heathlands of Europe, and occurs only in south-western Sweden and coastal parts of central Norway. It may be an important heath coloniser in both areas (Damman 1957, Vorren 1979, Fremstad et al. 1991, Nilsen 1998, Nilsen & Fremstad 2000, Nilsen & Moen 2003, Paper IV).

*Effects of management*

Because *Calluna* is the dominant heath species, it is important to find out how it reacts to different forms of management. Vegetative regeneration after burning is very common (Whittaker & Gimingham 1962, Kayall & Gimingham 1965, Gimingham 1972, Mallik & Gimingham 1983, Hobbs & Gimingham 1987, Forgeard 1990, Calvo et al. 2002) as, too, is seed germination (e.g. Gimingham 1972), but the age of the *Calluna* plant greatly influences the possibility for vegetative regeneration. If the interval between two burnings is more than 15 years, the amount of vegetative regeneration will decrease (Kayall &

Gimingham 1965, Miller & Miles 1970, Hobbs & Gimingham 1984). If the temperature of the fire is excessively high, this may also prevent vegetative sprouting (Mallik & Gimingham 1985) and also damage the seed bank (Whittaker & Gimingham 1962). In the burned plots on the coastal heaths of central Norway, *Calluna* was only observed to regenerate from seeds (Papers II and III), even where the burning interval was short and burning took place under acceptable temperature conditions (Paper III). Since *Calluna* germinated already the first summer after burning (before flowering), the seeds must have come from the seed bank (Granström 1988, Barclay-Estrup & Gimingham 1994), and studies on Kalvøya indicate that *Calluna* totally dominates the seed bank in heaths (Doeven 2003). It is known that seedlings most commonly occur on peaty soil and other soil with deep organic surface horizons (Whittaker & Gimingham 1962). The seed bank also has a better chance of surviving in damp, peaty soil (Miller & Cummins 1987). Papers II and III mostly deal with wet heath types, which dominate the heaths of central Norway (Paper I). This may explain the large number of seedlings, but not the absence of vegetative regeneration after fire. Vegetative regeneration is even important in western Norway (Aarrestad & Vandvik 2000). Even though regeneration occurred from seeds, the *Calluna* coverage increased rapidly and was more than 50 % three years after burning (Paper III), and varied between 10 % and 30 % two years after burning (Paper II).

Graminoids and herbs (Paper II) recovered rapidly after burning. Their abundance was often higher than before burning, possibly due to reduced competition from *Calluna*. This has also been found in other studies (e.g. Barclay-Estrup & Gimingham 1969, Gimingham et al. 1981, Forgeard 1990, Aarrestad & Vandvik 2000, Calvo et al. 2002). In old, species-poor heath, species with rhizomes quickly recover after burning (Hobbs & Gimingham 1984). *Rubus chamaemorus, Carex nigra, Deschampsia flexuosa* and *Eriophorum angustifolium* are examples of such species (Grime et al. 1988) and the abundance mostly increase immediately after fire. *Carex nigra* may also have a persistent seed bank (Grime et al. 1988), but vegetative regeneration seems to be more important. *Deschampsa flexuosa* may also germinate from seeds in burned areas, but this depends on the seed rain, as it does not maintain a seed bank (Hester et al. 1991). *Campanula rotundifolia, Taraxacum* sp., *Agrostis canina* and *Carex pilulifera* are among the very few species that were new to one or several sites after burning in paper II. All except *Taraxacum* sp. have persistent seed banks (Grime et al. 1988) and *Taraxacum* sp. has small, wind-spread seeds.

Pioneer plants like fire mosses and weeds often colonise areas of burned heath (Clémet & Touffet 1981, Gloaguen & Gautier 1981, Maltby et al. 1990, Aarrestad & Vandvik 1997). Their near absence in the plots studied here may either be due to a shortage of diaspores because such species may be locally rare, or the improbability of diaspores reaching burned areas because the plots were small. The former explanation seems likely as the same is observed on much larger areas of burned heath on both islands (L.S. Nilsen pers. obs.). Hobbs et al. (1984) suggested that the number of species after burning may be related to the "age" of the vegetation when burned (i.e. the length of the period between two successive fires). They found far fewer species after fires on heaths older than 15 years than on younger heaths. However, observations from burned eight-year-old heath on Tarva do not confirm this (Johansen 2003, L.S. Nilsen pers. obs.). On the other hand, the long period since the 1950s with only occasional fires on both islands may have severely restricted the abundance and distribution of ephemeral species such as weeds and mosses that are adapted to the special conditions caused by a fire. Moreover, the experimental sites are located far away from roads and on islands some distance from the mainland. However, on one island in the Froan archipelago, the outermost part of Frøya (Figure 3), *Rumex acetosella*, together with *Calluna* seedlings, totally dominated large parts of an area burnt a few years ago, whereas it was not seen on neighbouring islands (L.S. Nilsen pers. obs.).

According to Paper II, no effects on floristic composition caused by the fencing treatment was found. This is probably related to the small size of the experimental plots and to their surroundings, which were dominated by *Calluna*. They probably did not attract the animals as larger areas of grassland, salt marshes and burned heath were available nearby (L.S. Nilsen pers. obs).

*Conservation and management*

Management is needed when the conservation of a particular type of ecosystem depends on the prevention of unwanted changes (Gimingam 1992). Before starting, appropriate targets must be set, a management plan developed and then a monitoring programme set up to see that targets are being achieved (Marrs & Britton 2000). Historical factors are important when cultural landscape is to be conserved. Previous land use is often of overriding importance when one needs to understand how the systems operated. As part of the present project, Tretvik (2003) studied the land use in 1865-2000 on Tarva and on the neighbouring islands of Borgan and Kalvøya, and management plans were prepared for

both areas (Fremstad & Nilsen 2000, Nilsen & Moen 2003). Today, most of the remaining heathlands in north-western Germany, Denmark and the Netherlands are protected and managed (Rode 2003), and many in Britain too (Ward et al. 1995, Symes & Day 2003). The same interest has not been shown for Norwegian heathlands, and only a few heath areas are protected (Direktoratet for naturforvaltning 1995), mostly for the sake of sea birds and mammals.

Several problems which the protection of heath vegetation further south in Norway and in western Europe have in common are absent in the boreal heaths:

- *Pteridium aquilinum*, which is a problematic species in many heathland areas (Watt 1955, Marrs 1987, Marrs & Pakeman 1995), also in western Norway, is not present in either managed or unmanaged heaths in central Norway
- Atmospheric nitrogen deposition is very low in central Norway compared to the rest of the heathland area (de Smidt 1995, Tørseth et al. 1999) and the change from heath to more grass-dominated vegetation with, especially, *Deschampsia flexuosa* and *Molinia caerulea*, which is a huge problem in, for instance, the Netherlands, Denmark and Britain (Diemont 1996, Riis-Nielsen 1997, Marrs et al. 2004) is not a problem here. The expensive management method of turf stripping to remove nutrients, which is in common use further south (e.g. Bokdam & Gleichman 2000), is unnecessary
- Damaging attacks by the heather beetle (*Lochmaea suturalis*) (Berdowski 1987, Riis-Nielsen 1997) have not been reported in central Norway

Central Norway still has open heaths and they can rather easily be managed and kept open by burning and grazing. Restoring and managing colonised heaths will be a greater problem because woody species quickly regenerate after burning and increase their coverage (L.S. Nilsen pers. obs.). In addition, sheep seem to prefer to graze herbs and grasses in the newly burnt areas rather than the woody species. An appropriate grazing pressure with domestic animals that graze woody species will be essential. Paper II shows that after open heath has been burnt, the same species as before burning regenerate and woody species are absent, but here, too, a suitable grazing pressure is essential.

In addition to preventing scrub colonisation, heath burning hinders further paludification of the heathland which, over time, would lead to blanket bog vegetation. Burning prevents more raw humus and peat from building up, thus helping to preserve access to calcium-rich soils, on which the rich vegetation depends. Even though Kalvøya (Paper IV) is dominated by calcareous bedrock, rich heaths, fens and low-herb woodland vegetation cover only 20 % of the area, and this proportion may decrease in the future if burning does not take place.

**Concluding remarks and further studies**

The main aims of this study have been elucidated through the four papers. A classification of the heathland vegetation in the outermost areas of Trøndelag has been achieved and has been compared with the British system (at the alliance level). Additional phytosociological studies of heaths south and north of Trøndelag should be made to reveal a wider variation and make better comparison with the greater variation described in British vegetation.

In the experimental studies, permanent fences and permanently marked plots were established, and the current studies are intended to form the basis for long-term studies of central Norwegian coastal heaths. Even though the early succession in managed heaths has been documented, a four-year study is too short to follow the long-term dynamics and processes in these systems. More time is needed. There is also a need for several more studies on the same topics to compare with the present results. This study has demonstrated the absence of vegetative regeneration in *Calluna* and of pioneer species after fire. Further studies are required regarding the shift in the regeneration strategy in *Calluna* after burning and where this takes place. Regional studies along the coast should therefore be undertaken. Because the experiments revealed no effects of grazing, it will be necessary to control the grazing pressure in future studies. Studies on the competition and interactions between grass and ling species with different grazing pressures are relevant here.

The quantification of woodland regeneration in this coastal area during the last 40 years shows that major changes are taking place in the coastal landscape due to the change in land use. Further studies of this are needed for comparing the results, and the changes in vegetation should be followed in permanent plots.

**References**

Aarrestad, P.A. & Vandvik, V. 1997. *Leptodontium flexifolium* (Dicks.) Hampe new to Norway from a burnt *Calluna* heath. *Lindbergia* 22: 31-32.

Aarrestad, P.A. & Vandvik, V. 2000. Vegetasjonsendringer i vestnorsk kystlynghei – effekter av skjøtselsformene brann og sauebeite ved rehabilitering av gammel lynghei på Lurekalven i Hordaland. *NINA Rapport* 044: 1-60.

Aarrestad, P.A., Fremstad, E. & Skogen, A. 2001. Kystlyngheivegetasjon. In: Fremstad, E. & Moen, A. (eds.) Truete vegetasjonstyper i Norge, pp. 99-105. *NTNU Vitensk. mus. Rapp. bot. Ser.* 2001-4.

Aerts, R. & Heil, G.W. (eds.) 1993. *Heathlands: Patterns and processes in a changing environment*. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Aune, B. 1993. Air temperature normals, normal period 1961-1990. *DNMI Report* Klima 2: 1-63.

Barclay-Estrup, P. & Gimingham, C.H. 1969. The description and interpretation of cyclical processes in a heath community. I. Vegetational change in relation to the *Calluna* cycle. *J. Ecol.* 57: 737-758.

Barclay-Estrup, P. & Gimingham, C.H. 1994. Seed-shedding in a Scottish heath community. *J. Veg. Sci.* 5: 197-201.

Bennet, K.D., Boreham, S., Sharp, M.J. & Switsu, V.R. 1992. Holocene history of environment, vegetation and human settlement on Catta Ness, Lunnasting, Shetland. *J. Ecol.* 80: 241-273.

Berdowski, J.J.M. 1987. Transition from heathland to grassland initiated by the heather beetle. *Vegetatio* 72: 167-173.

Böcher, T.W. 1940. Studies on the plantgeography of the north-Atlantic heath-formation. I. The heaths of the Faroes. *K. Dan. Vid. Selsk., Biol. Med*. 15: 1-64.

Böcher, T.W. 1943. Studies of the plant-geography of the North-Atlantic heath formation. II. Danish dwarf shrub communities in relation to those of Northern Europe. *K. Dan. Vid. Selsk., Biol. Skr.* 2-7: 1-130.

Bokdam, J. & Gleichman, M.J. 2000. Effects of grazing by free-ranging cattle on vegetation dynamics in a continental north-west European heathland. *J. Appl. Ecol.* 37: 415-431.

Britton, A.J., Carey, P.D., Pakeman, R.J. & Marrs, R.H. 2000. A comparison of regeneration dynamics following gap creation at two geographically contrasting heathland sites. *J. Appl. Ecol.* 37: 832-844.

Calvo, L., Tarrega, R. & Luis, E. 2002. Regeneration patterns in a *Calluna vulgaris* heathland in the Cantabrian mountains (NW Spain): effects of burning, cutting and ploughing. *Acta Oecol*. 23: 81-90.

Christensen, S.N. & Johansen, I. 2001. The lichen-rich coastal heath vegetation on the isle Anholt, Denmark – conservation and management. *J. Coastal Conserv.* 7: 13-22.

Clémet, B. & Touffet, J. 1981. Vegetation dynamics in Brittany heathlands after fire. *Vegetatio* 46: 157-166.

Dahl, E., Elven, R., Moen, A. & Skogen, A. 1986. *Vegetation regions of Norway 1:1 500 000. National Atlas of Norway.* Statens kartverk, Hønefoss.

Dahl, R., Sveian, H. & Thoresen, M.K. (eds.) 1997. *Nord-Trøndelag og Fosen – geologi og landskap.* Norges geologiske undersøkelse. 136 p.

Damman, A.W.H. 1957. The South-Swedish *Calluna*-heath and its relation to the *Calluneto-Genistetum*. *Botaniska Notiser* 110: 363-398.

Diemont, W.H. 1996. *Survival of Dutch heathlands*. Ph.D.Thesis. DLO Institute of Forestry and Nature Research (IBN-DLO), Wageningen, the Netherlands.

Direktoratet for naturforvaltning. 1995. Naturvernområder i Norge 1911-1994. *DN-rapport* 1995-3: 1-178.

Doeven, H.M.W. 2003. *The potential of the soil seed bank in a colonizing heathland on Kalvøya, Central Norway.* Master Thesis. Dept. of Biology and Nature Conservation, Agricultural University of Norway. 34 p.

Ellenberg, H. 1996. *Vegetation Mitteleuropas mit den Alpen*. 5th ed. Ulmer, Stuttgart.

Fægri, K. 1960. *Coastal plants*. Oslo University Press. Oslo. 134 p.

Fjær, O. 1983. Kystlandskap i endring. Eksemplet Vikna i Nord-Trøndelag. *N. Geogr. Tidssk.* 37: 33-54.

Forgeard, F. 1990. Development, growth and species richness on Brittany heathlands after fire. *Acta Oecol.* 11: 191-213.

Førland, E.J. 1993. Precipitation normals, normal period 1961-1990. *DNMI Report* Klima 39: 1-63.

Fremstad, E. 1997. Vegetasjonstyper i Norge. *NINA Temahefte* 12: 1:279.

Fremstad, E., Aarrestad, P.A. & Skogen, A. 1991. Kystlynghei på Vestlandet og i Trøndelag. Naturtype og vegetasjon i fare. *NINA Utredning* 029: 1-172.

Fremstad, E. & Nilsen, L.S. 2000. Tarva: verdifull kulturmark i utmark. *NTNU Vitensk. mus. Rapp. bot. Ser.* 2000-10: 1-29.

Frisvoll, A.A., Elvebakk, A., Flatberg, K.I. & Økland, R.H. 1995. Sjekkliste over norske mosar. Vitskapleg og norsk namneverk. *NINA Temahefte* 4: 1-104.

Gimingham, C.H. 1961. North European heath communities: A "network of variation". *J. Ecol.* 49: 655-694.

Gimingham, C.H. 1972. *Ecology of heathlands*. Chapman & Hall, London.

Gimingham, C.H. 1978. *Calluna* and its associated species: some aspects of co-existence in communities. *Vegetatio* 36: 179-186.

Gimingham, C.H. 1981. Conservation of heathlands. In: Specht, R.L. (ed.) *Ecosystems of the World 9B, Heathlands and related shrublands,* pp. 249-259. Elsevier Amsterdam-Oxford-New York.

Gimingham, C.H. 1992. The lowland heathland management handbook. *English Nature Science* 8: 1-201.

Gimingham, C.H., Chapman, S.B. & Webb, N.R. 1979. European heathlands. In: Specht, R.L. (ed.) *Ecosystems of the world 9A. Heathland and related shrublands, descriptive studies,* pp. 365-413. Elsevier Amsterdam-Oxford-New York.

Gimingham, C.H., Hobbs, R.J. & Mallik, A.U. 1981. Community dynamics in relation to management of heathland vegetation in Scotland. *Vegetatio* 46: 149-155.

Gloaguen, J.C. & Gautier, N. 1981. Pattern development of the vegetation during colonisation of a burnt heathland in Brittany (France). *Vegetatio* 46: 167-176.

Granström, A. 1988. Seed banks at six open and afforested heathland sites in southern Sweden. *J. Appl. Ecol.* 25: 297-306.

Grime, J.P., Hodgson, J.G & Hunt, R. 1988. *Comparative plant ecology. A functional approach to common British species*. Unwin Hyman Ltd, London.

Grubb, P.J., Green, H.E. & Merrifield, R.C.J. 1969. The ecology of chalk heath: Its relevance to the calcicole-calcifuge and soil acidification problems. *J. Ecol.* 57: 175-212.

Haaland, S. 2002. *Fem tusen år med flammer. Det europeiske lyngheilandskapet*. Vigmostad & Bjørke.

Harper, J.L. 1977. *Population biology of plants.* Academic Press, London.

Hester, A.J. & Baillie, G.J. 1998. Spatial and temporal patterns of heather use by sheep and red deer within natural heather/grass mosaics. *J. Appl. Ecol*. 35: 772-784.

Hester, A.J., Gimingham, C.H. & Miles, J. 1991. Succession from heather moorland to birch woodland. III. Seed availability, germination and early growth. *J. Ecol.* 79: 329-344.

Hobbs, R.J. & Gimingham, C.H. 1984. Studies on fire in Scottish heathland communities. II. Post-fire vegetation development. *J. Ecol.* 72: 586-610.

Hobbs, R.J. & Gimingham, C.H. 1987. Vegetation, fire and herbivore interactions in heathland. *Adv. Ecol. Res.* 16: 87-173.

Hobbs, R.J., Mallik, A.U. & Gimingham, C.H. 1984. Studies on fire in Scottish heathland communities. III. Vital attributes of the species. *J. Ecol.* 72: 963-976.

Hoffstad, O.A. 1899. Vegetationen og floraen paa kysten af Trondhjems stift nordenfor Trondheimsfjorden. *Nyt Mag. Naturv*. 37-1: 1-39.

Hulme, P.D., Merrell, B.G., Torvell, L., Fisher, J.M., Small, J.L. & Pakeman, R.J. 2002. Rehabilitation of degraded *Calluna vulgaris* (L.) Hull-dominated wet heath by controlled sheep grazing. *Biol. Conserv*. 107: 351-363.

Johansen, L. 2003. *Suksesjon etter lyngbrenning på Tarva*. Master Thesis, Department of Biology, NTNU. Trondheim. 42 p.

Kaland, P.E. 1979. Landskapsutvikling og bosetningshistorie i Nordhordalands lyngheiområde. In: Fladby, R. & Sandnes, J. (eds.) *På leiting etter den eldste garden.* Universitetsforlaget, Oslo.

Kaland, P.E. 1986. The origin and management of Norwegian coastal heaths as reflected by pollen analysis. In: Behre, K.-E. (ed.) *Anthropogenic indicators in pollen analysis,* pp. 19-36. Balkema, Rotterdam.

Kayall, A.J. & Gimingham, C.H. 1965. Vegetative regeneration of *Calluna vulgaris* after fire. *J. Ecol.* 53: 729-734.

Legg, C. 1995. Heathland dynamics: A matter of scale. In: Thompson, D.B.A., Hester, A.J. & Usher, M.B. (eds.) *Heaths and moorland: Cultural landscapes*, pp. 117-134. HMSO, Edinburgh.

Lid, J. & Lid, D.T. 1994. *Norsk flora*. 6th ed. by R. Elven. Det norske samlaget, Oslo.

Mallik, A.U. & Gimingham, C.H. 1983. Regeneration of heathland plants following burning. *Vegetatio* 53: 45-58.

Mallik, A.U. & Gimingham, C.H. 1985. Ecological effects of heather burning. II. Effects on seed germination and vegetative regeneration. *J. Ecol.* 73: 633-644.

Maltby, E., Legg, C.J. & Proctor, M.C.F. 1990. The ecology of severe moorland fire on the North York moors: effects of the 1976 fires, and subsequent surface and vegetation development. *J. Ecol.* 78: 490-518.

Marrs, R.H. 1987. Studies of conservation of lowland *Calluna* heaths. I. Control of birch and bracken and its effects on heath vegetation. *J. Appl. Ecol*. 24: 163-175.

Marrs, R.H. & Britton, A. 2000. Conservation problems on Breckland heaths: from theory to practice. *Biol. Cons.* 95: 143-151.

Marrs, R.H. & Pakeman, R.J. 1995. Bracken invasion – lessons from the past and prospects for the future. In: Thompson, D.B.A., Hester, A.J. & Usher, M.B. (eds.) *Heaths and moorland: Cultural landscapes*, pp. 180-193. HMSO, Edinburgh.

Marrs, R.H., Phillips, J.D.P., Todd, P.A., Ghorbani, J. & Le Duc, M.G. 2004. Control of *Molinia caerulea* on upland moors. *J. Appl. Ecol.* 41: 398-411.

Miles, J. 1981. *Effect of birch on moorlands*. Institute of Terrestrial Ecology, Banchory.

Miller, G.R. & Miles, J. 1970. Regeneration of heather (*Calluna vulgaris* (L.) Hull) at different ages and seasons in North–East Scotland. *J. Appl. Ecol*. 7: 51-60.

Miller, G.R. & Cummins, R.P. 1987. Role of buried viable seeds in the recolonization of disturbed ground by heather (*Calluna vulgaris* (L.) Hull) in the Cairngorm mountains, Scotland, U.K. *Arct. Alp. Res.* 19: 396-401.

Mitchell R.J., Marrs, R.H., Le Duc, M.G. & Auld, M.H.D. 1999. A study of succession on lowland heaths in Dorset, southern England: changes in vegetation and soil chemical properties. *J. Appl. Ecol*. 34: 1426-1444.

Moen, A. 1999. *National Atlas of Norway: Vegetation*. Norwegian Mapping Authority, Hønefoss.

Nilsen, L.S. 1998. Skisse til skjøtselsplan for Kjeksvika-området i Nærøy, Nord-Trøndelag. *NTNU Vitensk.mus. Rapp. bot. Ser.* 1998-5: 1-22.

Nilsen, L.S. 2000. Botanisk kartlegging og plan for skjøtsel av sørvestlige deler av Aspøya i Flatanger, Nord-Trøndelag. *NTNU Vitensk.mus. Rapp. bot. Ser.* 2000-9: 1-26.

Nilsen, L.S. & Fremstad, E. 2000. Skjøtselsplan for Skeisnesset, Leka, Nord-Trøndelag. *NTNU Vitensk.mus. Rapp. bot. Ser.* 2000-1: 1-31.

Nilsen, L.S. & Moen, A. 2003. Plantelivet på Kalvøya ved Borgan, Vikna, og forslag til skjøtsel av kystlyngheilandskapet. *NTNU Vitensk. mus. Rapp. bot. Ser.* 2003-3: 1-51.

Odgaard, B.V. 1994. The Holocene vegetation history of northern west Jutland, Denmark. *Opera Bot.* 123: 1-171.

Øvstedal, D.O. 1985. The vegetation of Lindås and Austrheim, western Norway. *Phytocoenologia* 13: 323-449.

Pakeman, R.J., Hulme, P.D., Torvell, L. & Fisher, J.M. 2003. Rehabilitation of degraded dry heather (*Calluna vulgaris* (L.) Hull) moorland by controlled sheep grazing. *Biol. Conserv.* 114: 389-400.

Paus, Aa. 1982. *Paleoøkologiske undersøkelser på Frøya, Sør-Trøndelag*. Master Thesis, Department of Botany, University of Trondheim.

Prøsch-Danielsen, L. & Simonsen, A. 2000. The deforestation patterns and the establishment of the coastal heathland of southwestern Norway. *AmS-Skrifter 15*: 1-52.

Ramfjord, H. 1979. *Vegetasjons- og klimahistorie gjennom de siste 9000 år i Nærøy, Nord-Trøndelag.* Master Thesis, Department of Botany, University of Trondheim.

Ratcliffe, D.A. & Thompson, D.B.A. 1988. The British uplands: their ecological character and international significance. In: Usher, M.B. & Thompson, D.B.A. (eds.) *Ecological change in the uplands,* pp. 9-35. Blackwell Scientific Publications, Oxford.

Riis-Nielsen, T. 1997. *Effects of nitrogen on the stability and dynamics of Danish heathland vegetation.* Ph.D. Thesis. Department of Plant Ecology. University of Copenhagen. 183 p.

Rode, M. 2003. Process-oriented heathland management. In: *8th European heathland Workshop 3rd to 11th July 2003. Abstracts of talks and posters*, pp. 15. Alfred Toepfer Academy for Nature Conservation.

Rodwell, J.S., Dring, J.C., Averis, A.B.G., Proctor, M.C.F., Malloch, A.J.C., Schaminée, J.H.J. & Dargie, T.C.D. 2000. *Rewiew of the coverage of the national vegetation classification.* JNCC. Peterborough.

Rodwell, J.S. (ed.), Pigott, C.D., Ratcliffe, D.A., Malloch, A.J.C., Birks, H.J.B., Proctor, M.C.F., Shimwell, D.W., Huntley, J.P., Radford, E., Wigginton, M.J. & Wilkins, P. 1991. *British Plant Communities 2. Mires and heaths.* Cambridge Univ. Press.

Rodwell, J.S. (ed.), Pigott, C.D., Ratcliffe, D.A., Malloch, A.J.C., Birks, H.J.B., Proctor, M.C.F., Shimwell, D.W., Huntley, J.P., Radford, E., Wigginton, M.J. & Wilkins, P. 1992. *British Plant Communities 3. Grasslands and montane communities*. Cambridge University Press. 540 pp.

Sageidet, B.M. 1999. Lyngheienes historie på Smøla, Møre og Romsdal. In: Selsing, L. & Lillehammer, G. (eds.), Museumslandskap. Artikkelsamling til Kerstin Griffin på 60-årsdagen. *AmS-Rapport* 12A: 243-246.

Sedlakova, I. & Chytry, M. 1999. Regeneration patterns in a Central European dry heathland: effects of burning, sod-cutting and cutting. *Plant Ecol.* 143: 77-87.

Skogen, A. 1987. Conversion of Norwegian coastal heath landscape through development of potential natural vegetation. In: Miyawaki, A., Bogenrieder, A., Okuda, S. & White, J. (eds.) *Vegetation ecology and creation of new environments. Proceedings of the international symposium in Tokyo and phytogeographical excursion through central Honshu*, pp. 195-204. Tokyo, Tokai University Press.

de Smidt, J.T. 1967. Phytogeographical relations in the north west European heath. *Acta Bot. Neerl.* 15: 630-647.

de Smidt, J.T. 1979. Origin and destruction of northwest European heath vegetation. In: Wilmanns, O. & Tüxen, R (eds.) *Werden und Vergehen von Pflanzengesellsshaften,* pp. 411-435. J. Cramer, Vaduz.

de Smidt, J.T. 1995. The imminent destruction of Northwest European heaths due to atmospheric nitrogen deposition. In: Thompson, D.B.A., Hester, A.J. & Usher, M.B. (eds.) *Heaths and moorland, cultural landscapes*, pp. 206-217. SNH, Edinburgh.

Solem, T. 1989. Blanket mire formation at Haramsøy, Møre og Romsdal, Western Norway. *Boreas* 18: 221-235.

Solli, A., Bugge, T. & Thorsnes, T. 1997. *Geologisk kart over Norge, berggrunnskart Namsos, M 1: 250 000.* Norges geologiske undersøkelse.

Specht, R.L. 1979. Heathlands of the world. In: Specht, R.L. (ed.) *Ecosystems of the world 9A. Heathland and related shrublands,* pp. 1-18. Elsevier Amsterdam-Oxford-New York.

Symes, N. & Day, J. 2003. *A practical guide to the restoration and management of lowland heathland.* The Royal Society for the Protection of Birds, The Lodge, Sandy, Beds SG19 2DL. 307 p.

Thompson, D.B.A., McDonald, A.J., Marsden, J.H. & Galbraith, C.A. 1995. Upland heather moorland in Great Britain: a review of international importance, vegetation change and other objectives, for nature conservation. *Biol. Conserv.* 71: 163-178.

Tørseth, K., Berg, T., Hanssen, J.E. & Manø, S. 1999. Overvåking av langtransportert forurenset luft og nedbør. Atmosfærisk tilførsel, 1998. *SFT Rapp*. 768-99: 1-145.

Tretvik, A.M. 2003. Landskap og levemåte i små kystsamfunn. Tarva i Bjugn og Borgan i Vikna ca. 1865-2000. *NTNU Vitensk.mus. Rapp. bot. Ser.* 2003-4: 1-58.

Tveraabak, L.U. 2004. *Lowland Calluna heath vegetation along the coast of North Trøndelag and Nordland, Norway: present state, development and changes during the last 4-5000 years.* Dr. scient thesis. Department of Biology, University of Tromsø.

Vorren, K.D. 1979. Die Moorvegetation in Namdalen, Mittel-Norwegen. Eine Untersuchung mit besonderer Berücksichtigung des ozeanischen Gradienten der südborealen Hochmoorvegetation. *TROMURA Naturvitenskap* 8, University of Tromsø.

Ward, S.D., MacDonald, A.J. & Matthew, E.M. 1995. Scottish heaths and moorland: How should conservation be taken forward? In: Thompson, D.B.A., Hester, A.J. & Usher, M.B. (eds.) *Heaths and moorland: Cultural landscapes*, pp. 319-333. HMSO, Edinburgh.

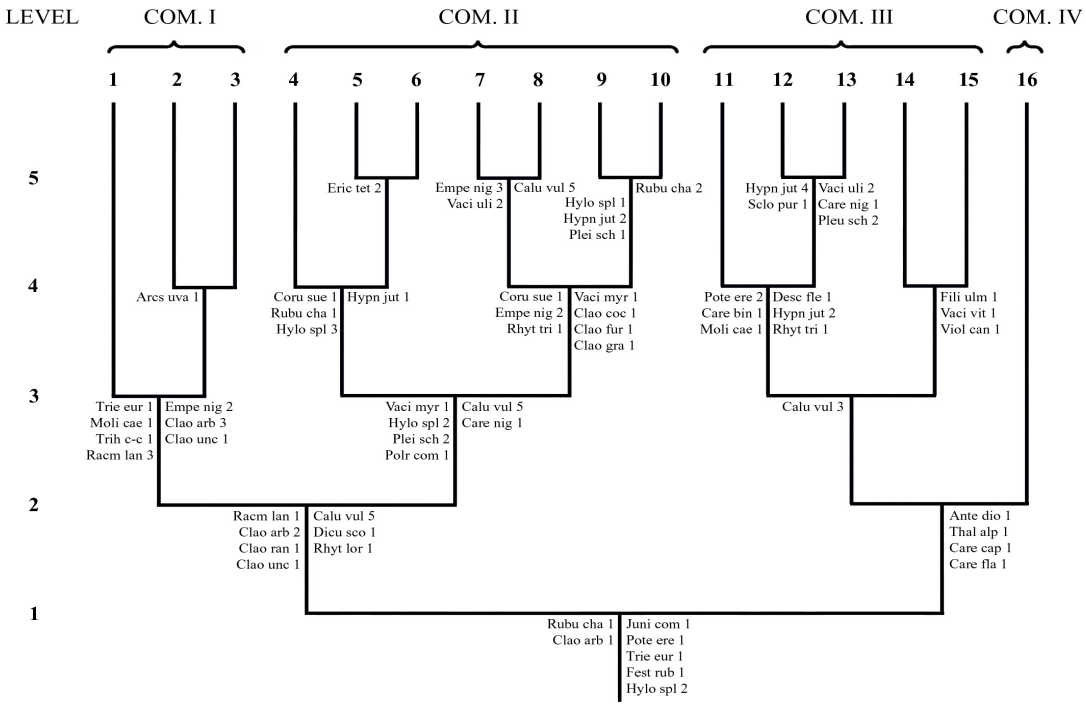
Watt, A.S. 1955. Bracken versus heather, a study in plant sociology. *J. Ecol.* 43: 490-506.

Webb, N.R. 1998. The traditional management of European heathlands. *J. Appl. Ecol.* 35: 987-990.

Whittaker, E. & Gimingham, C.H. 1962. The effects of fire on regeneration of *Calluna vulgaris* (L.) Hull. from seed. *J. Ecol.* 50: 815-822.

Wolff, F.C. 1976. *Geologisk kart over Norge, berggrunnskart Trondheim, M 1: 250 000*. Norges geologiske undersøkelse.

# Paper I


LEVEL
COM. I
COM. II
COM. III
COM. IV
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
5
4
3
2
1
Eric tet 2
Empe nig 3
Vaci uli 2
Calu vul 5
Hylo spl 1
Hypn jut 2
Plei sch 1
Rubu cha 2
Hypn jut 4
Sclo pur 1
Vaci uli 2
Care nig 1
Pleu sch 2
Arcs uva 1
Coru sue 1
Rubu cha 1
Hylo spl 3
Hypn jut 1
Coru sue 1
Empe nig 2
Rhyt tri 1
Vaci myr 1
Clao coc 1
Clao fur 1
Clao gra 1
Pote ere 2
Care bin 1
Moli cae 1
Desc fle 1
Hypn jut 2
Rhyt tri 1
Fili ulm 1
Vaci vit 1
Viol can 1
Trie eur 1
Moli cae 1
Trih c-c 1
Racm lan 3
Empe nig 2
Clao arb 3
Clao unc 1
Vaci myr 1
Hylo spl 2
Plei sch 2
Polr com 1
Calu vul 5
Care nig 1
Calu vul 3
Racm lan 1
Clao arb 2
Clao ran 1
Clao unc 1
Calu vul 5
Dicu sco 1
Rhyt lor 1
Ante dio 1
Thal alp 1
Care cap 1
Care fla 1
Rubu cha 1
Clao arb 1
Juni com 1
Pote ere 1
Trie eur 1
Fest rub 1
Hylo spl 2

# Coastal heath vegetation types in Trøndelag, central Norway

Liv S. NILSEN & Asbjørn MOEN, Norwegian University of Science and Technology, Museum of Natural History and Archaeology, N-7491 Trondheim.

With 4 figures and 4 tables

# Paper II

# Effects of burning and grazing on coastal heath vegetation in central Norway: an experimental study

**Nilsen, Liv S.**[1*] **& Pedersen, Bård** [2]

[1]*Norwegian University of Science and Technology, Museum of Natural History and Archaeology, N-7491 Trondheim;* [2]*Norwegian University of Science and Technology, Department of Biology, N-7491 Trondheim; E-mail baard.pedersen@bio.ntnu.no*

[*]*Corresponding author; Fax; +4773592249; E-mail liv.nilsen@vm.ntnu.no*

# Paper III

# Early stages of *Calluna vulgaris* regeneration after burning of coastal heaths on Tarva, central Norway

**Nilsen, Liv S.[1*]; Johansen, Line[1] & Velle, Liv G.[1,2]**

*[1]Norwegian University of Science and Technology, Museum of Natural History and Archaeology, Section of Natural History, N-7491 Trondheim, Norway; E-mail* line.johansen@vm.ntnu.no *[2]Present address; Norwegian Crop Research Institute, Fureneset Rural Development Centre, Fure, N-6967 Hellevik i Fjaler, Norway; E-mail* liv.velle@PLANTEFORSK.NO *[*]Corresponding author; Fax; +4773592249; E-mail* liv.nilsen@vm.ntnu.no

# Paper IV

# Woodland regeneration in a coastal heathland area in central Norway

LIV S. NILSEN[1,*], ANNE AASMUNDSEN[1,2], ASBJØRN MOEN[1] & ALF IVAR OTERHOLM[3]

[1]Norwegian University of Science and Technology, Museum of Natural History and Archaeology, N-7491 Trondheim, Norway; [2]Present address: Telemark University College, Department of Environmental and Health Studies, N-3800 Bø, Norway; [3]Norwegian University of Science and Technology, Department of Urban Design and Planning, N-7491 Trondheim, Norway

*Corresponding author, e-mail: liv.nilsen@vm.ntnu.no, fax: +4773592249