Report concerning the intensive monitoring of dune heaths 2002 to 2005 (Action F2).

Ib Johnsen¹, Torben Riis-Nielsen, Steen N. Christensen & Mogens Ring Petersen

Figure 1. From Hulsig Heath november 2005. PhD Torben Riis-Nielsen, MSc Steen N. Christensen and MSc Mogens Ring Petersen during field work.

¹ Corresponding author: Ib Johnsen professor, PhD, Biological Institute, University of Copenhagen
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Introduction.

During this part of the joined project the aim was to produce results to identify and qualify the best possible way to restore and maintain the Atlantic coastal dune heath, based on experiences obtained from various parts of the large Danish share of this high priority ecosystem in Europe. The study has generated a large number of results, of which some have yet to be analysed. The results presented in this report are those with particular relevance for management practice.

The study includes analyses of the vegetation of dune ecosystems before and shortly (up to three years) after management, including different ways of removal of self-sown mountain pine (*Pinus mugo*) and lodgepole pine (*P. contorta*) as well as use of e.g. extensive grazing as a heath restoration and long-term maintenance method. The observations made during this project were, however, compared with results from earlier and similar studies, so longer time series could be discussed and related to findings from dune heath areas outside this LIFE project.

The vegetation analyses took partly place outside but adjacent to the managed dune heath areas to describe the original minimally disturbed ecosystem (close to the expected outcome of the management effort), partly within the managed areas before and after the restoration treatment by the regional County or State Forest District under the Danish Forest and Nature Agency.

The recorded starting point (reference) before treatment and the character of the early successions after treatment were used to predict the probable outcome of the management effort and to suggest measures to maintain the Atlantic coastal heath to fulfil the criteria for acceptable favourable conservation status according to the Habitat Directive.

The Atlantic coastal heath in Denmark is a very complex ecosystem, being a mosaic of patches with different dominants and characteristic species, subject to the variation mainly with respect to hydrology and soil properties. The pre-quaternary formations vary strongly within the country, thus causing high variation in mineral composition of the subsoil. Normally, however, the coastal heath subsoil is overlain by aeolic sand, depleted of most of its mineral content.
The monitoring field work.

The SCI sites visited during the F2 action is shown in Table 1.

<table>
<thead>
<tr>
<th>NATURA 2002 designation</th>
<th>SCI no.</th>
<th>Geographic Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>DK00FX005</td>
<td>2</td>
<td>South of Råbjerg Mile</td>
</tr>
<tr>
<td>DK00FX118</td>
<td>10</td>
<td>Højsande, Læsø</td>
</tr>
<tr>
<td>DK00FX121</td>
<td>13</td>
<td>Svinklov</td>
</tr>
<tr>
<td>DK00EY124</td>
<td>16</td>
<td>Bulbjerg</td>
</tr>
<tr>
<td>DK00AX172</td>
<td>72</td>
<td>Lyngbos Hede; Kærgård Plantage</td>
</tr>
<tr>
<td>DK00AX173</td>
<td>73</td>
<td>Kallesmærsk Hede; Grærup Hede</td>
</tr>
<tr>
<td>DK00AY176</td>
<td>78</td>
<td>Wadden Sea, Fanø</td>
</tr>
<tr>
<td>DK00AY176</td>
<td>78</td>
<td>Wadden Sea, Rømø</td>
</tr>
<tr>
<td>DK00EX265</td>
<td>184</td>
<td>Klitheder mellem Stenbjerg og Lodbjerg</td>
</tr>
<tr>
<td>DK00EX266</td>
<td>185</td>
<td>Lild Strand</td>
</tr>
<tr>
<td>DK00FX274</td>
<td>193</td>
<td>Ejstrup klit og Egvands Bakker</td>
</tr>
</tbody>
</table>

Table 1. The sites analysed during the intensive monitoring project part (F2).

**SCI site no. 2, Råbjerg Mile and surroundings.**

This site has a high representation of undisturbed dune heath on acid sandy soil, representing the reference condition on the Skaw Spit (Skagens Odde) coast. Figure 2 show an example of the vegetation without adverse impact of invading conifers. The heterogeneity of the mosaic grey dune heath is evident, as the vegetation described in Figure 2 is composed of frequent species occurring mainly on the heath plains together with dune species characteristic of north facing slopes like *Peltigera hymenina*, *Polypodium vulgare* and *Pleurozium schreberi* and species characteristic of south facing slopes like *Corynephorus canescens*, *Cetraria aculeata* and *Cladonia foliacea*. The small differences in climatic conditions influence the distribution pattern of the species, and the climate characteristic of north facing slopes with higher relative humidity and reduced light exposure is somewhat similar to the climate in an open stand of *Pinus mugo*. For instance, the dominant species found in such open conifer stands typically e.g. include pleurocarpous bryophytes like *Pleurozium schreberi*. 
Figure 2. Typical species composition and relative cover (Pin Point frequency) of undisturbed grey dune vegetation acid sand.

**SCI 2 sites around Lodskovvad Mile.**

<table>
<thead>
<tr>
<th>GPS coordinates (WSG84)</th>
<th>Deg</th>
<th>Min</th>
<th>Sec</th>
<th>Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Felt 1</td>
<td>57</td>
<td>37</td>
<td>44</td>
<td>North</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>24</td>
<td>0</td>
<td>East</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>GPS coordinates (WSG84)</th>
<th>Deg</th>
<th>Min</th>
<th>Sec</th>
<th>Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Felt 2</td>
<td>57</td>
<td>37</td>
<td>41</td>
<td>North</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>23</td>
<td>59</td>
<td>East</td>
</tr>
</tbody>
</table>
Description of the area, where the plots were established:

The heath area is under invasion of various conifer species, mainly *Pinus mugo*, *Pinus contorta* and *Picea sitchensis*. It is by 2003 still rather open, but in the most closed tree vegetation, a marked change has taken place in vegetation structure and composition. The dwarf shrub most dominant in these areas is *Empetrum nigrum*, with *Carex arenaria* as subdominant. This stage is considered intermediary, and precedes the later succession stage with dominating *Empetrum nigrum*, *Deschampsia flexuosa*, *Pleurozium schreberi*, *Hypnum cupressiforme* and *Cladonia portentosa/C. ciliata*

*Empetrum nigrum* is the most sensitive dwarf shrub to physical impact (and thus benefits from the total absence of physical stress from e.g. herbivores and man in a more or less closed *Pinus mugo* stand), has a low compensation point and benefits most rapidly from nutrient supply (e.g. supplied from the tree canopies by leaching) (Tybirk et al. 2000).
Permanent plot (felt 1) in recently cleared area, Lodskovvad.

Permanent plot (felt 2) in recently cleared area, Lodskovvad.
Vegetation analyses from 2003:

**Lodskovvad Mile SCI 2, felt 1**

Recent Pinus clearing

- Calluna vulgaris
- Carex arenaria
- Cladonia portentosa
- Deschampsia flexuosa
- Empetrum nigrum
- Hypnum cupressiforme
- Pleurozium schreberi
- Salix repens

Pin point frequency %

The figure shows a species poor community with only 5 phanerogams, 2 bryophytes and one lichen species.

**Lodskovvad Mile SCI 2, felt 2**

Open undisturbed grey dune vegetation

- Carex arenaria
- Cetraria sp.
- Cladonia arbuscula
- Cladonia cornuta
- Cladonia diversa
- Cladonia glauca
- Cladonia gracilis
- Cladonia macilenta
- Cladonia merochlorophaea
- Cladonia portentosa
- Corynephorus canescens
- Hypochoeris radicata
- Jasione montana
- Polytrichum piliferum
- Rumex acetosella
- Stereocaulon sp.

Pin point frequency %

In this plot are 6 phanerogams (including *Ammophila arenaria*), 10 lichen species and 1 bryophyte.
It is seen, that the diversity decreases strongly with increasing *Pinus mugo* cover. Only by total removal of *Pinus mugo* combined with continuing abatement of invasion of conifers, may the system recover; the speed is strongly dependent on the distance to nearest intact dune heath vegetation and the timing of the clearing. The later the conifer clearing takes place, the longer the recovery.
SCI 10. Højsande, Læsø

At the island of Læsø, recordings of the flora of the grey dunes adjacent to and within the managed areas were made.

The area Højsande includes large areas with high ground water table and covered with *Betula* spp. (*B. verrucosa* and *B. pubescens*) forest. The removal of *Pinus* spp. from Højsande do not prevent the re-growth of the deciduous forest in the low lying areas, but may delay or even prevent establishment of forests at the dunes themselves. It is particularly important to monitor the vegetation development in the cleared areas in the years ahead, to answer the two questions: 1) Is the open condition stable, or does the *Betula* spp. forest invade the dunes? 2) Do the red-listed and rare species from the neighbouring grey dune re-enter the cleared dunes?

The vegetation of the dune heaths at Læsø is extremely valuable, and reestablishment of the open dune heath at Læsø is of particular high importance from a botanical point of view. The following table with comments qualify this statement.

The ice age relicts in the dune heaths are under severe pressure at present. Studies of the development of *Flavocetraria nivalis* at Spirbakke Mile have revealed a rapid decline in some of the permanent plots, selected originally due to the high cover of *F. nivalis*. There are a number of hypotheses put forward to explain this. One is the fixation by and strong growth of a grass carpet, being competitive towards the epigeic lichens, another is the current change in climatic conditions and finally the total removal of sheep grazing has been blamed. Which hypothesis or hypothesis combination that eventually may prove correct remain to be seen, but in the mean-time, management of the dune heath to ensure open conditions is a minimum prerequisite.

The highly diverse vegetation – especially with respect to lichens and bryophytes – of the heaths at Læsø is presented in the table below.

<table>
<thead>
<tr>
<th>Genus</th>
<th>Species</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Acarospora</em></td>
<td><em>fuscata</em></td>
<td>Epilithic lichen</td>
</tr>
<tr>
<td><em>Aira</em></td>
<td><em>praecox</em></td>
<td>Phanerogam</td>
</tr>
<tr>
<td><em>Alectoria</em></td>
<td><em>sarmentosa var. vexillifera</em></td>
<td>Red-listed, ice age relict. Epigeic lichen</td>
</tr>
<tr>
<td><em>Ammophila</em></td>
<td><em>arenaria</em></td>
<td>Phanerogam</td>
</tr>
<tr>
<td><em>Calluna</em></td>
<td><em>vulgaris</em></td>
<td>Phanerogam</td>
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<tr>
<td><em>Campylopus</em></td>
<td><em>introflexus</em></td>
<td>Bryophyte</td>
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<tr>
<td><em>Cephaloziella</em></td>
<td><em>divaricata</em></td>
<td>Hepatic</td>
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<tr>
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<td><em>purpureus</em></td>
<td>Bryophyte</td>
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<td><em>Cetraria</em></td>
<td><em>aculeata</em></td>
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<tr>
<td><em>Cetraria</em></td>
<td><em>chlorophylla</em></td>
<td>Epigeic lichen</td>
</tr>
<tr>
<td><strong>Cetraria</strong></td>
<td><strong>erictorum</strong></td>
<td><strong>Rare. Epigeic lichen</strong></td>
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<tr>
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<td><em>islandica</em></td>
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<td><em>muricata</em></td>
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<td>Genus</td>
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<td>floerkeana</td>
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<td>Cladonia</td>
<td>glauca</td>
<td>Epigeic lichen</td>
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<td>gracilis</td>
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<td>phyllophora</td>
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<td>pleurota</td>
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<td>portentosa</td>
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<td>canescens</td>
<td>Phanerogam</td>
</tr>
<tr>
<td>Deschampsia</td>
<td>flexuosa</td>
<td>Phanerogam</td>
</tr>
<tr>
<td>Dicranum</td>
<td>scoparum</td>
<td>Bryophyte</td>
</tr>
<tr>
<td>Dicranum</td>
<td>polysetum</td>
<td>Bryophyte</td>
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<tr>
<td>Drepanoclados</td>
<td>uncinatus</td>
<td>Bryophyte</td>
</tr>
<tr>
<td>Empetrum</td>
<td>nigrum</td>
<td>Phanerogam</td>
</tr>
<tr>
<td>Erica</td>
<td>tetralix</td>
<td>Phanerogam</td>
</tr>
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<td>Festuca</td>
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<td>Phanerogam</td>
</tr>
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<td>Hieracium</td>
<td>umbrillatum</td>
<td>Phanerogam</td>
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<td>Hylocomium</td>
<td>splendidens</td>
<td>Bryophyte</td>
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<td>Hypnum</td>
<td>cupressiforme</td>
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<td>Hypochoeris</td>
<td>radicata</td>
<td>Phanerogam</td>
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<tr>
<td>Hypogymnia</td>
<td>physodes</td>
<td>Epigeic and epiphytic lichen</td>
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<td>Jasione</td>
<td>montana</td>
<td>Phanerogam</td>
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<tr>
<td>Klebsormidium</td>
<td>sp.</td>
<td>Green alga</td>
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<td>Placynthiella</td>
<td>uliginosa</td>
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<td>corniculatus</td>
<td>Phanerogam</td>
</tr>
<tr>
<td>Polytrichum</td>
<td>juniperinum</td>
<td>Bryophyte</td>
</tr>
<tr>
<td>Polytrichum</td>
<td>piliferum</td>
<td>Bryophyte</td>
</tr>
</tbody>
</table>

**Ochrolechia frigida** | **Red-listed, ice age relict. Epigeic lichen** |
<p>| Parmelia   | mougeotii       | Epilithic lichen          |
| Parmelia   | saxatilis       | Epilithic lichen          |
| Platismatia | glauca         | Epigeic lichen            |
| Pleurozium | schreberi       | Bryophyte                 |
| Polypodium | vulgare         | Fern                      |
| Polytrichum | juniperinum     | Bryophyte                 |
| Polytrichum | piliferum       | Bryophyte                 |</p>
<table>
<thead>
<tr>
<th>Species</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pseudevernia furfuracea</td>
<td>Epigeic lichen</td>
<td></td>
</tr>
<tr>
<td>Ptilidium ciliare</td>
<td>Hepatic</td>
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</tr>
<tr>
<td>Racemitrium ericoides</td>
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<td>Rhizocarpon geographicum</td>
<td>Epilithic lichen</td>
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</tr>
<tr>
<td>Rhizocarpon obscuratum</td>
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</tr>
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<td>Rhizocarpon richardii</td>
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<td>Rhytidiadelphus triquetrus</td>
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<td>Salix repens</td>
<td>Phanerogam</td>
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<td>Stereocaulon condensatum</td>
<td>Epigeic lichen</td>
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<td>Stereocaulon saxatil</td>
<td>Epigeic lichen</td>
<td></td>
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<tr>
<td>Teesdalia nudicaulis</td>
<td>Phanerogam</td>
<td></td>
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<tr>
<td>Trapeliopsis granulosa</td>
<td>Epigeic lichen</td>
<td></td>
</tr>
<tr>
<td>Viola canina</td>
<td>Phanerogam</td>
<td></td>
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</tbody>
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SCI 13 sites at Svinklov.

Figure 3. The analysed area at Svinklov, near mouth of Slette Å.

Figure 4. The analysed area close to Svinklovene and Grønnestrand
The area is dominated by dwarf shrub heath and dry grassland with juniper, reflecting former grazing land-use. The proximity of cretaceous deposits and the resulting mineral supply from below is reflected in the frequent occurrence of e.g. *Cladonia furcata* and *Cladonia rangiformis*.

The investigated area includes heath around the mouth of Slette Å, Svinklovene (western end of plantation) and just east of Grønne Strand (highest point: Stenbjerg)

<table>
<thead>
<tr>
<th>Geographic position</th>
<th>Comments</th>
<th>Time of clearing of conifers</th>
<th>Permanent plot established</th>
<th>Dominant epigeic species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position: 57°09'01 N; 9°20'54 E</td>
<td>Recently cleared; no records due to strong disturbance</td>
<td>Jan/Feb 03</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>57°09'00 N; 9°20'53 E</td>
<td>Not yet cleared</td>
<td>Yes, 6th March 2003</td>
<td>Empetrum nigrum and Pleurozium schreberi</td>
<td></td>
</tr>
<tr>
<td>57°09'04 N; 9°20'57 E</td>
<td>Recently cleared; No records due to strong disturbance</td>
<td>Jan/Feb 03</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>57°08'55 N; 9°18'03 E</td>
<td>No records due to strong disturbance</td>
<td>Jan/Feb 03</td>
<td>No</td>
<td>Litorina-slope cleared for <em>Picea sitchensis</em> and <em>Pinus mugo</em>. Plantation of <em>P. sitchensis</em> extends to top of slope. Exposed soil rich in chalk occur due to wind and water erosion</td>
</tr>
<tr>
<td>57°07'36 N; 9°18'04 E</td>
<td>Open area with dune heath and no invasion of conifers</td>
<td>No</td>
<td>High biodiversity due to complexity of topography and soil properties</td>
<td></td>
</tr>
</tbody>
</table>
In figure 5 is shown the major impact on biodiversity due to invasion of *Pinus mugo* to dune heaths. Even if the grey dune does not belong to the systems with highest biodiversity, the number of species of plants, bryophytes and lichens together is reduced by 60 to 75%. Furthermore, the species lost by the invasion generally are species adapted to the conditions characteristic of grey dune heath, and therefore often uncommon and threatened.
SCI 13 sites at Kollerup.

<table>
<thead>
<tr>
<th>GPS coordinates (WSG84)</th>
<th>Deg</th>
<th>Min</th>
<th>Sec</th>
<th>Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Felt 1</td>
<td>57</td>
<td>7</td>
<td>55</td>
<td>North</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>17</td>
<td>42</td>
<td>East</td>
</tr>
<tr>
<td>GPS coordinates (WSG84)</td>
<td>Deg</td>
<td>Min</td>
<td>Sec</td>
<td>Direction</td>
</tr>
<tr>
<td>Felt 2</td>
<td>57</td>
<td>7</td>
<td>53</td>
<td>North</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>17</td>
<td>40</td>
<td>East</td>
</tr>
</tbody>
</table>

Figure 6. Map showing the two plots: Plot 1 and plot 2, Kollerup

Description of the area, where the plots were established:

The heath area is very open, and management has taken place over at least two periods. At some places, the conifers have been left at the site with all their needles, causing addition of minerals to the heath. This is probably reflected in the strong spot wise dominance of *Deschampsia flexuosa* at some places throughout the area at Kollerup.
View of the area at Kollerup, seen from S to N.

Permanent plot (felt 1) in cleared area, Kollerup
Vegetation analyses from 2003:

In this plot are 7 phanerogams (including *Calluna vulgaris*), 12 lichen species and 2 bryophytes.
Figure 7. Vegetation following conifer cutting and leaving all biomass at site

Figure 7 shows a species poor community with only 4 phanerogams, 1 bryophyte and 1 lichen species. The reason why only few species occur is primarily, that the clearing here was recent (two years back) and secondly that the needles were left behind. *Hypnum cupressiforme* is a dominant bryophyte, also present under *Pinus mugo* cover, while the strong dominance of *Deschampsia flexuosa* reflects the release of minerals and nutrients from needle decomposition, stimulating the growth of this grass species, which already occurred rather frequently in the heath. This development is paralleled with the replacement of dwarf shrubs with grasses on inland heaths, as a result of increased atmospheric deposition of N- and P-compounds.
List of Species (June 2003): 72 species of plants, lichens and bryophytes.

- Agrostis canina
- Ammophila arenaria
- Briza media
- Calamagrostis epigeios
- Calluna vulgaris
- Carex nigra
- Carex panicea
- Carex pilulifera
- Cladonia ciliata
- Cladonia glauca
- Cladonia portentosa
- Cladonia uncialis
- Cetraria sp. (Coelocaulon)
- Cirsium helenioides
- Cirsium paustre
- Cladonia portentosa
- Pinus contorta (seedlings)
- Pinus mugo (seedlings)
- Picea sitchensis (seedlings)
- Picea sitchensis
- Phragmites communis
- Platismatia glauca
- Juncus articulatus
- Juncus balticus
- Juncus bulbosus
- Juncus conglomeratus
- Knautia arvensis
- Luzula congesta
- Molinia coerulea
- Nardus stricta
- Oxyccocus palustris
- Picea sitchensis
- Pinus contorta (seedlings)
The analyzed area did not show any signs of burning, as the cleared material had been collected in piles and burnt on separate spots. There is, however, a substantial germination of conifers. The vegetation at this site is influenced by the proximity to chalk containing cretaceous formations, which have been overlain by drifting sand. On slopes and in low lying areas, however, the water brings minerals from below to the surface. This is seen in the species composition, e.g. occurrence of *Cirsium helenioides*, *Geranium sanguineum* and *Briza media*. The open vegetation is here particularly dependent of continued land use, preferably by grazing cattle, with no use of fertiliser. Maintenance of this species rich heath plant community at Bulbjerg requires clearing of exotic conifers followed by grazing without addition of nutrients.
Figure 8. Species composition and cover app. 1 year after clear cutting of Pinus mugo

Figure 9. The clearing analysed by transect. Results shown in Figure 11
In figure 11, the invasion of mainly epigeic lichens on the naked top soil is evident. The communities pioneering in the open gaps are species from the organophilic as well as minerophilic groups. The heterogeneity of the cleared area is thus reflected in the first succession stages. Both organic material and mineral soil are being exposed and become substrate for the cryptogam dominated pioneer community.
Figure 11. Comparison of 2002 and 2004 at the permanent plots in Kærgård.
**SCI 73 Grærup**

![Pinus mugo stand](image1)

![Grey (Yellow) dune](image2)

*Figure 12. SCI 73 Grærup; permanent plots*

**SCI 73, Grærup, in Pinus mugo stand**

- Campylopus introflexus
- Cladonia furcata
- Cladonia glauca
- Cladonia macilenta
- Cladonia merochlorophaea
- Cladonia portentosa
- Deschampsia flexuosa
- Dicranum scoparium
- Empetrurn nigrum
- Hypnum cupressiforme
- Hypogymnia physodes
- Pleurozium schreberi
- Ptilidium ciliare

**SCI 73, Grærup, Grey (Yellow) dune**

- Calluna vulgaris
- Carex arenaria
- Cetraria aculeata/muricata
- Cladonia diversa
- Cladonia foliacea
- Cladonia glauca
- Cladonia gracilis
- Cladonia macilenta
- Cladonia merochlorophaea
- Cladonia portentosa
- Cladonia ramulosa
- Cladonia uncialis
- Corynephorus canescens
- Deschampsia flexuosa
- Dicranum scoparium
- Hypochaeris radicata
- Hypogymnia physodes
SCI 78. Fanø

The area between Pælebjerg and Silkebjerg was visited 2002 before clearing took place. Three permanent plots were established and analysed, one in grey dune with no Pinus mugo growth, one in a yet open vegetation of Pinus mugo and finally one in dry grassland on acid, sandy soil, formerly grazed heath.

<table>
<thead>
<tr>
<th>Position (WGS84):</th>
<th>North</th>
<th>East</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>degrees</td>
<td>minutes</td>
</tr>
<tr>
<td>Dry grassland</td>
<td>55</td>
<td>22</td>
</tr>
<tr>
<td>Open Pinus mugo stand</td>
<td>55</td>
<td>22</td>
</tr>
<tr>
<td>Grey dune</td>
<td>55</td>
<td>23</td>
</tr>
</tbody>
</table>

Figure 13. Position of the permanent plots at Fanø.
It is seen from Figure 15, that dwarf shrubs (Calluna vulgaris and Empetrum nigrum) and bryophytes (mainly Pleurozium schreberi) dominate the heath with some Pinus mugo cover; the species while epigeic lichens are nearly absent.

In the figures below, the species composition of the three communities is shown.

**Diagram 1:**
- Veronica officinalis
- Vaccinium uliginosum
- Salix repens
- Rumex acetosella
- Polytrichum piliferum
- Polypodium vulgare
- Hypochoeris radicata
- Hylocomium splendens
- Hieracium pilosella
- Galium saxatile
- Erica tetralix
- Dryopteris sp.
- Dicranum scoparium
- Corynephorus canescens
- Cladonia uncialis
- Cladonia furcata
- Cladonia ciliata
- Cerastium fontanum
- Carex arenaria

- Open Pinus mugo stand
- Dry grassland, sandy soil
- Grey dune

**Diagram 2:**
- Pleurozium schreberi
- Cladonia portentosa
- Empetrum nigrum
- Calluna vulgaris
- Agrostis tenuis

- Open Pinus mugo stand
- Dry grassland, sandy soil
- Grey dune

---

30
SCI 78. Rømø

Maps (1-3) showing location of plots at Rømø (SCI 78)
Table with geographic positions of investigated locations at Rømø (SCI 78)

<table>
<thead>
<tr>
<th>Designation</th>
<th>Latitude (N)</th>
<th>Length (E)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hede 1 Stabil hede</td>
<td>55 08' 55&quot;</td>
<td>08 31' 34&quot;</td>
<td>Stable heath, no sanddrift</td>
</tr>
<tr>
<td>Hede 1 Vindbrud</td>
<td>55 08' 55&quot;</td>
<td>08 31' 34&quot;</td>
<td>Blow-out and surroundings</td>
</tr>
<tr>
<td>Hede 2</td>
<td>55 08' 51&quot;</td>
<td>08 31' 37&quot;</td>
<td></td>
</tr>
<tr>
<td>Hede 3</td>
<td>55 08' 37&quot;</td>
<td>08 31' 39&quot;</td>
<td></td>
</tr>
<tr>
<td>Hede 4</td>
<td>55 06' 26&quot;</td>
<td>08 31' 02&quot;</td>
<td></td>
</tr>
<tr>
<td>Hede 5</td>
<td>55 06' 44&quot;</td>
<td>08 30' 18&quot;</td>
<td></td>
</tr>
<tr>
<td>Hede 6</td>
<td>55 07' 13&quot;</td>
<td>08 30' 20&quot;</td>
<td></td>
</tr>
<tr>
<td>Hede 7</td>
<td>55 07' 10&quot;</td>
<td>08 30' 29&quot;</td>
<td></td>
</tr>
<tr>
<td>Hede 8</td>
<td>55 06' 22&quot;</td>
<td>08 30' 40&quot;</td>
<td></td>
</tr>
<tr>
<td>Hedemose 1</td>
<td>55 08' 47&quot;</td>
<td>08 31' 38&quot;</td>
<td></td>
</tr>
<tr>
<td>Hedemose 2</td>
<td>55 08' 44&quot;</td>
<td>08 31' 36&quot;</td>
<td></td>
</tr>
<tr>
<td>Hedemose 3</td>
<td>55 08' 50&quot;</td>
<td>08 31' 39&quot;</td>
<td></td>
</tr>
<tr>
<td>Hedemose 4</td>
<td>55 06' 27&quot;</td>
<td>08 31' 13&quot;</td>
<td></td>
</tr>
<tr>
<td>Hedemose 5 flyvesandskilt</td>
<td>55 07' 15&quot;</td>
<td>08 30' 09&quot;</td>
<td>Aeolic dune, stabilised</td>
</tr>
<tr>
<td>Hedemose 5 selve mosen</td>
<td>55 07' 15&quot;</td>
<td>08 30' 09&quot;</td>
<td>The main part of the dune slack</td>
</tr>
<tr>
<td>Hedemose 6 selve mosen</td>
<td>55 07' 06&quot;</td>
<td>08 30' 35&quot;</td>
<td>The main part of the dune slack</td>
</tr>
</tbody>
</table>
Pictures from each location at Rømø (SCI 78)

Hede 1 Stabil hede. Heath with strong dominance of Empetrum and Calluna; invasion of Pinus spp.

Hede 2. Heath with old dune slack. Dominants are Empetrum and Erica tetralix (right)

Hede 3. Deschampsia flexuosa dominant

Hede 4. Deschampsia flexuosa dominant
Hede 5. Top: Empetrum dominance with Deschampsia flexuosa invading. Little or no lichen cover. Bottom: Similar, but with stronger Empetrum dominance

Hede 6. Aeloic dunes, now stable with dense cover of Empetrum and Deschampsia flexuosa
Hede 7. Strong dominance of Deschampsia flexuosa. Very little Calluna, but high Cladonia spp. cover.

Hede 8. Top and bottom: Dune ridge with Empetrum, Calluna and Deschampsia flexuosa as dominants.
Hedemose 1. Dune slack with Molinia coerulea and occurrence of Gentiana pneumonanthe

Hedemose 2. Dune slack with Molinia coerulea and Eriophorum angustifolium. Salix repens in foreground.


Hedemose 4. Former grazed dune slack with high cover of Eleocharis multicaulis and Sphagnum spp.

The pictures of hedemose 3 and 4 expose the large variation of the dune slack communities. It shows, that land-use practice of the wetlands in the coastal heaths has a profound influence on the vegetation development. These two locations indicate, that given maintenance of open tree-less and nutrient poor conditions, a wide range of plant communities may develop, all being a part of the highly complex coastal heath ecosystem. The conifers in the background represent a major potential threat.
Hedemose 5. Slack with Molinia and Phragmites australis; little Calamagrostis canescens

Hedemose 6. Slack with strong dominance of Molinia coerulea

Estimated mean cover percentages for species groups, Rømø (SCI 78)

<table>
<thead>
<tr>
<th>Dune heath (hede) no.:</th>
<th>Hede 1a</th>
<th>Hede 1b</th>
<th>Hede 2</th>
<th>Hede 3</th>
<th>Hede 4</th>
<th>Hede 5</th>
<th>Hede 6</th>
<th>Hede 7</th>
<th>Hede 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dwarf shrubs</td>
<td>77,5</td>
<td>2,5</td>
<td>82,5</td>
<td>7,5</td>
<td>12,5</td>
<td>70</td>
<td>65</td>
<td>2,5</td>
<td>55</td>
</tr>
<tr>
<td>Conifers</td>
<td>5</td>
<td>0</td>
<td>5</td>
<td>2,5</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>2,5</td>
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<tr>
<td>Graminoids, totally</td>
<td>55</td>
<td>2,5</td>
<td>15</td>
<td>5</td>
<td>80</td>
<td>5</td>
<td>17,5</td>
<td>60</td>
<td>72,5</td>
</tr>
<tr>
<td>Lichens, totally</td>
<td>2,5</td>
<td>7,5</td>
<td>5</td>
<td>2,5</td>
<td>17,5</td>
<td>3</td>
<td>7,5</td>
<td>70</td>
<td>10</td>
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<tr>
<td>Sum of species cover (%)</td>
<td>145</td>
<td>25</td>
<td>115</td>
<td>27,5</td>
<td>120</td>
<td>93</td>
<td>112,5</td>
<td>135</td>
<td>145</td>
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Estimated mean cover percentages species groups, Rømø (SCI 78)

<table>
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<th>Dune slack (hedemose) nr.:</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5 (dune)</th>
<th>5</th>
<th>6</th>
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<td>Dwarf shrubs</td>
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<td>95</td>
<td>7,5</td>
<td>80</td>
<td>5</td>
<td>7,5</td>
</tr>
<tr>
<td>Conifers</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Graminoids, totally</td>
<td>80</td>
<td>10</td>
<td>92,5</td>
<td>82,5</td>
<td>12,5</td>
<td>82,5</td>
<td>92,5</td>
</tr>
<tr>
<td>Lichens, totally</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sum of species cover (%)</td>
<td>120</td>
<td>35</td>
<td>195</td>
<td>110</td>
<td>97,5</td>
<td>99,5</td>
<td>102,5</td>
</tr>
</tbody>
</table>
Methods.

Botanical inventories.
The botanical inventories were performed as E-W or N-S transect analyses with description of plant communities and their relative abundance along the lines, which were separated by about 50 m. The topography was reported, and digital pictures were taken from points with positions determined by GPS.
Species occurrence in general, and occurrence of rare species as well as indicator species (i.e. species particularly characteristic for a certain plant community) was noted. The communities were also characterised in terms of relative cover between the groups: Dwarf shrubs, herbaceous plants, graminoids, epigeic lichens (mainly Cladonia spp.) and bryophytes. The area of gaps, mainly with biological crusts, in percentage of total for the plant community in question, was recorded.

Permanent Plots.
The permanent plots were always placed as pairs (with one exception: Fanø) in order to describe a before/after situation. The ‘before situation’ is linked to a specific management action, and the ‘after situation’ refers to the original, more or less ideal state of the ecosystem at the specific part of the project site.
The geographic position was measured for the marker placed in the middle of 4 rectangular shaped grids, each with 24 squares of 20*20 cm2. For each square, the cover for all species was estimated in %. The total number of squares per plot was thus 96. The analysis is quite time-consuming even with experienced personnel. The plots were photographed digitally.

Vegetation analysis method for the burnt spots:
A rectangular frame measuring 40 cm * 60 cm was divided into 24 small quadrates each measuring 10 cm * 10 cm using a nylon mesh (Figure 16). The data retrieved were in the following categories:
a) Number of quadrates with occurrence of the species in question relative to the theoretical total of 24
b) The cover of the species within each quadrate, estimated by eye in %
c) The number of hits of the species at each meshes crossing point relative to the theoretical total of 15 (pin point frequency).

Figure 16. Frame used for vegetation analysis
Results and discussion.

In this chapter, selected results from the previous chapters are used to highlight the main findings, which are discussed in relation to the overall aim: To describe guidelines for best management practice in relation to the Atlantic coastal heath in Denmark.

*How does the succession proceed after clearing of forest-like conifer growth (mainly Pinus mugo) in grey dune vegetation?*

The figures below show the typical succession after removal of conifer growth. The example is from Stokmile, Skagen Plantation north of Hulsig Heath. The time period was from 1981 to 1999. The area was photographed 2005 (see below). The starting point was a closed stand of *Pinus mugo*, which was cut with subsequent immediate removal of the above ground biomass from the area. It is seen, that after approximately 10 years, the pattern of change no longer seems to be related to the clearing event. In stead, the natural cyclical succession of heaths with *Calluna vulgaris* as a dominant takes over.

![Succession after conifer removal](image)

Figure 17. Succession after conifer removal, dominant phanerogams
Figure 18. Succession after conifer removal. Ground cover, mainly cryptogams

Figure 19. Stokmile, area cleared 1981. Photograph from 2005.
The above figures from Stokmile suggest that the grey dune vegetation is fully recovered after approximately 10 years. The high dominance of Carex arenaria few years after clearing of the conifers seem to fade and the species finally cover about one third of the area. There may be a change in grass cover, especially two species are becoming more and more frequent in the Stokmile clearing: Deschampsia flexuosa and Calamagrostis epigeios. The reason for this may be higher deposition of nutrients from the atmosphere.

The mechanical clearing method is of importance for a positive outcome of the dune heath regeneration. It is necessary to remove all above ground tree biomass from the cleared area, before any significant needle loss has taken place. Most of the minerals accumulated in the tree biomass are concentrated in the needles. The removal of newly cut tree biomass must be done, when tree saws (motorized or hand-held power saws) of various kinds have been used.

The cut material may be left in piles for burning at selected spots (discussed below), or chopped into wood chips for energy production.

Using weed and brush cutters should preferably be avoided, as the above ground biomass is being left at the site. Instead of weed and brush cutters, removal of tree seedlings by hand pulling is preferable, even if the task is more tedious.

The grey dune vegetation is particularly sensitive to mechanical disturbance, and motorized transport should always be avoided in the dunes. In stead, motorized transportation of cut tree biomass should take place using vehicles with broad, non-profile tyres, and the route should be placed about 50 m from the foot of any dunes, i.e. close to the edge of the adjacent flat (often with dune slack vegetation). The tracks formed by these vehicles may be used later for a similar purpose. The vegetation recovery in such tracks is rather fast, but the micro topography change is changed nearly permanent.

![Figure 20. Tracks left in dune slack terrain after clearing of Pinus mugo. Lodskovvad, November 25th 2003.](image)
The follow up after first time removal of Pinus mugo is necessary to secure the restoration generation of the former dune heath vegetation and its maintenance.

The follow up should include the following:
1. Phase 1. Manual removal of seedlings every year for at least three years/
2. Phase 2. Continued manual removal eventually combined with mosaic burning (s.d.)

**How does the succession proceed after fire? Analyses of fire spots from burning of organic material from cuttings and mosaic burning sites**

The field work to evaluate the impact of fire as management tool was made in SCI no 2 (Lodskovvad and Hvide Klit) and Hulsig Heath (former LIFE project report: Nature Conservation on Hulsig Hede, LIFE-Nature Final Report. June 2002). It is based on detailed analyses of the vegetation development in the spots themselves as well as transects analyses of the impact on the surrounding vegetation from fire.

**Succession at spots and their immediate surroundings, where tree cuttings have been burned**

![Figure 21. Map showing the analysed area of SCI 2 with burnt spots. Management by County of Nordjylland.](image-url)
The succession at the burnt spot sites was as follows:
Pioneer stage with few, rapidly invading plants, bryophytes and fungi. The plant species are often *Senecio silvaticus* and *Chamaenerion angustifolium*; the bryophyte species of main importance is *Funaria hygrometrica*. (Fig 23). Several fungus species invade the spots at this early stage, e.g. *Peziza echinispora* (Fig 24). This stage last for 1-2 years, depending of the substrate; in most dune heaths the substrate is sandy and easily depleted of its mineral content, thus reducing the time span of the pioneer stage.
The second intermediary stage is typically dominated by the phanerogams *Carex arenaria, Salix repens* and *Carex panicca;* some germination of *Calluna vulgaris* seeds take place. Bryophytes characteristic of this stage are *Polytrichum* spp. and *Ceratodon purpureus*. Lichens enter the scene here, typically crustose species like *Placynthiella* spp. and *Trapeliopsis granulosa* as well as primary foliose thalli of *Cladonia* spp. The second stage last for app. 2 years, from the 2nd to the 4th year after burning.
The final stage represents the phase, where the actual regeneration of the original dune heath takes place. Depending of the amount of organic matter in the top soil, the succession includes a stage with organophilic lichen species mainly of the genus *Cladonia*.
The end point is always the well known mosaic community of dwarf shrubs, graminoids and gaps with *Cladonia* sect. *Cladina* ssp. and bryophytes like *Dicranum* ssp., *Hypnum* ssp. and *Pleurozium schreberi*. Figures 26 and 27 show examples of the pioneer stage based on analyses of burnt spots shortly after burning, from SCI 2 (Lodskovvad and Hvide Klit). The examples are from an area with short distance to the ground water table, with depressions often flooded during winter. The maximum distance to the ground water table during summer time is estimated to 1 m. The occurrence of species like *Erica tetralix, Agrostis canina, Phragmites australis, Carex nigra* and *Myrica gale* reflects the short vertical distance to the ground water table.
Figure 23. The bryophyte *Funaria hygrometrica* on burnt spot, SCI 2, Lodskovvad, October 6th 2004. The picture was taken only few months after burning.

Figure 24. The discomycete *Peziza echinispora* on burnt spot, SCI 2, Lodskovvad, October 6th 2004. The picture was taken only few months after burning.
Figure 25. Area recently cleared with burnt spots, separated by app. 25 m. The vegetation is still composed of the graminoid communities of the *Pinus mugo* thickets. The burnt spots are only few months old. SCI 2, Lodskovvad, October 6th 2004.

Figure 26. Vegetation on burnt spot in dune slack community
It is seen from Figs 26 and 27 that the naked soil dominates shortly after fire. In this case, the bryophyte invasion is rapid, and in accordance with Vestergaard & Alstrup (2001) the crustose lichens are anticipated to enter the scene already one year after burning and then gradually become subdominant on the soil surface during the following two to three years.

In Fig 28, comparison of the edge (white section of bars) of the burnt spots and the vegetation within the spots (red section of bars) is done. The area is composed of a mosaic of vegetation types, reflecting small differences in topography. The burnt spots are rapidly dominated by e.g. *Senecio sylvaticus* and *Rumex acetosella*, while the more unaffected edge is characterized by *Myrica gale*, *Carex nigra* and *Carex arenaria*. It is believed, that this early succession stage has changed to a stage similar to the original heath vegetation after app. 5-10 years.
Mosaic burning
The mosaic burning is a feasible management method, as the method secures common occurrence of several succession stages of dune heath, including the initial phase. Due to challenge from serotiny in e.g. *Pinus contorta*, it is preferable to restrict the use of mosaic burning to areas, where proximity to nutrient and mineral resources (below and/or above ground) induce a rapid change in the heath vegetation towards grass dominance, which may cause nearly irreversible changes in the heath ecosystem, if left to proceed. The
effect of burning is release of minerals (ashes) which on coarse sandy soils may easily be leached out. Mosaic burning is most successful, where several stages of the cyclic heath dynamics occur in the vicinity.

**Post-fire succession in extended heath areas with invasion of especially *Pinus mugo* and *P. contorta***:

The data retrieved from Lodskovvad and Hvide Klit of SCI 2 here was compared to data from a fire 1996 at Hulsig Hede, where analyses were made across the front limit of the naturally extinguished fire into the intact, original heath vegetation. The succession with respect to dominants from 1997 to 2004 at Hulsig Hede is shown in Figure 29.

![Figure 29. Succession after fire, Hulsig Heath. Heath flat burned naturally 1996.](image)
The development in biodiversity follows the scheme of the natural, circular succession characteristic of *Calluna vulgaris*-dominated heaths. The burnt flats may be compared to gaps replacing dying senescent *Calluna* dwarf shrubs according to their app. 30 years life cycle. The highest biodiversity in this analysis was observed between 3 and 8 years after burning, mainly pioneer species of plants, lichens and bryophytes. The control represents a senescent heath area, with a rather low biodiversity, dominated by *Calluna vulgaris* and *Erica tetralix*.

In Figure 31 the succession after the fire 1996 is shown for a large, flat dune slack area – an aeolic deflation plateau. The succession is different from the one showed in Figure 29 as the dune slack dwarf shrub *Erica tetralix* and the bog bryophyte *Polytrichum commune* dominates at the end. Again, the time span to recover from the disturbance, in this case a natural fire is about 10 years. In some areas, the succession may proceed to form shrub land with *Salix* spp. (mainly *Salix repens*, *S. aurita* and *S. canescens*) or open forests primarily of *Betula* spp. and *Populus tremula*. This latter stage is highly influenced by the climatic conditions, and retrogression is often observed. In modern time, however, the changing climate (higher temperature and perhaps increasing precipitation) as well as high atmospheric deposition of nutrients, may favour the development of the final forested succession stage.

![Figure 31. Succession after fire, Hulsig Heath. Area close to ground water table.](image)

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2 *Placynthiella* spp.: *P. uliginosa*, *P. oligotropha* and *P. icmalea*
The findings were compared to the results by Vestergaard, P. & Alstrup, V. (2001). Vestergaard & Alstrup find that the initial three years is a recruitment phase with increasing diversity, followed by – during their five year study – two years of declining vegetation change. Furthermore they state, that epigeic crustose lichens (such as *Placynthiella* spp.) play an important role in the early stages of recovery from fire. The results from this study are to a large extent in accordance with Vestergaard & Alstrup. It is seen from figures 29 and 31 that a stabilisation of the vegetation of the dry heath occurs from 1997 to 2004, see e.g. *Calluna vulgaris*. The species characteristic of dune slacks, e.g. *Erica tetralix*, however, still increases in cover 7 years after the fire. The initial stage with dominance on the soil surface of crustose lichens is also found in this study. In figure 31, the cover of naked soil declines rapidly, and *Placynthiella* spp. has its maximum cover 2 years after the fire.

**What is the ideal time interval between burnings at selected fire spots?**

The answer to this question depends on the success with manual removal of pine seedlings during the first three years after clear cutting of a certain heath area. Using always the same spots, a frequency of 5-10 years is recommended, if this approach is considered necessary due to reinvasion in particular of *Pinus* spp.

**What is the ideal geographic position and distance between the fire spots?**

The fire spots should be placed with a mutual distance of app. 50 meters, preferably on flat terrain. The fire pots should never be placed on the grey dunes or in the transition zone between grey dunes and the neighbouring flat terrain, often with dune slack vegetation. Transportation of tree cuttings should be manually or by trucks with broad, non-profile tyres. The tracks left after truck transportation should be left unchanged.

**What are the main effects of fire on vegetation dynamics, e.g. due to serotiny, and nutrient circulation?**

This question is very broad, and only aspects of its answer of direct relevance of coastal heath management shall be mentioned here. Naturally, coastal heath fires occurred almost only after lightning strikes, and should accordingly be considered an exception in management practice. The main problems due to burning in coastal heaths are: The increased germination of conifer seeds (mainly *Pinus contorta*) due to serotiny and the locally strong impact of minerals released during the fire. On the other hand, fire restarts the cyclical succession process characteristic for heaths, and may favour the initial succession stages, which today are suppressed due to the more favourable climatic and nutritional conditions. Furthermore, the fire releases e.g. nitrogen and phosphorous compounds to the atmosphere, which may be removed from the heath ecosystem.
The change in ecological conditions as reflected in the succession of the ground vegetation after conifer clearing.

The figures below based on weighted Ellenberg indices for all plant groups of the ground vegetation, show some general changes in the ecological conditions, as they change with time following clearing of *Pinus* spp. and *Picea* spp.
It is seen, that the light index increases with time, as species adapted to high light exposure become more abundant. These light species are mainly species of the grey dune community in this case. It is seen from the graph that the change ceases after ca. 10 years, in accordance with the above mentioned vegetation development.(Figure 17 & Figure 18).

Also the N index increases slightly, which probably is due to the atmospheric deposition of nitrogen compounds and accumulation of nitrogen in living and dead biomass with time.

The acidity index R drops slightly over time, which reflects the leaching of minerals from the top soil, here mainly sand with only very little organic matter.
Discussion

It can be seen from the above that a succession towards the original dry sand heath begins very soon after the clearing of Mountain Pine. The speed of succession is slow if the starting point was a closed, forest-like Mountain Pine plantation which had existed as such for a long period of time, e.g. more than 50 years. In this case, long phases of dominance with Sand Sedge (*Carex arenaria*) and grass species are observed, which can be attributed to the more beneficial nutrient and mineral conditions as a result of the earlier Mountain Pine growth’s accumulation of nutrient salts and minerals in litter and humus under the trees. However, it cannot be excluded that today’s atmospheric deposition of nitrogen compounds (in Denmark of the order of 15-20 kg N ha\(^{-1}\) year\(^{-1}\), which is believed to be 5-10 times larger than 60 years ago) means that this graminoid-dominated phase will be maintained over a longer period in relation to earlier.

In addition, it can be seen that the shift in composition of species which is to be expected after burning in this area is very slight. In both dry and wet areas of Hulsig Hede which suffered a natural fire in 1996, a rapid invasion of species which are associated with the early stages in the development of the dry sand heath has occurred. Only in one area has asporadic invasion of narrow-leaved fireweed (*Chamaenerion angustifolium*) and Heath Groundsel (*Senecio silvaticus*) been observed; both species are already declining after 3 years.

The clearing of Mountain Pine which has been carried out has been a success, and according to these studies the area will be well on the way to returning to the original dry dune heath only about 6 years after clearing has taken place. The large unbroken areas with closely-scattered self-propagating Mountain Pine which are suddenly opened will, however, be mainly populated by plant communities which are associated with the initial stages in the dune heath’s natural cyclical dynamics. A period of at least 30 years will have to elapse before it is to be expected that all phases are represented as in the old thy sand heath. However, it should be noted that just 10 years after the clearing of Mountain Pine, a total of 16 species of *Cladonia* spp. and 30 species of cryptogams were found in some of the areas studied.

Vigorous new growth of Mountain Pine has been found in parts of the mechanically cleared and burnt areas, which underlines the need for a fast and consistent follow-up of the clearing work already carried out. If conservation work in the form of the removal of new growth of Mountain Pine (which can be carried out by hand) is not implemented within the next few years, the extensive clearing work will have been wasted.

It is deemed that annual inspection and clearing will be necessary for a 5-year period after the first major clearing. It will subsequently be possible to reduce the frequency of inspection and clearing to every three to five years.

It is recommended to continue monitoring of the habitat in the areas based on the previously laid out permanent sampling areas and transects. In this way it will be possible to assess whether the vegetation dynamics are developing as expected, and the need for any conservation measures in order to achieve the goals for the Atlantic coastal heath habitat can be continuously evaluated.
The Mountain Pine invasion in dune heaths has meant a rapid acceleration of succession towards closed woodland, particularly in the low-lying areas. Before clearing, this woodland consisted of Mountain Pine, Downy Birch (Betula pubescens) and Silver Birch (Betula verrucosa), European Aspen (Populus tremula), Grey Willow (Salix canescens), Eared Willow (Salix aurita), Common Rowan (Sorbus aucuparia) and scattered Common Oak (Quercus robur). Following a selective removal of Mountain Pine from these succession woodland areas, the deciduous trees remain; the climate has become harsher and the hydrological circle has changed radically after the clearing of Mountain Pine, so it may be assumed that the woodland succession will be arrested and that a minor retrogression will probably take place. There has always been and will continue to be thicket of willow and birch in the heath slacks which can act as a shelter and foraging site for the area’s wildlife. It has also been seen that some of the remaining deciduous tree groups which previously stood in Mountain Pine-dominated plantations die as a result of the drastic change in conditions as a consequence of clearing. It is recommended that, in connection with the monitoring program, the heath slack’s vegetation development is followed with particular focus on the slacks in which a massive invasion of Mountain Pine had occurred.

Grazing in the area plays a role for the development of the vegetation. A grazing intensity calculated as the number of sheep per ha should not exceed the figure 0.1. It is necessary for the authorities to ensure that this grazing intensity is not exceeded.

With the current numbers of visitors to most of the dune heath, tourist wear is not believed – with a few exceptions - to lead to an unacceptable impact on the vegetation. There is thus no reason to introduce restrictions with regard to tourism at present, but this aspect should also be closely followed by the authorities. A way of regulating the wear and tear on the vegetation from visitors is the construction of car parks and marked paths through less vulnerable areas; in fact, this already happens.

Experience from this project in combination with former LIFE projects at Hulsig and on Anholt has revealed the following succession process:

**Starting point: Old Mountain Pine with well-developed organic top soil layer, flat terrain:** Wavy Hair Grass and Sand Sedge dominate for the first 10 years, after which heather and reindeer lichens migrate to the area; after 18 years the original type of vegetation is yet to be fully developed.

**Starting point: Old Mountain Pine on sandy base, thin organic top soil layer, flat terrain:** Sand Sedge is almost completely dominant for the first 5-10 years, and acrocarpous mosses such as Dicranum scoparium and reindeer mosses begin to appear after about 2 years. After 18 years the grey dune/dry sand heath is more or less re-established.

**Starting point: Old Mountain Pine with well-developed organic top soil layer, south-facing slopes:** Crowberry, Sand Sedge and pioneer lichen communities migrate into the area and establish open vegetation. In the course of 18 years the grey dune community is practically re-established.

**Starting point: Old Mountain Pine with well-developed organic top soil, north facing slopes:** Moss dominance disappears after about 5 years and is replaced by organophilic lichen communities, and reindeer mosses belonging to the subgenus Cladina appear within 5 years.
Conclusions and guidelines for best management practice with respect to Atlantic coastal heaths.

**Overall conclusions**

1. The Mountain Pine invasion and development towards forest growth involves determination of the growth of the trees’ biomass and an accumulating amount of humus consisting of macro nutrients (particularly N, P and K compounds) and a number of other minerals on the forest floor, such that the heath’s bio-geochemical banks and ecological cycle are radically changed to a completely new cycle of matter. This new system forms the basis of a more productive ecosystem which has the alpine tree species Mountain Pine as a dominant feature and whose prerequisite is in part the Mountain Pine’s unique adaptation to extreme growth conditions (pioneer species at the tree-line in the Alps) and in part the accumulation of matter in biomass and humus mentioned above. Today this accumulation is bolstered by human activities which result in air pollution — with nutrients, among other things. The overall effect on the original grey dunes and dry sand heath ecosystem is the suppression of, in particular, dwarf shrub dominated vegetation such that a rather uniform forest habitat occurs with a more or less dense crown and ground vegetation dominated by a few pleurocarpous mosses (almost exclusively *Hypnum cupressiforme/Hypnum jutlandicum, Pleurozium schreberi* and *Hylocomium splendens*) and/or reindeer mosses (almost exclusively *Cladonia portentosa* and *Cladonia ciliata*, both belonging to the subgenus *Cladina*). The biggest biological variation in this new forest habitat is found in the form of epiphytic lichens on Mountain Pine trunks and branches.  

2. Re-establishment of the original grey dune or dune heath requires removal of the accumulation of matter described above and the prevention of its return in the future. This must take place through the removal of the Mountain Pine above the ground, whereas stumps and roots can be left. It is particularly important that needle-carrying branches are removed and chipped or burned at selected sites where the direct effect of this is as insignificant as possible. The succession towards the original vegetation begins immediately, but the length of the re-establishment period is particularly dependent on the age and exposure of the Mountain Pine (dependent on relief).  

3. With the removal of old, dense, planted Mountain Pine a time scale of 15-18 years is not sufficient to recreate a dwarf shrub heath with *Cladina* spp., whereas 10 years appear to be sufficient if the removal is of an open self-propagating Mountain Pine thicket with several gaps.  

4. The corresponding development in the event of a starting point with young Mountain Pine (self-propagating) is in all cases faster than above, and an important conclusion is therefore that clearing must take place at a very early stage and conservation work must be carried out on an ongoing basis in order to prevent the Mountain Pine from re-establishing itself.
5. Reestablishment of the original Atlantic coastal heath after clearing of *Pinus mugo* may last between 5 and 15 years, depending on the density and age of the *Pinus mugo* stands; furthermore, the recovery is inhibited in areas neighbouring intensive agricultural land.

6. The succession after *Pinus mugo* clearing usually follows a sequence of three steps: a) Open flats with pioneer species of plants, lichens, bryophytes and fungi; b) Flats dominated by *Carex arenaria* and *Salix repens*; c) Dominance of *Calluna vulgaris* and *Deschampsia flexuosa* with scattered cover of *Cladonia* spp. and acrocarpous bryophytes.

7. The terricolous lichen species *Flavocetraria nivalis*, *Ochrolechia frigida*, *Cladonia stellaris* and *Alectoria sarmentosa* var. *vexillifera* are considered ice age relicts (i.e. their occurrence in coastal heaths probably date back to the post-glacial period after the Weichsel ice age, which ended about 14000 years ago). Partly during this study, their distribution and vigour has been demonstrated to undergo a rapid decline. To some extent, this may be counteracted by the clearing of self sown *Pinus* and *Picea* species in the coastal heaths.

8. Grey dune and dune heath vegetation can be regenerated after clearing and other impacts. It has been shown that dune heath is an ecosystem which possesses a high degree of reversibility. Nature conservation therefore makes sense in such an area provided that major external impacts do not alter the basic conditions for the vegetation.

9. The conservation initiatives carried out have been successful, and throughout the project area a development is taking place which will result - either in the short-term or the long-term - in the regeneration of the original dune heath ecosystems.

10. The effect of the atmospheric deposition of nutrient salts cannot be ascertained precisely, in addition to which climatic changes may play a hitherto unknown role for the succession currently in progress.

11. It is crucially important that a follow-up to the conservation initiatives in the form of the clearing of Mountain Pine growth takes place, and ongoing monitoring of the development of the vegetation is recommended.

12. The use of mosaic burning is recommended for areas affected strongly by nutrient and mineral resources, i.e. dune heaths receiving high levels of nutrients from the sea, with short vertical distance to moraine deposits and/or with short horizontal distance to agricultural land. Mosaic burning may counteract the otherwise rapid succession towards closed shrub and forest vegetation. In such areas, grazing by cattle and/or sheep should also be considered after clearing.
Guidelines for best management practice with respect to Atlantic coastal heaths

1. Clearing of invasive exotic conifers (such as *Pinus mugo*, *Pinus contorta* and *Picea sitchensis*) should take place at the earliest possible occasion. The reason is that trees are highly competitive with respect to light and change the microclimate strongly, especially with respect to temperature and humidity variation. Furthermore, trees accumulate organic matter and minerals in the topsoil, which prolongs the recovery time for the original conditions for the nutrient poor dune heath. Clearing of the trees is a prerequisite for the development of a favourable conservation status.

2. Clearing of conifers should always imply a total removal of the above ground biomass, including needles and cones. The total above ground biomass should be collected and burnt on selected spots in the field or chopped outside the cleared heath area, e.g. for use in power plants. The choice of burning in piles at selected spots is only recommended, when very large, rather inaccessible heath areas are to be managed.

3. Manual removal of self-sown young plants of conifers is necessary every year at least the first three years immediately after clearing of conifer growth. Thereafter the manual removal should be done every third year, until no seed germination of conifers occur.

4. In some parts of the coastal heaths, extensive grazing (mainly by sheep, but in some cases cattle) is recommended in order to maintain open vegetation dominated by herbs, after clearing of self-sown conifers. This is particularly recommended in areas close to moraine deposits below the Aeolian sandy topsoil, as it is the case for large parts of the project areas in SCI 78 and SCI 16. In particular, formerly grazed coastal heaths with present dominance of *Empetrum nigrum* should be managed by extensive grazing, preferably by cattle.

5. It is beneficial (both in practical and economic terms) to carry out the clearing of *Pinus mugo* in dry heaths and dune slacks using heavy equipment on wide, preferably smooth tyres, and driving in the same tracks and preferably in the slacks, in order to avoid damaging the often very vulnerable plant communities in the dry heath and in the relatively broad transition zone between the dry heath and the adjacent dune slacks. *Empetrum nigrum* dominated dry heath (as in large parts of SCI 78), however, may benefit from temporary destruction of the dense shrub cover through impact of heavy equipment. Introduction of e.g. cattle grazing (see 5) may then secure the maintenance of the original, more bio diverse heath.

6. Fire spots for pile burning should be placed with a mutual distance of app. 50 meters, preferably on flat terrain. The fire pots should never be placed on the grey dunes or in the transition zone between grey dunes and the neighbouring flat
terrain, often with dune slack vegetation. Transportation of tree cuttings should be manually or by trucks with broad, non-profile tyres. The tracks left after truck transportation should be left unchanged.

7. A time interval of 5-10 years is recommended between burnings at selected fire spots, using always the same spots, if this approach is considered necessary due to reinvasion of conifers.

8. When habitat quality values outside the criteria range defining a favourable conservation status on a particular site are registered, management activities should be initiated as soon as possible.

The above guidelines summarize the experience from this and previous LIFE projects. It must be emphasized, that only through continuous management and monitoring of the vegetation and its ecological conditions may we be able to maintain the extremely valuable dune heath ecosystem in Denmark.

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*Ib Johnsen, January 2006*
Background literature


