ANNEX F: Extensive Monitoring Report

Action F.1

Contribution of:
National Environmental Research Institute, Dept. of Terrestrial Ecology, Vejlsoevej 25, P.O.box 314, 8600 Silkeborg, Denmark.

Project participants:
Research scientist, Dr. Knud Erik Nielsen ken@dmu.dk and Marianne Hilligsøe, National Environmental Research Institute, Dept. of Terrestrial Ecology, Vejlsoevej 25, P.O.Box 314, 8600 Silkeborg, Denmark

Testing favourable conservation status for dune heathlands, Denmark

The present monitoring report summarises the final results of the subproject Action F1 (extensive monitoring) of the project "Restoration of Dune Habitats along the Danish West Coast (LIFE02 NAT/DK/8584). The monitoring project has received funding from LIFE, the Financial Instrument for the Environment of the EU.

Summary
How can changes in ecosystem structure, function and composition be assessed and how are they related to conservation status? One of the main purposes for the extensive monitoring in the LIFE project was to design a monitoring programme for large areas in order to assess the conservation status.

The member states of the EU are obliges to maintain or to restore defined habitat types in a direction of favourable conservation status. In an attempt to operationalise the general criteria of function, structure and composition of species sets of science-based and specific criteria and indicators for habitat types have been developed and tested in this investigation. These criteria have been developed to fulfil the obligations for habitat types in the EU-Habitat-directive in Denmark. The development of indicators and criteria's for favourable conservation status has acted as the main driver in a project on four dune heathlands in Denmark. By combining biological and chemical criteria the intention has been to secure elements of diagnosis as well as prognosis for state and development of the research areas.

The C/N ratio for the upper soil layers is such a prognostic tool. The C/N ratio for the morlayers of the dune heathlands are approaching 25 which eventually will lead to changes in the nitrogen cyclus. Based on this ratio it must be concluded that the conservation status for these areas is unsafe. There are no data to support how a lowering of the C/N ratio will affect the vegetation dynamics.

On Rømø succession towards a dense mat of *Empetrum nigrum* has resulted in a low diversity of lichens. The only one present belongs to the late established species like *Cl. portentosa* and one belonging to the organophilic society *Cl. merochlorophea.* Together with a major dominance of *Empetrum nigrum* this is a clear sign that there is little dynamic on this locality which will affect the conservation status in a negative direction.

On Fanø in 2002 the cover of trees and the widespread and locally dominance of the invasive moss *Camylupu introflexsus* results in unfavourable conservation status. A repeated survey in 2004 showed a nearly total removal of the trees and decrease in the cover of the invasive moss. The removal if the trees have exposed the mineral sand over large areas – causing the decrease in the invasive moss. The removal of trees is a prerequisite for a favourable development of the conservation status.

Introduction

The dune heaths form part of the dynamic coastal ecosystems with occurrence of breaches and sand drift. The system from the white dunes to the green and grey dunes to the more stable Empetrum dune heath represents an acidification gradient. The pH gradient ranged typically from around 5.2 to less than 4 (Stützer, 1998). Fixed dunes are colonised by a more or less closed vegetation carpet of perennial grass, herbs, lichens and mosses. The grey dunes represent a typical lichen habitat requiring continuous disturbances to be competitive to mosses and vascular plants. The classification of the dune series follows the system from the EUNIS classification system where the different habitat types are characterised by a four-number code (http://europa.eu.int/comm/environment/nature/nature_conservation/eu_enlargement/2004/pdf/habitats_im_en.pdf).The dynamics of the grey and green dunes (habitat type no. 2130) is more pronounced than in the decalcified fixed dunes with *Empetrum nigrum* (type 2140). The third main habitat dune type in this investigation is the dune slack (code no. 2190). Depending on the height of the water table, areas between sand hills may be damp or even contain standing water. Often such areas are well defined and constitute 'dune-slacks'. Receiving nutrients leached from surrounding dunes, they may be occupied by lime-loving species ('calcicoles') and can be floristically rich and contain local or national rarities (Pihl et al, 2000). Dunes are highly dynamic and diverse environments. The combination of dry and moist spots, north and south exposed slopes, open and dense vegetation provides different biotopes. Due to succession and succession reset by sand movement or by local disturbances many plants and animals co-occur, each characteristic for a certain successional stage or a combination of stages.

The long-term maintenance of these natural habitat types primarily depends on management measures aiming at maintaining this type as an open natural habitat type. From the beginning of the 16th century authorities have tried to curb the sand drift by protecting the dune heath vegetation, which was used for a variety of purposes like fodder, roofs, insulation, firewood etc. Later on restrictions were also imposed on the common grazing in the dunes. The general grazing continued, however, until the 20th century and was not completely stopped until after the Second World War. From around 1860 to 1930 a massive planting of mugo pine, lime and marram grass took place. Concomitant large areas were drained. The former use of the dune heathlands did counteract the growth of bushes, trees and grass and created local breaches resulting in drifting sand. Thus the wide range of measures such as planting, drainage, dune stabilisation, coastal protection and prohibition of grazing has for a number of years supported the physical stability in the coastal landscapes at the expense of the natural dynamics of this habitat type and resulted in a massive invasion of trees, bushes and tall grasses (Soegaard et al. 2003).

In NW-Europe, acidification and eutrophication, drainage and changes in land use cause accelerated vegetation succession in coastal dunes. During the last decades these impacts results in a loss of open- and species-rich vegetation and a widespread encroachment by tall grasses and invasive bushes (Veer and Koijman, 1997). The most obvious threat to the Danish coastal heaths is a massive invasion of mainly exotic trees and bushes like *Pinus mugo, Rosa rugosa* and *Sarothámnus scopárius*. The most comprehensive summary on effects of airborne pollutants on heathlands is given by Bobbink et al. (1998). However, the discrimination between changes due to nitrogen deposition and changes due to natural succession and absence of management is not clear-cut (Riis-Nielsen, 1997; Ashmore, 1997). In the Netherlands where the nitrogen deposition is considerably higher, observations have revealed comprehensive damage to lichen and a tremendous growth of mosses at the expense of lichens (DeSmidt and Van Ree, 1991; Greven 1992). Observations from heathland habitats show a higher dominance of grasses at the expense of scrubs (Bobbink et al. 1998). Observations in Denmark have demonstrated damage to species of reindeer mosses and the damage can be related to the impact of nitrogen depositions (Søchting 1990). In the early 1990's he observed black-dying of reindeer mosses in near-shore areas. In Denmark the nitrogen deposition are close to the critical load for dune heaths signifying that changes might only be noticeable in the long term. The critical load for nitrogen for dune heath has been set to 10-20 kg/ha-1 year-1 (Bobbink et al., 2002).

In the Netherlands an increased dominance of mosses has been observed on the dry sand heaths (Ketner-Oostra et al. 2004). The invasive moss species, *Campylopus introflexus*, is one among several moss species supposed to be able to colonise the dunes at the expense of other bryophytes, herbs and grasses because of the intensified acidification of the dunes (van der Meulen et al. 1987).

The different type of pressures against the dune habitats together with the general ecological knowledge has been used to formulate preliminary criteria for favourable conservation status. One of the objectives in the Danish dune heath project was to construct a monitoring strategy for terrestrial habitats based on habitat specific criteria's. The overall aim of the Danish dune heath project is to restore favourable conservation status for 5700 ha of coastal dune areas, mostly dune heath areas along the west coast of Denmark. Along a north south gradient in the western parts of Denmark four dune heath areas have been investigated in order to establish the conservation status of the areas. This paper describes the overall conservation status before the beginning of the restoration started.

Description of the investigated localities

The location of the four research areas is shown on figure 1. Two dune heathland, Lodbjerg and Stenbjerg situated in the north-western part of Denmark were investigated together with two localities in the south-western part, Rømø and Fanø, situated in the region of the Wadden Sea.

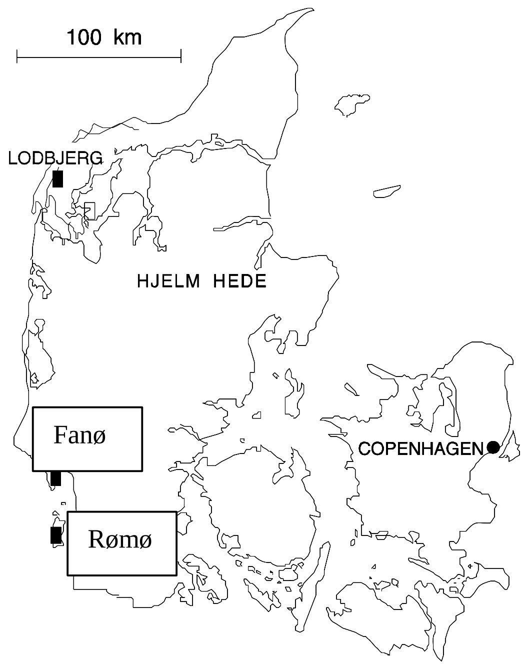


Figure 1. Position of the investigated areas. Stenbjerg is localized at Lodbjerg.

The size of the investigated areas is respectively 30, 20, 10 and 5 km^2. The only true tidal coast zone in Denmark is situated in the Southwest part of Jutland. Fanø and Rømø are both barrier islands. The dunes evolve due to fusion of the longshore bars with the beach whereas on the other locations the dunes are derived from coastal erosion of moraine cliffs. The development of the dune heath and the character of the aeolean soil material are supposed to be the same on the four localities. Fanø and Rømø belong to the lime- and iron-poor Wadden district (Kooijman and Besse, 2002). The historical background and analysis of the geological origin and soil types are only investigated on Lodbjerg and Stenbjerg (see Nielsen et al. 2000, and Stützer, 1998).

The three to five kilometre wide zone of windblown sand along the West Coast of northern Jutland has been moving eastwards for centuries because of coast erosion and strong wind activity. The strong wind and the sea erosion of the nearby 10 m high coastal moraine cliff have been the driving forces in the formation of a more than 10 m thick cover of windblown sand. An effort to stop the sand was taken from the beginning of the 16 Th. Century mainly by restricting both sheep grazing and haymaking. However, the common sheep grazing continued until about 1900 and did not cease totally until shortly before World War II. The landscape was more open, with sand drift activity and young dense *Calluna* dominated the vegetation. Today the vegetation is dominated by crowberry *Empetrum nigrum L.* and marram grass *Ammophila arenaria (L.)* Link .

The soil in the dune sands in the coastal heath is a shallow, weakly developed young soil, and according to the American Classification System is a Typic Udisamment (Nielsen et al. 2000). The top organic horizon is difficult to separate into L and F horizons and there is no H horizon. These soils are dated to be less than 300 years old (Nørnberg 1977). Andreas Stützer (1998) analysed soils from the white dune, Empetrum dune heath to a 100 yrs old sitka plantation in the area of Lodbjerg/Stenbjerg. Because of advancing accumulation of mor, the pH_{H2O} values in the upper mineral layers have decreased from 5 to around 4 within a few decades. The mor layers are typically 2- 4 cm in thickness showing little decomposition and the C/N ratio is very wide (>40).

During the 30-year period from 1961 to 1990 the mean annual precipitation was around 1000 mm in Southwest parts of Jutland, 750-900 mm in north-western parts of Jutland. A total annual nitrogen deposition of 13.5 kg ha-1 yr. was measured as an average for 1993-1995. Wet deposition of nitrogen was 80% of the total due to the proximity of the field station to the sea. Only approximately 49% of the total nitrogen deposition was reduced nitrogen (Hansen and Nielsen, 1998).

Criteria for favourable conservation status

According to the EU Council Directive 92/43/EEC (the Habitat Directive) (http://proaction.tripod.com/infoandlinks/id10.html) there is a common need for all EU Member States to ensure biological diversity by conservation of natural habitats and wild flora and fauna. A coherent European ecological network of special areas has been set up under the title NATURA 2000 including natural habitat types and habitat of species. Furthermore, Member States shall undertake surveillance of the conservation status and design measures to maintain or restore favourable conservation status considered as such when:

- the area occupied by the habitat type is stable or increasing, and
- the specific structure and functions which are necessary for its long-term stability exist and are likely to continue to exist for the foreseeable future, and
- the conservation status of its typical species is favourable.

Against the background of the above-mentioned main and very general criteria there is a need for criteria formulated specific for each natural habitat types. Specific criteria for favourable conservation status are presented in the enclosure at the end of the status report for habitat types in the dune ecosystems. Criteria should comprise relevant indicators/properties for the habitat type in question with sets of specific values or intervals needed to be fulfilled to obtain favourable conservation status. These habitat type-specific criteria are based on the following:

- form the basis for development of the adequately monitoring leading to assessment of the conservation status
- should be scientifically based, biological relevant and lead to the wanted state of conservation, i.e. support the goal for the monitoring
- should be simple and easy to understand, i.e. based on scientific justifiable simplifications
- should be operational, quantitative, objective and reproducible
- should be sensitive enough to detect changes within a short timespan
- should be thoroughly tested, i.e. robust
- be able to come up with a diagnose as well as a prognoses of the conservation status of the habitattype

Enclosure 1a -c tells precisely what kinds of information need to be sampled in the field. The purpose of the proposed criteria is to operationalise the formulation of favourable conservation status in a way that ensures a systematic monitoring of state and development related to an objective. As an example enclosure 1 shows the criteria for the habitat types 2130 "grey dunes" and 2140 " Decalcified fixed dunes with *Empetrum nigrum*". Enclosure 1a-c mentions the specific criteria, which must be achieved to obtain favourable conservation status for the nature type.

Method

The four research areas were delimited to a natural unit on aerial photo. The selected areas mainly represents the primary habitat type" Decalcified fixed dunes with *Empetrum nigrum*" (habitatnumber 2140). Within the delimited area a number of other dune habitat types are present in greater or smaller natural mosaic. The aerial photo of each station was then covered with points of the national 10x10m referencenet. From the referencenet 30 sample points was randomly selected. The field research was connected to these 30 stochastically distributed sample points. Each sample point consisted of 6 sub-sample points along a 10-m transect always pointing north. As some sample point will be located in places not belonging to the habitat in question like forest, lakes or roads it is necessary to select a greater number of points. The co-ordinates of the sample points were transferred to a GPS. Data sampling was performed at the sampling points. In the field the sample points was localised by GPS as waypoints with a precision of ±5 m. The sample points are randomly and objectively selected and thus without any preference from the surveyor. Due to the general inaccuracy of the GPS localisation the sample point can be regarded as randomised point each year. A sample point cannot be used if it is consolidated, agricultural area or a plantation. According to the habitat-directive the habitat types should be defined broadly (http://eunis.eea.eu.int/habitats.jsp) which means that both potential favourable and unfavourable areas should be included in the investigation. The habitat type belongs to the following three main type 1) 2130 "grey (and green) dunes", 2) 2140 " decalcified fixed dunes with *Empetrum nigrum*" and 3) 2190 "wet dune slacks". Other habitat types belonging to the dune family are found in mosaic. The extent of these additional habitat types of the dune family are normally so small that it gives no meaning to establish a station and far less meaning to report the conservation status.

Arriving to a sample point the habitat type was determined by use of http://eunis.eea.eu.int/habitats.jsp. The classification of the type was based on the habitat type found in the 50 by 50-cm sample point together with observations of the dominant type in found in the 5 –m circle surrounding the sample point.

The pinpoint frame is 50 x 50 cm with 16-grid point. A sample point consisted of six sub-samples along a 10 m transect pointing north. The total number of grid point in the pinpoint analysis was 96. Unpublished data from investigations in other dune heath project shows that the cover of vegetation is best done with a relatively small frame which is then repeated along a transect. The total length of "monitoring walk" in Lodbjerg dune heath was 45 km, which highly motivated a small and practical frame for vegetation analysis. The pinpoint method was chosen because data were more robust than data from frequency analysis (unpublished). The main objective of the vegetation monitoring is to follow increase and decrease of the dominant species over decades.

A 5 m circle is made around the first sample point in the 10 m transect. In the 5 m circle supplementary species and the cover of trees is noted. In table 1 it is noted which data are collected in the sample point and which belongs to the 5 m circle. In this investigation only the cover of trees was estimated in the 5-m circle.

The monitoring programme was performed in 2002 and part of it was repeated in 2004.

Table 1. *Sampling and observations attached respectively to the samle plot and the 5 m circle.*

Observations and sampling in the sample plots	Observations in the 5 m circle:
Cover of species Supplemental species pH in soil/water Conductivity C/N - ratio Phosphorous Nitrate in soil/water N in shoots, mosses and lichens	Frequency of supplementary species Vegetation height Pct. cover of woody species pct. flooding pct. gaps in vegetation (outblows) pct. cover of invasive species pct. cover of herbivory (heather beetle attack) pct. hollows in bog structure

Chemical analysis
Samples of the mor-layer was taken by a steel cylinder with a diameter of 48 mm. Samples were taken every 2 m along the 10 m transect as whole horizons. The composite samples was dried at 80°C, homogenised, chrushed and weighed into sample boats. Total carbon and nitrogen content were analysed on an elemental analyser (Europa Scientific RoboPrep-C/N). Shoots of *Calluna vulgaris*, *Empetrum nigrum*, and the living part of *Cl. portentosa/ciliata* and *Dicranum scoparium/pleurozium* were analysed the same way as composite samples taken along the transect. Samples of cryptogams were from freely exposed cushions with no cover of branches from dwarf scrubs (avoiding contamination from throughfall). PH was determined in 1:1 soil-liquid ratios of water and in distilled water.

Results

The conservation status of the main habitat types belonging to dune ecosystems, 2130, 2140 and 2190 which have been dominant is this investigation has been assessed. As shown in table 3 the major part of the investigated plots belongs to the habitat type 2140, the *Empetrum* dune heath. In table 3a all six sub-sample plots have been aggregated to represent one habitat type. In 3b all sub-sample plots are ascribed to one habitat type based on the dominating type within the 5 m circle. Often the dune habitats are present in a more or less pronounced mosaic that changes within short distance. Therefor 3b represent the distribution of the three habitat types better than 3a.

Table 3a. *Upper: Distribution of dune types aggregated from the 10 m transect – all six sub-sample from the transect are aggregated to one single sample*
Lower:3b. Distribution of dune types single frames, i.e. all sub-samples are treated as independent samples.

	2130 %	2140 %	2190 %
Lodbjerg	23	43	33
Stenbjerg	7	57	37
Fanø	26	52	5
Rømø	4	75	21

	2130	2140	2190
Lodbjerg	23	47	29
Stenbjerg	17	49	34
Fanø	35	39	5
Rømø	10	66	24

Nitrogen in shoots, lichens and mosses
The nitrogen content in leaf has been shown to reflect the atmospheric inputs of nitrogen (Pitcairn et al., 1995; de Vries et al. 1995; Bobbink et al. 1996). In the present investigation it is the only parameter which can react on changes in nutrient input in a short timespan. On the basis of figure 2 it is seen that the nitrogen content in lichens all are grouped around the chosen criteria – 0.6%. As expected the two northernmost stations are both slightly below opposed to the southernmost. Except from Fanø the variation between September 2002 and 2004 are small. The levels in June are higher.

In 1987 according to Söchting (1995) a value of 0.5% N, the lowest value in Denmark, was found in the north of Denmark. In the central and southernmost parts of Jutland the nitrogen content on inland heath was generally above 0.8%.

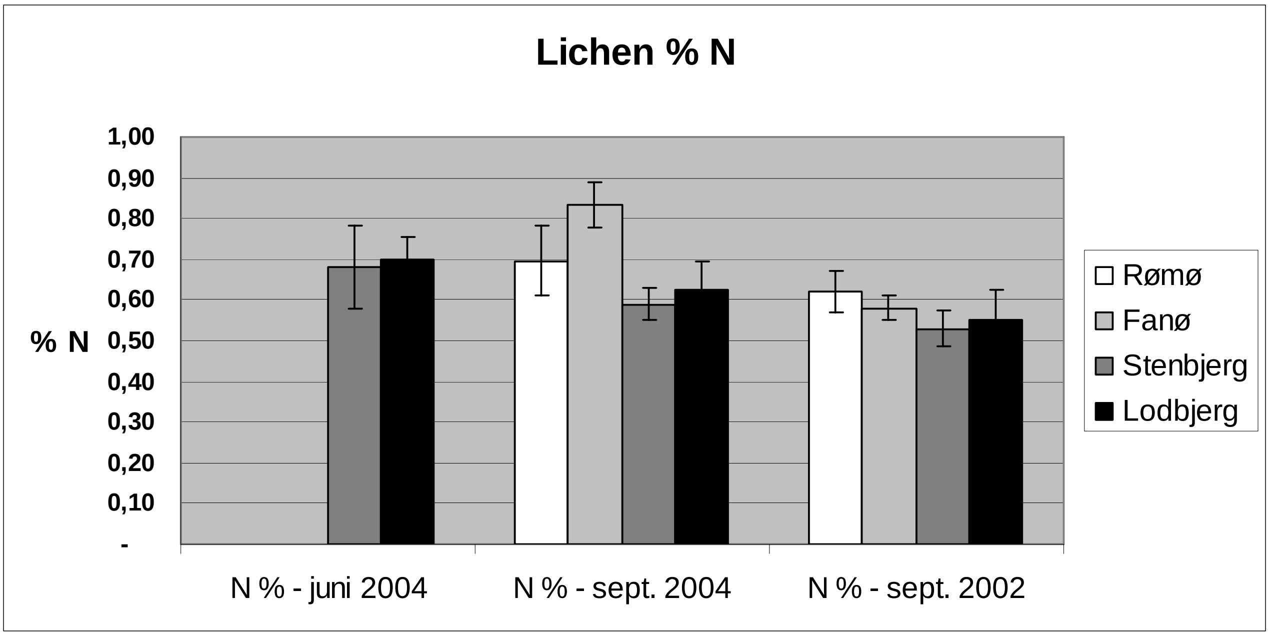
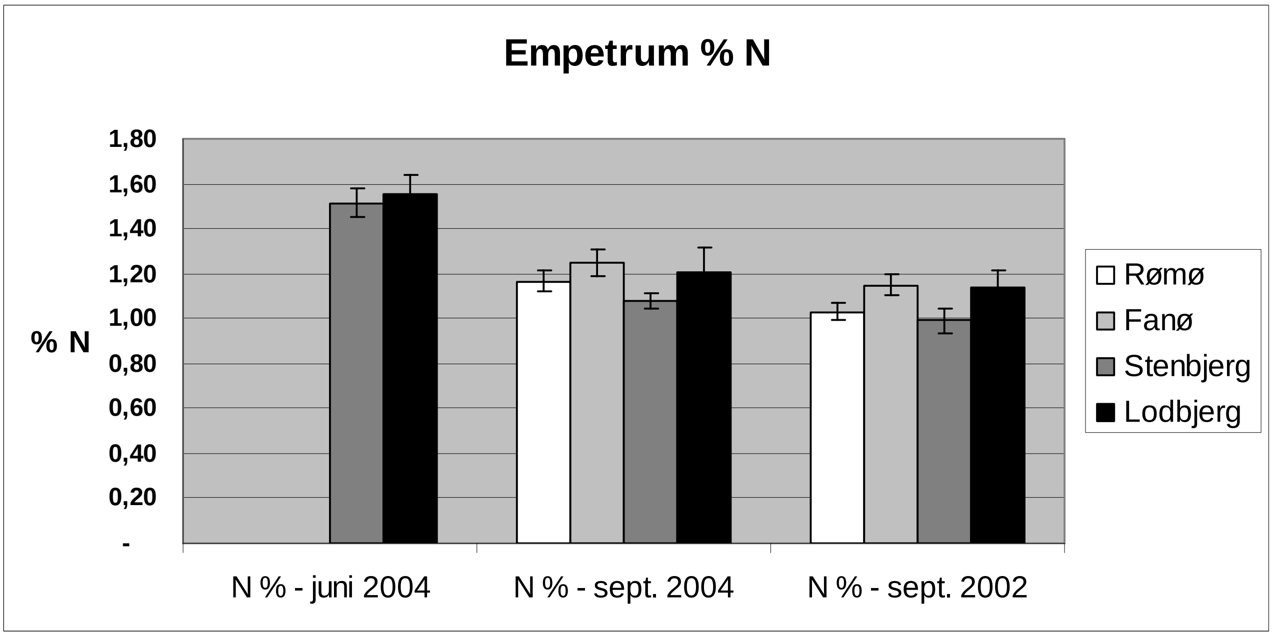


figure 2. Content of nitrogen I lichens in September 2002, and June and September 2004

Phytochemical analysis expresses first of all the nutrient status and therefor also an indication of the present load on the locality. It has been demonstrated that species of lichens (e.g. *Cladonia portentosa* and *Hypogymnia physodes*) are very efficient absorbents of nitrogen compounds (Söchting, 1995, Crittenden, 1989; Reiners, 1984). Transplanting of lichens and sphagnum mosses between areas with different level of deposition shows a very quick response in the nitrogen content of the thalli to the changed condition (S¨chting, 1995). Söchting also introduced a method where lichens have been used as biomonitors of deposition. Further he investigated samples of lichens from different parts of Scandinavia showing level of nitrogen in thalli from 0.2-0.3 % in the northern part of Sweden to 0.8 % in the southern parts of Denmark. Judged from data from Denmark the national criteria for nitrogen content in thalli from reindeer lichens has been set to 0.6 % by national experts (Soegaard et al. 2003).

In figure 3 it is seen that there are no big difference between analysis of shoots from Empetrum from September 2002 and 2004, as opposed to a higher level in the beginning of the growing season. It was concluded to perform the monitoring at the end of the august or beginning of September where the dynamics typically will be smaller than in the beginning. End of growing season is also more easily defined that the beginning of season, which climatically vary much more from year to year.



C/N ratio in the upper soil horizons

The amount of organic matter and the relationship between carbon and nitrogen in the top organic horizons are of crucial importance for the ability of resistance towards acidification and eutrophication from atmospheric pollutants. Gundersen (1998) established a close relationship between the forest floor C/N ratio net nitrification in field incubations and nitrate leaching. This relationship seems to be best for mor horizons (Nilsson et al. 1998). Unfertilized terrestrial ecosystems are usually characterized by relatively closed N cycling, i.e. N input and output are comparably small in relation to N exchange within the soil/plant subsystem (Fenn et al, 1998). In such systems soil organic matter is mainly described as more or less inert pools of C and N but actually it is a highly dynamic component in the nutrient cycling. The maintenance of low availability of nitrogen in dune heath soils is a major factor for the stability of the habitat type. Mor-layers of forest and heathlands contain the major part of the functional root systems including symbiotic relationship with mycorrhiza. (Johannson, 2000). Up to a certain level it can function as a buffer against acidification and eutrophication (Kristensen and Mccarthy, 1999). Nielsen et al. (2000) found that the ability to retain added as well as deposited nitrogen requires the presence and the integrity of a humifyed H-sub-horizon.

Analysis of soil samples from the four locations shows that the C/N ratios in the upper organic horizons are approaching 25, figure 4. Based on results from Nielsen et al. (1987a, 2000), Kristensen et al. (1998) and Stützer (1997) the criteria for this indicator has been set to be larger than 30. A C/N ratio of 25 in the mor layer is a low ratio and indicate a risk of nitrate formation in the upper soil layer.

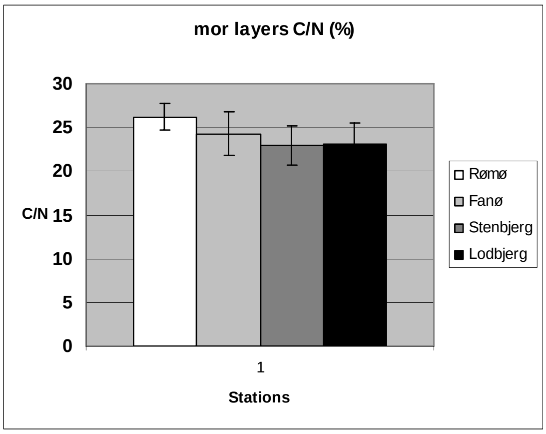
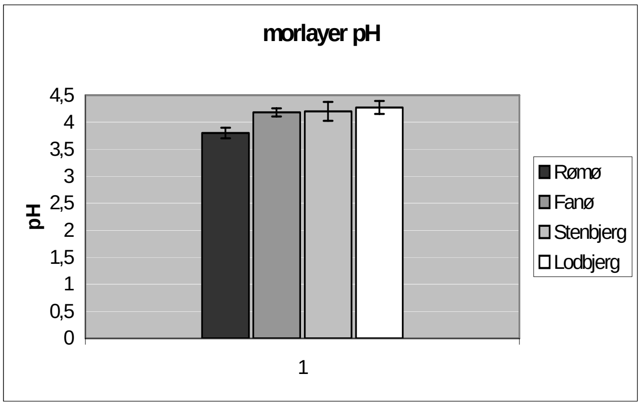


Figure 4. C/N ratio of the mor layers on the four localities.

Especially for the habitat types with an accumulation horizon or with a high content of carbon in the upper soil major changes in the nutrient turnover happens Currie (1999). There is a considerable time lag between a certain influence and a visual effect on the vegetation due to a considerable buffer capacity both biological and chemical. The criteria of the C/N ratio is a strong prognostic tool to predict future changes in the vegetation.

Soil samples have been analysed for pH, figure 5 and the values in the mor layers are all close to 4 in accordance with similar investigations (Stützer, 1997, Nielsen et al. 2000 and Vestergaard (2001).



Cover of vegetation

The total amount of *Empetrum* and *Calluna* approaches 70% on Rømø and on the other stations the cover are around 40%, see table 2. On Rømø the succession of the dune heath has proceeded far and more than half of the total cover is dominated by *Empetrum nigrum*. The area of Stenbjerg is more dominated by wet slack areas judged from the higher cover of species belonging to the wet dune slacks – i.e. *Erica tetralix*, *Vaccinium uliginosum* and *Molinia coerulea*. On Fanø parts of the dune heath has more resemblance to acid grasslands with a relatively high amount of *Agrostis canina*. Part of the investigated area on Fanø was highly disturbed by rabbit.

Table 2 *Cover in % of the most dominant species*

	Lodbj.		Stenbj.		Rømø		Fanø	
	2002	**2004**	**2002**	**2004**	**2002**	**2004**	**2002**	**2004**
Calluna vulgaris	20	17	26	22	21	14	12	23
Empetrum nigrum	19	29	15	25	43	56	9,4	15
Carex arenaria	11	26	12	31	4,0	8,9	23	36
Erica tetralix	3,7	7,4	12	18	0,5	4,3	1,6	1,3
Ammophila arenaria	13	16	7,6	11	2,4	3,3	2,5	4,1
Vaccinium uliginosum	5,3	6,8	7,3	10	6,2	10	1,5	1,0
Molinia coerulea	5,8	7,6	8,7	10	5,6	6,0	0,1	1,5
Deshampsia flexuosa	4,0	3,2	16	20	11	16	7,5	9,3
Calamagrostis canescens	0,0	1,7	0,0	0,0	0,0	0,0	0,0	0,0
Agrostis canina	0,5	1,2	0,8	0,9	0,6	1,2	13	14
				0,0				
Campylopus introflexus	0,0	0,1	0,6	0,9	0,1	0,3	0,0	3,1

This pattern of the dominating vegetation is also reflected in the distribution of the three habitattypes, codeno. 2130, 2140 and 2190, shown in table 3.

In 2002 nearly 50% of the plots at the location on Fanø have more than 50% cover of mugo pine. In 2004 the investigated areas on Fanø was treeless. No major changes in cover of trees at the other location were noted in the extensive monitoring. At Lodbjerg less than 20% of the sample plots have a cover of trees of more than 20%. Here *Salix* dominates a few plots. The invasion of trees has many implications on the vegetation process. Beneath mugo pine the dwarf scrubs are replaced by grasses – mainly *Deschampsia flexuosa.* Besides the influence on the ground vegetation the trees also changes the soil processes (Nielsen et al. 1987a,b and 1999). Within a few decades oak trees are able to reverse the general acidification process known as podsolisation beneath dwarf scrubs to a development towards brown soils by a process known as depodsolisation. A change back to a dominance of the acidifying vegetation is not a straightforward process and many management project on heathland have failed to restore the heahtland vegetation. A paradigm shift in nutrient turnover results from invasion of trees. It is not guaranteed that removal of trees helps to restore favourable conservation status for heathland habitat types within a short time span.

Table 4. *Cover in m2 of trees in the 5 m circle*

		0 m^2	1-<10 m^2	10:<20	20:<40	40:<80	80:100
lodbjerg	**2002**	21	3	2	2	2	0
	2004	23	3	1	2	1	0
Stenbjerg	**2002**	21	8	0	0	1	0
	2004	21	8	0	0	1	0
Fanø	**2002**	8	1	1	2	5	3
	2004	20	0	0	0	0	0
Rømø	**2002**	18	1	0	0	2	0
	2004	18	1	0	0	2	0

Table 5 shows the lichen/moss ratio on the four localities and there seems to be a big difference between the Lodbjerg and Stenbjerg on the one hand and Rømø and Fanø on the other. There is a general consensus among scientists that a high deposition of N reduces the cover of lichens at the expense of moss cover.

Table 5 *Lichen/moss ration on the four localities.*

Lodbjerg	0,80
Stenbjerg	0,60
Rømø	0,30
Fanø	0,25

The cover of the invasive moss *Campylupus introflexus* is locally dominant on Fanø. The deposition of N from the atmosphere is higher than 20 kg ha^{-1} yr^{-1} year in the southern parts of Jutland whereas in the northern part the level is around 15 kg ha^{-1} yr^{-1} (Hansen and Nielsen, 1998). By comparing the data from a 1960-survey of dune heathlands in the Wadden Sea area by presence occurrence Ketner-Oostra and Sykora (2004) found a large decrease in lichen-diversity at the expense of grass and moss encroachment. Van Ree and De Smidt (1989) compared recordings of moss and lichen flora in the province of Gelderland from 1965 to 1975 with mappings in 1988 and found that 25 cryptogamic species have been nearly or completely lost. Average moss cover declined from 50 to 60% in 1965–1975 to 2–10% in 1988 within the heathland areas. This is attributed both to direct effects of eutrophication, as well as to an increase of dense grass canopies preventing moss growth. Drastic loss in species diversity was observed in liverworts, with only three of the 13 species found in 1965–1975 still being present in 1988. In a similar manner, 12 of the 18 commonly found lichen species have disappeared or become rare.

Table 6 shows a total lack of early succession lichen on the location on Rømø. This must be a result of the lack of disturbance and the concomitant creation of exposed mineral soil. Rømø was characterized by a dense carpet of crowberries.

In areas with low nitrogen deposition (< 8 kg N ha-1 year-1) like Læsø and Anholt and the coast of Northern Sealand the load is not assessed to make up a threat. Repeated surveys of botanical test plots on Læsø showed practically no changes in the composition of the vegetation over a 45-year period (Christensen, 1989).

Table 6. *Number of observations of lichens in the pin-point analysis.*

	Lodbj.		**Stenbj.**		**Rømø**		**Fanø**	
	2002	**2004**	**2002**	**2004**	**2002**	**2004**	**2002**	**2004**
Cetraria sp.	5	7	7	5	0	0	19	3
Cladonia foliacea	6	17	12	21	0	0	16	8
Cladonia gracilis	9	11	8	22	0,1	0	2	8
Cladonia macilenta	11	14	9	9	1	0	0,1	2
Cladonia merochlorophaea	47	33	38	22	6	7	11	3
Cladonia portentosa:ciliata	478	419	306	300	147	159	148	96
Cladonia rangiformis	6	3	8	3	0	0	8	0
Cladonia subulata	27	10	17	1	4	0	5	0
Cladonia uncialis	1	0	12	9	0	0	0	0

Conclusion

According to the EU Council Directive 92/43/EEC (the Habitat Directive) (http://proaction.tripod.com/infoandlinks/id10.html) there is a common need for all EU Member States to ensure biological diversity by conservation of natural habitats and wild flora and fauna.

Against this background there is a need for harmonised criteria formulated specific for each natural habitat types mentioned in the directive. Criteria should comprise relevant indicators/properties for the habitat type in question with sets of specific values or intervals needed to be fulfilled to obtain favourable conservation status.

The practical way to investigate large terrestrial areas and to establish the conservation status has not been tried before in Denmark. The experience from the research of conservation status of four major dune heath localities along the west coast of Denmark will be used to design a terrestrial monitoring programme for natural habitats highly restricted towards the needs of the habitat-directive (ref.). In order to say anything scientifically about the development of habitat nature it is fundamental that the monitoring is based on sampling of data, which can be reproduced. It is also fundamental that the strategies of sampling are based on representative principles.

Due to lack of suitable national vegetation data it is clear from this first attempt to set criteria's of favourable conservation status that the chemical criteria are much easier to set opposed to the much more variable biological indicators. The criteria's for the composition of the vegetation should comprise the total variation expected for the specific habitat type – and the types should be broadly interpreted according to the Directive.

The C/N ratio transcends the proposed criteria. As this ratio is a key ecosystem component that integrate deposition history and change in land-use the assessment of conservation status must strongly rely on this parameter. The conservation status for all the investigated sites is not favourable. The tight N cyclus found in the soil may be susceptible to disruption because of the limited capacity of this habitattype to remove nitrogen from the soil. In the inland heath situated 15 km from the coast the C/N ratio was around 20. In large part of this heathland *Chaemerion angustifolium* are scattered amongst the dwarf scrubs clearly indicating release of inorganic nitrogen.

The criteria related to nitrogen in shoot and lichen thalli are fulfilled for all stations. Opposed to the C/N ratio this parameter is chosen to reflect short-term changes. If a change happens in the local surroundings it should be reflected in the shoot chemistry and on the longer term also on the C/N ratio and the composition of the vegetation.

In a monitoring programme where you are only allowed (due to economy) to sample vegetation data and samples for analysis once a year one has to choose the "right season for sampling". The repeated analysis of nitrogen in lichen in June and September show a slightly higher level in the early summertime. It is expected that the variation in the beginning of the growing season will be high opposed to later on when the vegetation has "outlived" the growing season. At that time – end of august to September -it is expected that the dynamics will be less. End of growing season also allows a much longer time period for sampling.

The vegetation data are much more difficult to asses due to lack of historical data but there are a general agreement that major changes towards encroachment of tall grasses and decrease in the lichen diversity has happened. It is therefor important that the registrations are quantitative in order to document long-term changes in cover of grasses and cryptogams. From the data it is possible to construct different ratios which are relevant as indicator. Grasses/dwarf-scrubs, lichen/moss ratio or Empetrum/Calluna ratio are all relevant ecological index but what the ratios should be in order to be favourable is a matter to discuss.

The purpose of the proposed criteria in this research is to operationalise the formulation of favourable conservation status in a way that ensures a systematic monitoring of state and development related to an objective. The criteria are preliminary and will be adjusted from time to time as data will be reported from the ongoing monitoring and the knowledge increases.

A value outside the acceptable limits/value should then act as a trigger of restoration for a given location. A monitoring programme should not only be designed to detect any changes in conservation status for species and habitats but also to give answers to why the changes have happened involving habitat-related parameters. Within the work of reducing the effects of the transboundary air-pollution – critical load, Løkke et al.(1996), points to the lack of well-defined biological criteria. Combining elements from the monitoring of forest ecosystems with elements from monitoring of biodiversity the concept behind the Danish model seek to "bridge the gap" between the traditional biodiversity monitoring and the monitoring of effects on air-pollution. The choice of criteria's must reflect the ability of diagnosis as well as prognosis.

References

Aerts, R., 1990. Nutrient use efficiency in evergreen and deciduous species from heathland. Oecologia **84**, pp. 391–397.

Ashmore, M., 1997. Plants and pollution. In Plant Ecology, 2nd edition, ed M.J.Crawley pp. 568-581. Blackwell Science Ltd. Oxford.

Bobbink, R, Hornung M., Roelofs J.G.M., 1998. The effects of air-borne nitrogen pollutants on species diversity in natural and semi-natural European vegetation. Journal of Ecology 86, 717-738.

Bobbink, R., Ashmore, M, Braun, S., Flückiger, W. and I.J.J. Vam dem Wumgaert. Empirical nitrogen critical loads for natural and semi-natural ecosystems: 2002 updata. http://www.oekodata.com/pub/mapping/manual/nitrogen_background.pdf

Christensen, S. N. 1989. Floristic and vegetational changes in a permanent plot in a Danish coastal dune heath. Ann. Bot. Fennici 26:389-397

Currie, W.S. 1999. The responsive C and N biogeochemistry of the temperate forest floor. Tree 14, 316-320.

DeSmidt, J.T., Van Ree, P., 1991. The decrease of bryophytes and lichens in Dutch heathlands since 1975. Acto Botanica Neerlandica 40, 379.

Ellermann, T., Hertel, O., Ambelas Skjøth, C., Kemp, K. & Monies, C. (2003): Atmosfærisk deposition 2002. NOVA 2003. National Environmental Research Institute. Faglig rapport from NERI: 466, 94pp (in Danish).

Greven, H.C.,1992. Changes in the moss flora of the Netherlands. Biological Conservation 59, 133-137.

Gundersen, P., 1998. Impacts of nitrogen deposition on nitrogen cycling: a synthesis. Forest Ecology and Management. 101, 37-55.

Hansen, B., Nielsen, K.E.,1998. Comparison of acidic deposition to semi-natural ecosystems in Denmark - coastal heath, inland heath and oak wood. Atmospheric Environment 32, 1075-1086.

Ketner-Oostra R., Sykora, K.V., 2004. Decline of lichen-diversitly in calcium-poor coastal dune vegetation since the 1970s, related to grass and moss encroachment. Phytocoenologia 34, 4: 521-549.

Kooijman, A.M., Bessse, M., 2002. The higher availability of N and P in lime-poor than in lime-rich coastal dunes in the Netherlands. Journal of Ecology 90, 394-403.

Kristensen, H.L. and Henriksen, K., 1998. Soil nitrogen transformations along a successional gradient from Calluna heathland to Quercus forest at intermediate atmospheric nitrogen deposition. Appl. Soil Ecol., 8: 95-109.

Kristensen, H.L. and McCarty, G.W., 1999. Mineralization and immobilization of nitrogen in heath soil under intact Calluna, after heather beetle infestation and nitrogen fertilization. Applied soil Ecology 13, 187-198.

Løkke, H., Bak, J., Falkengren-Grerup, U., Finlay, R.D., Ilvesniemi, H., Nygaard, P.H. & Starr, M., 1996. Critical Loads of Acidic Deposition for Forest Soils. Is the Current Approach Adequate? Ambio 25, 510516.

Nielsen, K E , Ladekarl U.L., Nørnberg, P., 1999 Dynamic soil processes on heathland due to changes in vegetation to oak and Sitka. Forest Ecology and Management 114, 107-116.

Nielsen, K.E., Hansen, B., Ladekarl, U.L. & Nørnberg, P. (2000): Effects of N-Deposition on Ion Trapping by B-Horizons of Danish Heathlands. - Plant and Soil 223: 265-276.

Nilsson, S.I., Berggren, D and Westling, O. 1998. Retention of deposited NH_4^+-N and NO_3-N in coniferous forest ecosystems in southern Sweden. Scandinavian Journal of Forest Research, 13, 393-401.

Nørnberg, P. 1977. Soil profile development in sand of varying age in vendsyssel, Denmark. Catena 4, 165-179.

Pihl, S., Ejrnaes, R., Soegaard, B., Aude, E., Nielsen, K.E., Dahl, K. & Laursen, J.S., 2000. Habitat and Species Covered by the EEC Habitats Directive. A Preliminary Assessment of Distribution and Conservation Status in Denmark. NERI Technical report no. 365, 121 p. The report is only available in electronic version (http://www.dmu.dk/1_viden/2_Publikationer/3_fagrapporter/abstrakter/abs_365_uk.asp)

Riis-Nielsen, T., 1997. Effects of nitrogen on the stability and dynamics of Danish heathland vegetation. PhD Thesis, University of Copenhagen, Denmark.

Pitcairn, C.E.R., Skiba, U.M , Sutton, M.A., Fowler, D., Munro, R , Kennedy, V., 2002. Defining the spatial impacts of poultry farm ammonia emissions on species composition of adjacent woodland groundflora using Ellenberg Nitrogen Index, nitrous oxide and nitric oxide emissions and foliar nitrogen as marker variables. Environmental Pollution 119, 9-21.

Reiners, W.A. , Olson, R.K., 1984. Effects of canopy components on throughfall chemistry: An experimental analyssis. Oecologia (Berlin) 63, 320-330.

Soegaard, B., Skov, F., Ejrnaes, R., Nielsen, K.E ., Pihl, S., Clausen, P., Laursen, K., Bregnballe, T., Madsen, J, Baatrup-Pedersen, A., Søndergaard, M., Lauridsen, T.L., Moeller, P.F., Riis-Nielsen, T., Buttenschoen, R.M., Fredshavn, J., Aude, E. & Nygaard, B. 2005. Criteria for favourable conservation status in Denmark. Natural habitat types and species covered by the EEC Habitats Directive and birds covered by the EEC Bird Protection Directive.DRAFT VERSION. NERI Technical Report 2005. http://forum.europa.eu.int/irc/DownLoad/kYeWAgJBmqG9XYPPuRRC-bEk-Z8D1q6z4pYxtvF37-8Bo6HYLYCI1UmOzCmyU8kIYjP/FCS-Report_2005_Denmark%20%282%29.doc

Swift, M.J ., Heal, O.W., Anderson, J.M., 1979. Decomposition in Terrestrial Ecosystems. Blackwell science, Oxford.

Stützer, A., 1998. Early stages of podzolisation in young aeolian sediments, western Jutland. Catena 32, 115-129.

Söchting, U., 1995. Lichens as monitors of nitrogen deposition. Cryptogamic Botany 5, 264-269.

Thomson, D.B.A. Baddeley, J., 1991. Some effects of acidic deposition on montane Racomitrium lanuginosum heaths. In: The effects of Acid Deposition on Nature Conservation in Great Britain, ed. S.J. Woodin and A. M. farmer. Nature Conservancy Council, Peterborough, pp17-28.

UNECE. 2003 UNECE, 2004. Mapping manual. Modelling and mapping critical loads and levels and air pollution effects, risks and trends. UNECE http://www.oekodata.com/pub/mapping/manual/mapman_5_2.pdf

Veer, M.A.C., Kooijman, A.M., 1997. Nitrogen availability in relation to vegetation changes resulting from grass-encroachment in Dutch dry dunes. Plant and Soil, 192, 119-128.

Van Breemen, N. and Van Dijk, H.F.G., 1988. Ecosystem effects of atmospheric deposition of nitrogen in the Netherlands. Environmental Pollution **54**, pp. 249–274.

Van der Meulen, F., Van der Hagen, H. and Kruijsen, B., 1987. *Campylupus introflexus*. Invasion of a moss in Dutch coastal dunes. Proceedings of the Koninklijke Nederlandse Akademie van Wetenshchappen. Series C – Biological and medical sciences, 90, 73-80.

Van Ree, P.J., De Smidt, J.T., 1989. Loss of cryptogams in heathlands since 1975. Vortrag Arbeitstagung zur Heideforschung, Willingen, Germany, 25–26 September 1989.

Enclosure 1a-c showing criteria for favourable conservation status for the investigated dune habitats.

Enclosure 1. Criteria for favourable conservation status on site level for the habitat type 2130.

Type 2130	Property	Unit of measurement	Criteria	Comments
Area	Area (hectares)	Number of hectares	Stable or increasing	
Structure and function	Natural low nutrient level	Nitrogen deposition (kg/N/hectare/year)	Not exceeding the critical load	The critical load 10-20 kg/N/hectare/ year, UNECE 2003
	Natural low nutrient level	Nitrogen content (mg/g) in Cladonia portentosa. Damages on foliage leaf are observed by N >8 mg/g and by N=13 mg/m lichen are dying	Within the natural range of the habitat type in Denmark. Stable or improving	Should be less than 6 mg/g. Level in countries without N-load 2-4 mg/g, in Denmark 5.3-9.6 mg/g, lowest in Western Jutland, highest in Mid-Jutland
	Acidity	pH	The pH must be stable and not considerably lower than the natural acidity of the locality.	If no historical information is available, the natural pH can be predicted by model
	(P) Mechanical impact	Proportion of area influenced by wear and tear from e.g. tourism	Stable or decreasing	Should not exceed 10%
	Open, herb dominated vegetation	Coverage of non-indigenous trees and bushes	Stable or improving	Overgrowth is partly due to seed-pressure from plantations and invasive species. Mountain pine, dune pine, Norway spruce and Japanese rose should be removed
	Cryptogams	Lichen/moss-ratio in grey dune	Within the natural range of the habitat type in Denmark. Stable or improving	Should be higher than 3:1. The grey dune is characteristic of a rich lichen flora. The criterion is preliminary, but studies have shown that eutrophication is increasing the proportion of mosses
	Species composition of plants	Deviation from the species composition of this habitat type in reference condition	The deviation is within the expected variation of the natural habitat type in Denmark	The species composition is a diversity indicator of changes in the environment factors
Characteristic species	Population of characteristic species	Index of populations of characteristic species present	Long-term maintenance on a stable or increasing level	Register by species, e.g. using the DAFOR scale. Variations are natural. In special cases declines may be acceptable /targeted.

Enclosure 1b. Criteria for favourable conservation status on site level for the nature type 2140.

Type 2140	Property	Unit of measurement	Criteria	Comments
Area	Area (hectares)	Number of hectares	Stable or increasing	Loss due to dynamic shifts forth or back in the dune succession is accepted – e.g. breach or scrub invasion to type 2180
Structure and function	Naturally low nutrient level	Nitrogen deposition (kg/N/hectare/year)	Not exceeding the critical load	Critical load 10-20 kg/N/hectare/year, UNECE (2003)
	Naturally low nutrient level	Nitrogen deposition in year-shoots in dwarf bushes in mg/g	Within the natural range of the habitat type in Denmark. Stable or improving	Should be <1,4 mg/g. High N% is an indicator of eutrophication and can increase the leaf beetle attack on heather. Bobbink et al. (1998)
	Naturally low nutrient level	C/N relation in raw humus layer	Within the natural range of the habitat type in Denmark. Stable or improving	Should be >30. Low C/N relation increase the mineralising, risking dominants of grasses. Nielsen et al. 2000, Christensen et al. 199???
	Acidity	pH	The pH must be stable and not considerably lower than the natural acidity of the locality.	If no historical information is available, the natural pH can be predicted by model
	Continuity	Proportion of area with extensive wood felling, grazing and other previous exploitation	Stable or increasing, apart from this if untouched succession is chosen as a long-term, general target	The nature type will be overgrown without previous management or similarly.
	Open vegetation	Coverage of non-indigenous trees and bushes	Stable or decreasing	Overgrowing is partly due to seed-pressure from plantations and invasive species. Mountain pine, dune pine and Japanese rose should be limited/removed
	Invasive species	Coverage/frequency of the moss-species *Campylopus interflexus* compared to cryptograms	Stable or decreasing	Should be <5%. The moss-species is invasive and an aggressive competitor to lichens, thus it should be limited
	Species composition of plants	Deviation from the species composition of the habitat type in reference condition	The deviation is within the expected variation of the natural habitat type in Denmark	The species composition is a strong indicator of changes in the environment
Characteristic species	Population of characteristic species	Index of populations of occurring characteristic species	Long-term maintenance on a stable or increasing level	Register by species, e.g. using the DAFOR scale. Variations are natural. In special cases decline may be accepted /targeted.

Enclosure 1c. Criteria for favourable conservation status on site level for the nature type 2190.

Type 2190	Property	Unit of measurement	Criteria	Comments
Area	Area (hectares)	Number of hectares	Stable or increasing	Dynamics and interaction with other types are dominant and new dune slacks will be made – in the beginning often without vegetation.
Structure and function	Naturally low nutrient level	Nitrogen deposition (kg/N/hectare/year)	Not exceeding the critical load	Critical load 10-25 kg/N/hectare/year, UNECE (2003)
	Natural hydrology	Influencing effort on hydrology	Stable and decreasing effort for dredging and ditching	The water level is of fundamental importance. Natural hydrology should be the goal. Ongoing drainage should be stopped and influence from water abstraction should be reduced as much as possible
	Acidity	pH	The pH must be stable and not considerably lower than the natural acidity of the locality.	If no historical information is available, the natural pH can be predicted by model
	Open vegetation	Coverage of non-indigenous trees and bushes	Within the expected variation of the natural habitat type in Denmark. Stable or improving	For instance should juniper, aspen, birch, oak, broom, sea buckthorn and elder only be present as scattered occurrences due to shading and increased evaporation
	Species composition of plants	Deviation from the species composition of the habitat type in reference condition	The deviation is within the expected variation of the natural habitat type in Denmark	The species composition is a strong indicator of changes in the environment
Characteristic species	Population of characteristic species	Index of populations of occurring characteristic species	Long-term maintenance on a stable or increasing level	Register by species. Variations are natural. In special cases decline may be accepted /targeted.