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The lichen-rich coastal heath vegetation on the isle of Anholt, Denmark – conservation and management

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Abstract. The high conservational value of the lichen-rich vegetation and landscape of the marine foreland Ørkenen on the isle of Anholt is treated from a Danish as well as a European perspective. The sensitivity of the lichen-rich vegetation to physical disturbance is emphasized. The impact of invasive species such as *Pinus mugo* as well as the effect of atmospheric deposition of nutrients on the heaths at Anholt is described. Considerations related to the development of a management plan for Ørkenen are presented.

Keywords: *Alectoria sarmentosa*; Beach ridge; *Campylopus introflexus*; *Cladonia*; Coastal heath; *Corynephorus canescens*; Dune; *Empetrum nigrum*; Invasion; Lichen; Lichen heath; *Pinus mugo*; *Rosa rugosa*; Shingle; Trampling.

Nomenclature: Nomenclature follows Hansen (1981) for vascular plants, Andersen et al. (1976) for mosses and Santesson (1993) for lichens.

Introduction

On the isle of Anholt, in the middle of the Kattegat, an open heath vegetation type is found in the central parts of the marine foreland called Ørkenen (= the desert). The vegetation type here is often characterized as lichen heath. Lichen heath vegetation may refer to either lichen-rich dwarf shrub heaths or lichen-rich grey dune vegetation. The latter may also be termed acidic grass heath (*Corynephoretum*) (Andersson 1950). Biermann (1999) discusses the plant sociology of this vegetation. In the central part of Ørkenen, grey dune vegetation is predominant. The EU habitat codes are no. 2131 (Pal. Class.: 16.221): northern grey dunes with the community *Corynephorion canescentis*, and no. 2140 (Pal. Class.: 16.23): stable lime-poor dunes with *Empetrum nigrum*.

Well-developed lichen-rich *Corynephorus canescens* vegetation on dry, nutrient-poor mineral soil is rare in Europe. Large marine forelands composed of shingle beach ridges with only little anthropogenic influence are even more rare. Ørkenen combines the two and is thus a high-priority landscape.

In a companion paper (Christensen & Johnsen 2001) the physical features and the vegetation of Ørkenen has been described as well as the historical background for the present vegetation. The aims of the present paper are (1) to describe the conservation value of the ecosystems of the marine foreland of Anholt, (2) to specify and discuss their susceptibility towards actual and potential threats, (3) to point out measures to mitigate these threats and (4) in this perspective, to suggest guidelines for the future management of these ecosystems.

Conservation importance

The Danish perspective

In a general inventory of the Danish dune landscapes, the total Danish dune area was calculated to be 1270 km^2, ca. 3% of the total area of Denmark (Brandt & Christensen 1994). 21 Danish dune localities with a total area of ca. 265 km^2 were rated highest with respect to conservation value from a geomorphologic and botanical perspective. 7.2% (= 19 km ^{2}) of these highest-ranked dune localities were in Ørkenen (Brandt & Christensen 1994). Ørkenen is one of five Danish dune areas singled out for its valuable lichen flora (Alstrup 1994) and it has the most extensive area of stone and pebble flats in Denmark. Ørkenen is also classified among the most valuable areas in Denmark from a cultural, recreational, educational as well as scientific point of view (Christensen 1997).

Danish lichen-rich *Corynephorus canescens* vegetation is characteristic of coastal grey dunes, in particular along the west coast of Jutland. It occurs also on inland aeolian dunes and dunes originally of Weichselian or pre-Weichselian age (Christensen 1997; Biermann 1999).

Though stone-fields and lichen-rich *Corynephorus* vegetation (grey dunes) occur in many places in Denmark, only Råbjerg Stene is internationally famous. Ørkenen at Anholt represents, however, by far the most extensive area of this nature type in Denmark.

Characteristic and rare lichens and mosses

Several epigeic and epilithic cryptogamic species are of importance in the vegetation of Ørkenen and occur here in higher quantities than on most other Danish dunes and pebble flats. Some of these species have a very high conservation value. Their ecological requirements make them particularly well adapted to the habitat conditions in this special environment. In the following paragraphs these species are characterized.

The Danish populations of the arctic-alpine epigeic lichen, *Alectoria sarmentosa* ssp. *vexillifera*, are considered post-glacial relicts. Böcher (1941, 1952) described the habitat preference of *Alectoria sarmentosa* ssp. *vexillifera* on the island of Læsø. In the Danish Red List the species is characterized as vulnerable (Stoltze & Pihl 1998). *A. sarmentosa* ssp. *vexillifera* is known from four localities in Denmark: (1) the isle of Læsø, between Østerby Havn and Holtemmen, (2) Råbjerg Stene in North Jutland, (3) Ørkenen on Anholt, and (4) the heath south of Hasle on the island of Bornholm. The population on Bornholm is probably extinct, that of Læsø is threatened by the recent construction of a golf course immediately landward of its occurrence, and the population on Råbjerg Stene is probably small, as it was only recently found despite numerous botanical excursions to the area, including lichenological excursions. That leaves the Anholt population as probably the largest and most viable in Denmark and the European lowland. According to Degelius (1986) it occurred rather abundantly at several places east of Sønderbjerg on old beach ridges. He also found the species in the Bassen area, at the airfield, west of Ostebakke and northeast of Hermansgave. Our experience, however, is, that today's population of *A. sarmentosa* ssp. *vexillifera* is very sparse, probably reflecting a population decline since the observations by Degelius. The population at Anholt deviates from typical specimens of *A. sarmentosa* ssp. *vexillifera* by being relatively thin-lobed (Fig. 1). Maybe the present epigeic specimens have derived from epiphytic populations that might have existed in the former Scots pine forest of Anholt.

Cladonia zopfii is common in Ørkenen (Degelius 1986) and occurs mainly on the south facing slopes of the aeolian dunes. *C. zopfii* "is clearly the most important *Cladonia* in the most exposed situations on acid and poor soils" (Böcher 1952: 19). It is particularly common on the nutrient-poor dune sand in inland dunes of Jutland. *C. zopfii* is endemic to NW Europe.

Cladonia cervicornis ssp. *pulvinata* is, apart from being abundant in open areas in Ørkenen (Degelius 1986), found in comparable situations in the inland dunes of Jutland (Christensen et al. 1986). It is confined to nutrient-poor sandy soil. This subspecies has a subatlantic distribution in NW Europe (Norway, Denmark, Germany, The Netherlands, Belgium, France and the British Isles), to which it is endemic.

Stereocaulon saxatile is common in Ørkenen. In Europe it occurs mainly on rocks and gravel in the boreal zone and in the mountains of the temperate zone. In Denmark, however, it occurs typically on non-stabilized inland dunes with old leached, very nutrient-poor sand. (Fig. 2) In The Netherlands, *S. saxatile* occurs exclusively on inland dunes on loose sand in *Corynephorus* vegetation (Brand & Sipman 1977), i.e. under similar circumstances as in Denmark.

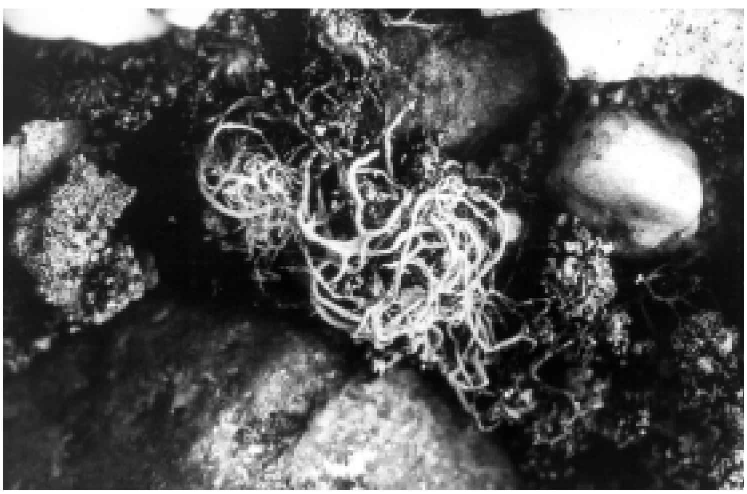

Fig. 1. *Alectoria sarmentosa* ssp. *vexillifera* among pebbles on an old beach ridge, Ørkenen, 14 Nov. 1997 (cf. Christensen & Johnsen 2001, Table 4, Fig. 4).

Racomitrium lanuginosum is observed rather frequently in depressions between beach ridges in Ørkenen. This moss species is uncommon in Denmark (known e.g. from Lønborg Hede in SW Jutland) and has an Atlantic, northerly distribution in Europe.

The European perspective

Danish dunes constitute a substantial part of Europe's coastal dunes. "The sand-dunes of Denmark are not only extensive, but also include some of the most active dune landscapes in Europe" (Doody & Skarregaard 1994; Olson & van der Maarel 1989, Fig. 4). Ørkenen is the largest area of lichen heath in Northwest Europe and is of great international value. The vegetation type of Ørkenen is a high priority nature type in relation to the EU habitat directive.

Lichen-rich *Corynephorus*-dominated dune vegetation on acidic sand occurs in Europe in the Wadden Sea Area, the west coast of Jutland, on the islands Læsø and Anholt in Kattegat, scattered along the coast of Kattegat and the Baltic Sea, and in a few places along the British North Sea coast. In comparison with the situation in Germany and The Netherlands, where the vegetation is often disturbed and potentially threatened, the Danish stands are in relatively good condition and often optimally developed (Biermann 1999).

The EU Red List of macrolichens (Serusiaux 1989) emphasizes, among lichen-rich biotopes to be given high conservation priority, the calcareous and acidic (grey) dunes of the Atlantic coast, especially *Empetrum*-dominated and *Corynephorus canescens*-dominated dunes of NW Europe (North Sea coast of Denmark, Germany and The Netherlands), because of their importance for epigeic *Cladonia* and *Stereocaulon* species. The dunes of the islands of Læsø and Anholt should have been included as well, but were not, probably because they are less known internationally.

According to Degelius (1986), the lichen flora of Anholt contains a number of noteworthy species in a European context. Five lichens have a northern distribution in Eurasia: *Cetraria nivalis*, *Hypogymnia intestiniformis*, *Lecidea pilati*, *L. vorticosa* and *Ochrolechia frigida*. One species, *Alectoria sarmentosa* ssp. *vexillifera*, has an eastern distribution in Eurasia and five species are common on Anholt, but rather rare in the rest of Scandinavia: *Cladonia cervicornis* ssp. *pulvinata*, *Lecidea chalybeiza*, *L. pilati*, *Rhizocarpon reductum* and *Stereocaulon saxatile*.

In conclusion, the Danish dunes are outstanding in Europe, due to the acidic nature of the sand and its corresponding species assembly, particularly the abundant epigeic lichen flora. The extent and the relatively authentic nature of the Danish dune ecosystems make them exceptional in the European context. In particular, Ørkenen of Anholt is important due to its extensive lichen-rich grey dune, shingle and dune heath vegetation and its unique lichen flora.

Threats to the natural ecosystems

Invasion of exotic species in Ørkenen

Pinus mugo

The forestation of Ørkenen with the non-indigenous *P. mugo* commenced in the beginning of the 20th century. The extent of the plantations and the self-sown thickets is treated by Christensen & Johnsen (2001).

The ecological conditions of the floor of *Pinus mugo*

Fig. 2. *Stereocaulon saxatile* in a lichen-rich *Corynephorus* heath, Ørkenen, 1. Aug. 1998 (cf. Christensen & Johnsen 2001, Table 3, Fig. 3).

thickets differ markedly from those on the ground in grey dune and dune heath vegetation. During the establishment of the thicket and when the canopy is closed, the light that reaches the ground vegetation, the amplitude of temperature, of wind speed and of relative humidity are reduced; the average level of the latter, however, increases. This change in microclimatic conditions results in replacement of e.g. light-demanding lichen species, such as *Cladonia zopfii* and *C. arbuscula*, to pleurocarpous moss species that thrive under more shaded and humid conditions, such as *Pleurozium schreberi*.

In the pine thickets, a needle litter layer accumulates, eventually forming a more or less thick humus layer. This needle litter and the resulting mor layer reduce the pH and enhance the water capacity of the soil surface, which in turn influence the ground flora and vegetation (Køie 1938). The species of the thicket floor not only have to be able to grow under the new soil conditions; they also have to be able to grow fast enough to compete with the accumulating litter layer. Furthermore, atmospheric deposition on the *Pinus mugo* canopy may result in an increasing supply of e.g. nitrogen compounds to the thicket floor by throughfall.

The ground vegetation in the *Pinus mugo* thickets is very scarce with respect to phanerogams. Depending on the degree of openness and exposition, there may be an extensive cover of lichens, mainly *Cladonia portentosa*, or mosses, mainly pleurocarpous species such as *Pleurozium schreberi*, *Hypnum cupressiforme* and *Hylocomium splendens*, as well as acrocarpous species such as *Dicranum* species and the hepatic *Ptilidium ciliare*.

Following clearance of a *Pinus mugo* thicket progressive breakdown of the mor layer and litter occur. A succession towards the natural dune vegetation will commence. In a study south of Skagen, north Jylland, Vinther-Larsen (1993) divided clearings of *P. mugo* stands into patches on the basis of the dominant species. In the young clearing (3 years), lichens were co-dominant in 22% of the total area and *Corynephorus* was co-dominant in 18% of the area, while the figures for the old clearing (8-11 yr) were 80% and 44%, respectively. *Carex arenaria*, on the other hand, decreased from co-dominance in 46% of the 3-yr old clearing to 40% of the 8-11-yr old clearing. It seems that with age, the patches where lichens or *Corynephorus* co-dominate increase, whereas patches where *Carex arenaria* co-dominates decrease. The species composition of the early stages of succession after clearing and the duration of the early stages of succession will be greatly influenced by the thickness and the character of the organic matter left after the clearing of a pine thicket.

Christensen & Johnsen (in prep.) treat the vegetation of *Pinus mugo* dune plantations in Denmark and the succession following deforestation.

Rosa rugosa

The natural distribution of *Rosa rugosa* is found in the coastal areas of the Northern Pacific: Alaska, Kurilian Islands, Kamtchatka, Manchuria and Japan. It was introduced to Europe in the last half of the 18th century. The first record of it in Denmark is from 1845, but not until the 20th century it was widely planted in cottage areas, along railways etc. Birds and sea currents spread its seeds. When established, the hardy species proliferates by rhizomatous growth. Almost everywhere along the coasts of Denmark, as well as in Germany (Eigner 1992), *Rosa rugosa* poses a serious treat to the natural open coastal ecosystems, such as dunes and dry coastal grasslands.

On Anholt, *Rosa rugosa* was first noted at the lighthouse in 1941 and by 1961 it was found on several places, e.g., in the dunes near Sønderbjerg, at the coast along Flakket and at the harbour (Hansen 1962). At present, the species is still being planted around summer cottages, is frequent in large patches on the moraine hills in the west of Anholt, and is probably spreading along the coast of the island.

Campylopus introflexus

Campylopus introflexus is present in Ørkenen, Anholt, in small areas and, therefore, has probably reached the island recently. The possible spread of this aggressive colonizer in Ørkenen may pose a serious threat to the natural plant communities.

Nutrient enrichment: long distance air pollution

In The Netherlands, a substantial decrease in lichen-rich vegetation has been observed in recent decades. For example, in a *Corynephorus canescens* community in the dry dunes of the island of Terschelling, vegetation analysis in 1966 and 1990 demonstrated a decline in lichen cover and an increase in graminoid species, such as *Ammophila arenaria*, *Calamagrostis epigeios* and *Carex arenaria* and, to a certain extent, mosses, whereas the grass *Corynephorus canescens* 'is hardly able to survive'. Accumulation of litter has taken place and the amount of bare sand has been reduced considerably. Nitrogen deposition and natural succession are two possible explanations for these observations (Ketner-Oostra 1992; Ketner-Oostra & Sýkora 2000; Ketner-Oostra & van der Loo 1998). Comparable observations have been made in Danish inland dunes, where the combined effects of natural succession and high nitrogen deposition are thought to be the cause (Johnsen & Søchting 1994). Despite the normally smaller deposition of atmospheric N-compounds in coastal areas, the impact of today N-deposition levels on the coastal heaths is probably significant. Recent studies (Riis-Nielsen 1997; Riis-Nielsen, Christensen & Johnsen in prep.) have shown, that while inland heaths are phosphorus limited, the coastal heaths are N-limited. The result is an increasing succession rate and presumably finally a more grass (*Deschampsia flexuosa*, *Molinia caerulea*) dominated vegetation replaces the lichen-*Corynephorus*-dwarf shrub mosaic community.

Physical disturbance: damage by tourists

The reaction of a vegetation to physical disturbance is the result of two factors: the susceptibility of the vegetation to the particular disturbance and the ability of the vegetation to regenerate. Physical disturbance may be caused by several human activities, e.g. clearance of pine thickets, or by natural agents, e.g. strong winds. In the present paper the effects of damage by tourists will be emphasized.

The total number of tourists on Anholt during 1984 is estimated to 30 000 to 40 000 persons, corresponding to 4000-5000 persons on a daily basis during the season (Vedel 1986). The carrying capacity (durability) of Ørkenen is estimated to be very low, though no studies into the matter have been conducted here. Considering the vulnerability of the landscapes and the number of residents (ca. 150), Vedel (1986) regards the tourist pressure to be in excess of the carrying capacity of the island.

Damage by tourists is most severe in the foredunes along Sønderstrand, which is the most popular beach on the island. Vedel (1986) illustrated its escalation in this area during 1945-1975. During that period the total length of the paths has increased with a factor 4 (Vedel 1986). The dwarf shrub heath behind the fore dunes has also been severely damaged (Fig. 3), due to the sensitivity of *Empetrum* to trampling.

Studies in Danish dunes by Christensen (1986, 1994) have shown that formation of trampled paths in grey dune and dune heath communities causes a reduction in the organic content of the soil, a rise in pH and a reduction in conductivity and carbonate content. Concomitantly, a considerable decrease in the cover of the vegetation, with no or only a few species left in the central, more trampled parts, takes place. In the moderately trampled zones along paths in dwarf shrub heaths a community of colonizers or early succession species normally found in grey dune habitats and blowouts develop. In the grey dune vegetation, reduction in species number and cover takes place in the moderately trampled zones compared to the undisturbed ones.

Regenerative ability in lichens

Lichens are able to establish on mineral soil through thallus fragments (Christensen 1988). Provided a limited area of destruction and a moderate distance to undisturbed vegetation, the re-establishment on mineral soil of a lichen-rich *Corynephorus*-dominated grey dune community probably takes place after a few years, presumably within 5 yr, and not longer than 10 yr.

In cases where the original minerophilic vegetation has been destroyed by forestation or by self-sown pine thickets, development of an organic topsoil prevents the original vegetation to re-invade after clearance (see below).

Remedial action – counteractive measures and their consequences

In this section, an outline of some particularly important measures necessary to be taken in order to re-establish the conditions under which lichen heaths may develop again, are described and discussed.

Fig. 3. Damage by tourist at Sønderstrand. Note the wedge shaped system of paths. View from the moraine hill Sønderbjerg, 7 Aug. 1999.

Removal of Pinus mugo

The humus layer of the *Pinus mugo* thickets, litter of needles, the carpet of living and dead mosses and the chopping produced during tree clearing must be disintegrated before minerophilic species of the lichen-rich *Corynephorus* community will be able to colonize the former pine thicket (Fig. 4).

Succession after clearing may vary, depending on the physical structure and thickness of the uppermost layer of organic material as well as the humidity of the underlying soil. Two succession scenarios were observed: 1. In the presence of a relatively humid substrate, organophilic lichens and mosses colonized the substrate, giving rise to a more or less moss-rich cup lichen community. 2.Where the uppermost layer of the litter is too dry for mosses and lichens to colonize, the lower, more humic and therefore more degraded, parts of the organic layer were colonized by rhizomatous plants, such as *Carex arenaria*, *Chamaenerion angustifolium* and *Salix repens* (Fig. 5). Combinations of these two scenarios were seen.

The common phenomenon of invasion of nitrophilic species like *Chamaenerion angustifolium* and *Senecio silvatica* following clearing of tree stands was also observed at Anholt in the *P. mugo* clearings, when needles form a substantial part of the remains. The extent and vigour of this invasion, in terms of plant numbers and their average size was, however, rather small in clearings with only little needle biomass left. It may therefore be inferred, that the decomposition of fine roots is very slow and/or immobilization of soil N-compounds is very efficient.

A community of organophilic lichens, with species such as *Cladonia merochlorophaea*, *C. glauca*, *C. macilenta* and *Placynthiella uliginosa*, which normally occur on dwarf shrub litter, has been observed at Anholt to developing on organic remains of a pine thicket. The rate, at which a minerotrophic community similar to the original vegetation may replace this organophilic community, depends on the decomposition rate of organic matter. This rate is a function of mainly the chemical composition of the litter, its water-holding capacity and several climatic factors (temperature, precipitation, relative humidity, wind patterns). The organophilic community may thus prevail for a long time period.

These observations, which to some extent are based also on analysis of historical data, are to be addressed in detail in a paper under preparation. The initial succession pattern after removal of *Pinus mugo* includes the following main stages, occurring roughly in the following order: (1) death of most pleurocarpous bryophytes originally abundant in *Pinus mugo* thickets; (2) temporary occurrence of pioneer phanerogam species such as *Chamaenerion angustifolium*, *Rumex acetosella* and *Senecio silvatica*; (3) strong positive impact on growth and distribution of *Carex arenaria* and *Salix repens* in cleared areas (Fig. 5); (4) invasion of an organophilic cryptogam community on litter and tree remains; (5) increased abundance of species common to wet depressions in heaths such as *Juncus squarrosus* and *J. balticus*.

Due to the very slow rate of decomposition of organic matter at Anholt it may take decades before the original minerotrophic lichen heath vegetation of Ørkenen has been re-established. The time-scale of this scenario is, however, difficult to predict since no studies on the decomposition rates of litter left after clearings have been conducted.

Fig. 4. *Pinus mugo* clearing. The thick layer of chips has been invaded by *Salix repens* and in the foreground by *Carex arenaria* as well. The *Betula* trees have established in a slack in the former thicket. Ørkenen, Pakhusbugten, clearing 3A, 14 Aug. 1999.

Fig. 5. *Pinus mugo* clearing dominated by *Carex arenaria*. Ørkenen, W of the airstrip, 2 Nov. 1999.

Air pollution and land-use

Atmospheric deposition of N and P constitutes a major threat to natural ecosystems such as lichen heaths. The reason for this is, that these ecosystems are adapted to nutrient-poor conditions and have extremely slow growth rates, i.e. very slow vegetation dynamics and correspondingly low regeneration capacity. This means that species with a higher demand for nutrients and a higher competitive capacity under the present eutrophic conditions may replace the original lichen-heath species.

With respect to coastal dunes in The Netherlands Kooijman et al. (1998) concluded, that the effect of atmospheric deposition of nutrients such as N- and P-compounds, was, that N-limitation probably occurs in the Wadden district with a low P-content in the soil but relatively high P-availability, while co-limitation of N and P was observed in lime- and iron-rich coastal districts. The Anholt situation is believed to be comparable to the Dutch situation in the Wadden district with a low P-content.

Indeed, fertilization studies initiated in 1998 (Riis-Nielsen et al. in prep.) demonstrated, that the *Corynephorus canescens-Empetrum nigrum* community at Anholts Ørken is nitrogen-limited. Also, studies by Riis-Nielsen (1997) have indicated, that nitrogen is a limiting factor for growth in Danish coastal heaths, while phosphorus is a main limiting factor for growth in inland heaths on leached quartz sand soils in Denmark.

The competition between dwarf shrubs, grass species and cryptogams may change following eutrophication with the possible result, that the slow growing cryptogams become extinct (Søchting & Johnsen 1990).

We believe that neither the acid rain nor the atmospheric deposition of heavy metals have any negative impact on lichen heaths, but the photochemical oxidants (ozone) scenario may have an impact on the mutual competition between e.g. some of the dwarf shrub species (Johnsen et al. 1991), and thus change the species composition and dynamics of the lichen heaths. This latter scenario is still of major concern, and plant damaging levels of ozone above 100 ppb are reached every summer in northwestern Europe.

Former use of heaths by grazing, heather harvest and turf cutting resulted in removal of nitrogen compounds from the heaths to the cultivated fields closer to the farms. This process of re-arrangement of the available nitrogen resource of the farm as a whole was a main task for the heath farmer. As heath farming was abandoned, a succession from *Calluna vulgaris* dominated vegetation towards dominance initially by *Empetrum nigrum*, and then grasses (*Molinia coerulea* and *Deschampsia flexuosa*) took place (Degn 1997). This succession is probably accelerated today due to the above-mentioned increased deposition of atmospheric nitrogen compounds. Management of heaths with the purpose of maintaining the original plant community and its dynamics, must thus be based on the ecological principles practically applied by the heath farmer, resulting in regular nutrient removal from large parts of the heath.

Regulation of visitors behavioural pattern

The plant cover of lichen-dominated heaths is characterized by very slow growth. This implies, that frequent trampling by visitors may impair the development of later succession stages, which become a rare element in the vegetation. Lichen-dominated heaths may in this respect be regarded as sensitive to trampling by visitors. On the other hand, the trampling of man and animal husbandry has caused, and still causes, the reduction in competitive strength from e.g. dwarf shrubs such as *Calluna vulgaris* and *Empetrum nigrum*, which is necessary to allow co-occurrence of lichens and bryophytes as integral parts of the heath community. Furthermore, the early succession stages following e.g. blowouts in dunes, may be reduced in frequency, if the natural geomorphological processes causing these events to happen are inhibited. These processes are important to secure the complete ecological dynamics of coastal dune systems, with repeated occurrence of all natural succession stages.

The most affected areas are (1) the wedge-shaped pattern of bathing paths at the beach Sønderstrand, the southwest corner of Ørkenen (Fig.3), see also Christensen & Johnsen 2001: Fig. 1), which has been described by Vedel (1986), and (2) the areas along and at the end of the scenic walk Ørkenstien to the dune Bassen (the path touching the south end of the northern dune plantation, Christensen & Johnsen 2001: Fig. 1). In the first mentioned area, a mesh of paths along which a number of pioneer mosses and lichens find living space traverses a dense species-poor *Empetrum nigrum* dominated dune heath. This increases the biodiversity of the area. In the second case, the biodiversity of the lichen-rich *Corynephorus* vegetation is strongly reduced by trampling. Considering the affected areas in relation to the extent of the remainder of Ørkenen, the present level of tourist wear at Ørkenen seems acceptable, provided the present strict regulations with respect to vehicle transportation of visitors etc. are maintained

Discussion and Conclusion

Almost all dune systems throughout Europe have been used for different purposes throughout the centuries, notably for grazing and harvest of dune grasses (Doody 1998). In a previous paper (Christensen & Johnsen 2001) the development of the present vegetation at Ørkenen was described. The present vegetation is a result of human destruction of the original forest ecosystem covering most of Ørkenen and subsequent overexploitation of the organic resources. This has left space for an open grass heath community of *Corynephorus canescens* with pioneer cryptogam vegetation. It is known from other closed dune grasslands that such a system can maintain itself for many years after the abandonment of grazing (Boorman & van der Maarel 1997). This nature type is of extremely high conservation value, in a Danish as well as in a European context. The shingle habitat of the old beach ridges with the epilithic lichen vegetation is of equally high conservation value.

Empetrum nigrum and *Juniperus communis* occur more or less frequently in patches in this community. Nearly stable aeolian dunes occur in Ørkenen due to the reduced sand drift in Ørkenen of today. These dunes are covered with *Ammophila arenaria* of poor growth together with *Corynephorus canescens* and a pioneer cryptogam community. The dynamics of today's vegetation is very slow, reflecting the low productivity of this very nutrient-poor habitat. The observed die-off of e.g. *Empetrum nigrum* plants in patches seems to be outweighed by the slow rate of dispersal of this species. *Juniperus communis* is expanding eastwards, at present reaching the area around Bassen. Christensen & Johnsen (2001) demonstrated the expansion of areas with patchy *Calluna* dwarf shrub vegetation in Ørkenen, as well as vigorous self-sowing of *Juniperus communis*. This natural succession that occurs on the expense of the valuable lichen heath, is an irreversible process, unless catastrophic events occur. Degn (1997) showed in a Danish inland heath, that this succession under present conditions probably mainly is linear and results in the formation of heaths dominated initially by dwarf shrubs, secondly by grass species at the expense of the epigeic lichen vegetation. The long-term succession at Anholt is believed to restore a more or less forested ecosystem, with the tree species *Quercus robur*, *Betula pubescens*, *B. pendula* and probably also *Pinus sylvestris*. The rate is extremely slow and the process may well take several hundreds of years.

A factor that strongly influences the succession rate towards forest is the introduction of the non-indigenous *Pinus mugo*. This species is a permanent threat to the open heath vegetation, especially in areas with a relatively high ground water table. If the open heath vegetation is to be maintained, the expansion of *Pinus mugo* and removal of new growth at regular intervals must be monitored.

The succession rate is also increased by atmospheric deposition of nutrients. Preliminary experiments (Riis-Nielsen et al. in prep.) have shown, that the growth of *Empetrum nigrum* and *Corynephorus canescens* is strongly enhanced by increasing supplies of nitrogen compounds. If such ecosystems, characteristic of nutrient-poor conditions, are to prevail, the airborne nutrient supply must be strongly reduced. Anholt is privileged in this respect due to its geographical position in central Kattegat and the absence of intensive agriculture and industry on the island. Reduction of the post-clearing succession rate may, however, result from either increased human impact (notably by tourists) and/or re-introduction of grazing animal husbandry.

The ecosystems of Ørkenen are very sensitive to damage by tourists and animal husbandry, in particular the lichen-rich *Corynephorus* communities. The vegetation is easily worn down to open sand. However, the species of the *Corynephorus* communities are adapted to dispersal by fragments, spores or seeds that can colonize the affected open areas when the disturbance ceases. The regeneration may take years, in the case of the lichen-rich *Corynephorus* communities, or even decades, in the case of reindeer lichen-rich dwarf shrub communities.

Recommendations regarding management of Ørkenen at Anholt

When preparing management plans for an ecosystem such as this, knowledge of the history of land-use, the development of the ecosystem and the present ecological conditions are indispensable. For dunes and heath-lands which are potentially rich in lichens and mosses, a detailed knowledge of the composition and distribution of the cryptogamic element of the vegetation is important for the proper conservation rating and management of a given area (Biermann et al. 1995).

Even though there are many good arguments for a more dynamic approach to management of coastal areas (Wanders 1989), conservation of particular stages of the succession may be preferable for certain valuable landscapes, often semi-natural biotopes which are the results of former human use (Gimingham 1994). In the case of Ørkenen on Anholt, the conservation effort should be directed towards conservation of the present large expanses of lichen heath, while the coastal dunes, with the exception of removal of *Rosa rugosa*, should be left unmanaged to the natural dynamics of the dune ecosystem. The management shall in other words seek to maintain the vast areas of pioneer vegetation on the expense of the natural succession. It is, therefore, important that the natural dynamics of the vegetation is monitored and the succession rate towards dwarf shrub heath and *Juniperus* thicket must be determined. For the same reason the N-deposition should be monitored. Regrowth of *Pinus mugo* shall continuously be removed and patches of *Rosa rugosa* eradicated.

The grazing of natural herbivores is very moderate (hares, roe deer), and due to the low productivity, there is no basis for turf cutting or hay cutting, formerly a part of extensive heath land use in Denmark.

Should monitoring of the vegetation dynamics show a progressive expansion of the dwarf-shrub heath areas, management by very extensive husbandry grazing should be considered in the future. It must be emphasized, that the grazing pressure should be kept low and the effects monitored closely.

The magnitude of today‘s human impact seems acceptable from an ecological point of view, even if the concentration of human wear poses aesthetic problems in terms of path systems at hot spots for tourism. It is recommended to monitor the size of this tourist wear and maintain the ban for vehicle transport in Ørkenen.

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