Technical Report 2008 16/24

MANAGEMENT of Natura 2000 habitats

* Nordic alvar and precambrian calcareous flatrocks

6280

Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora

EUROPEAN COMMISSION

environment

The European Commission (DG ENV B2) commissioned the Management of Natura 2000 habitats. 6280 *Nordic alvar and precambrian calcareous flatrocks

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ISBN 978-92-79-08329-7

Eriksson M.O.G. & Rosén E. 2008. Management of Natura 2000 habitats. 6280 *Nordic alvar and precambrian calcareous flatrocks. European Commission

This document, which has been prepared in the framework of a service contract (7030302/2006/453813/MAR/B2 "Natura 2000 preparatory actions: Management Models for Natura 2000 Sites"), is not legally binding.

Contract realized by: ATECMA S.L. (Spain), COMUNITÀ AMBIENTE (Italy), DAPHNE (Slovakia), ECOSYSTEMS (Belgium), ECOSPHÈRE (France) and MK NATUR- OCH MILJÖKONSULT HB (Sweden).

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Nordic alvar on the island of Öland, SE Sweden, with the endemic Öland rockrose (Helianthemum oelandicum). Photo: Markus Forslund.

62 Semi-natural dry grassland and scrubland facies

EUNIS Classification:

E1.2 Perennial calcareous grassland and basic steppe, E1.25 Alvar steppes

* Priority habitat

Summary

Alvar and calcareous flatrocks are characterised by openness (reinforced by grazing), flatness, limestone bedrock, exposure to winds causing dryness in summer and the impact of frost and freezing in winter. A main characteristic is a very thin soil layer (0-30 cm). The soil is primarily a product of weathering, with scattered deposits of siliceous soils from old beach ridges. The vegetation cover is often incomplete with bare patches. Plant and invertebrate communities are mostly rich in species, and many of them have developed various adaptations to tackle the harsh conditions linked to dry summers, frosty winters and windy conditions. The flora includes several plants whose main distribution lies elsewhere, plus some endemic species and subspecies.

World-wide, calcareous flatrocks have a very limited distribution, restricted to the Baltic Region of Europe and Great Lakes Region in North America, with almost 90% of the area in Europe. Within the European Union, the habitat is only found in Sweden (primarily on the islands of Öland and Gotland) and Estonia, with minor areas in south-west Finland.

Calcareous flatrocks mostly occur in a mosaic with related habitats, such as semi-natural dry grasslands (6210), rupicolous calcareous or basophilic grasslands (*6110) and limestone pavements (*8240), and a holistic management approach is advisable.

Zero or low grazing intensities will inevitably result in scrub encroachment and loss of species (where deep soil is present), with a drastic decline when the scrub cover reaches around 70%. Although there are patches of "natural" alvar areas where thin soil and drainage via fissures in the bedrock make the establishment of any other kind of habitats impossible, grazing is a basic prerequisite for the long-term maintenance of nature conservation values over large areas. Regular clearing may be a necessary complementary measure in order to assure the basic requirements. When reopening an overgrown site for grazing, restoration in order to remove scrub vegetation and to overcome problems of internal fertilising is usually a necessary first step. For sites where the protection of threatened and rare species is a key objective, management usually has to consider species-specific requirements.

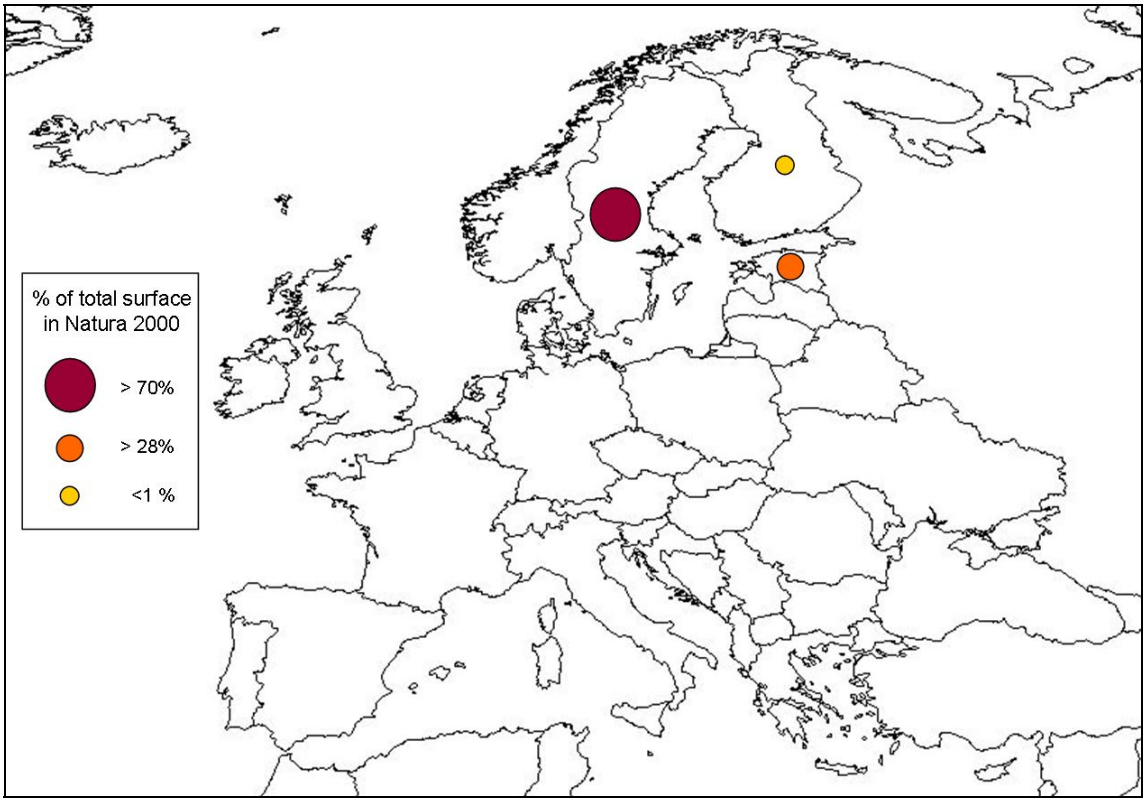
Clearing should preferably be initiated before the critical level of around 70% scrub canopy cover is reached, and in most cases it is more effective, from both a conservation and a cost perspective, to prioritise less overgrown areas. Evaluations of various techniques have shown that motor-manual clearing is the most effective alternative from a conservation point of view, although time-consuming in the short term.

1. Description of habitat and related species

The habitat includes a variety of often species-rich plant and animal communities on very thin soils, mostly formed by weathering, on calcareous flatrocks. Edaphic conditions such as grain size, depth (mostly <30 cm) and movement pattern of the soil are important factors affecting the physiognomy and representation of species at a specific site.

Distribution

Inside the European Union the habitat is exclusive to Sweden, Estonia and Finland, with roughly one third in the Boreal region and two thirds in the Continental region. The high proportion in the Continental region can be related to the extent areas of alvars on the southern part of Öland, south-east Sweden, with as much as 58% or 15,089 ha of the total surface area found at one large site, Stora Alvaret (SE033 0176).



Percentage distribution of the total surface of Nordic alvar and precambrian calcareous flatrocks in Natura 2000.

Nordic alvar and precambrian calcareous flatrocks in Natura 2000 sites

The following data have been extracted from the Natura 2000 Network database, elaborated by the European Commission with data updated on December 2006. The surface was estimated on the basis of the habitat cover indicated for each protected site and should be considered only as indicative of the habitat surface included in Natura 2000.

Biogeographical region	Nº of sites	Estimated surface in Natura 2000 (ha)	% of total surface in Natura 2000
Continental	2	16,145	62.0
Boreal	153	9,893	38.0
Countries	**Nº of sites**	**Estimated surface in Natura 2000 (ha)**	**% of total surface in Natura 2000**
Sweden	71	18,475	70.9
Estonia	66	7,323	28.1
Finland	18	240	1.0
TOTAL	**155**	**26,038**	**100**

Note: 123 (79.3%) of the 155 sites belong to the Nordic alvar subtype (see below), including the two sites in the Continental region, making a total of 25,682 ha (98.5%) with 57 sites in Sweden 18,359 ha and all sites in Estonia. All sites in Finland and 14 sites in Sweden belong to the Precambrian bedrock subtype.

*Please also note that these figures refer to habitat *6280 strictly; in practice the calcareous flatrocks mostly occur in mosaics with some related habitats (see below) and most published figures on surface areas of "alvars" etc. refer to the whole habitat complex.*

Main habitat features, ecology and variability

Briefly, the alvar and calcareous flatrocks can be characterised by openness (reinforced by grazing), flatness, limestone bedrock, exposure to winds causing dryness in summer and impact by low temperatures and frost induced soil movements in winter. A main characteristic is a very thin soil layer (0-30 cm).

The soil is primarily a product of weathering, and the vegetation cover is often in-complete with bare patches. The openness of the habitat makes it exposed to sun and winds causing dryness during the vegetative period. In winter, snow is blown away over large areas (and accumulated in drifts at sheltered locations) which make the ground exposed to freezing. On land with poor drainage capacity, annual freezing and thawing may give rise to soil movements resulting in small patches of bare soil in a polygon-shaped pattern (Königsson 1968). Plant and invertebrate communities are characterised by species that have developed various adaptations to tackle the harsh climatic conditions (Rosén 1982, EC 2007, Airaksinen & Karttunen 1999).

World-wide, calcareous flatrocks have a very limited distribution, restricted to regions with dry summers and frosty winters and with influence of ice formation in the soil as a common feature. These conditions are only met in the Baltic Region of Europe and Great Lakes Region in North America, with almost 90% of the area in Europe. Here, the habitat is restricted to Sweden and Estonia plus minor areas in south-west Finland and south-west of St. Petersburg in Russia. As much as around 70% of the world distribution is found on Öland and Gotland Islands in South-east Sweden.

The flora of alvars and related habitats includes a mixture of plants with their main distribution elsewhere (e.g.: Schillander & Hultengren 1998, Pärtel *et al*. 1999, Rosén & Borgegård 1999, Lager *et al.* 2001 and Ekstam & Forshed 2002). From an European perspective, these floral elements may be referred to the following groups:

- A North European / Arctic-Alpine group including *Draba incana, Poa alpina, Potentilla crantzii, Viscaria alpina* and *Cerastium alpinum* among vascular plants, and various lichens including *Cetraria nivalis* and *Thamnolia vermicularis*.
- A Continental-Siberian group, including *Artemisia rupestris, Oxytropis campestris* ssp. *campestris* and *Anemone sylvestris.*
- A South-western European group including *Baldellia ranunculiodes, Globularia vulgaris, Plantago (Littorella) uniflora* and *Teesdalia nudicaulis*.

- A South European group including species primarily found in the Mediterranean region, e.g. *Anthericum liliago, Anthericum ramosum, Apera interrupta, Fumana procumbens, Hippocrepis emerus, Hornungia petraea, Petrorhagia prolifera* and *Veronica praecox*.
- A South-eastern European group with species primarily found in South-eastern Europe, e.g. *Allium lineare, Asperula tinctoria, Gypsophila fastigiata, Linosyris vulgaris, Plantago tenuiflora, Pulsatilla pratensis, Ranunculus illyricus* and *Vincetoxicum hirundinaria*.
- Circumpolar species, including *Dasiphora (Pontentilla) fruticosa* which is a very frequent species in the alvars of Öland Island but with a scattered distribution in north-western Estonia.

There are also some vascular plants that are endemic to areas where the alvars occur, e.g. *Allium schoenoprasum* var. *alvarense, Arenaria gothica, Artemisia oelandica, Festuca rubra* ssp. *oelandica, Galium oelandicum, Helianthemum oelandicum* var. *oelandicum, Helianthemum oelandicum* var. *canescens, Pulsatilla vulgaris* ssp. *gotlandica, Senecio jacobea* ssp. *gotlandicus* and *Silene uniflora* ssp. *petraea.*

The South European flora elements are almost absent in Estonia.

Main Subtypes identified

Two subtypes are identified:

Nordic alvar (6280a) with a thin layer (<30 cm) of soil created by weathering on limestone of cambro-siluric origin. Soils are seldom completely covered by vegetation and plant communities are often species-rich, including endemics (see above). This subtype is found on the Swedish islands of Öland and Gotland, minor areas in mainland Sweden (primarily Västra Götaland County) and in north-western Estonia including Hiiumaa, Muhu, Saaremaa and Vormsi Islands plus a an outpost site SW of St. Petersburg in Russia. Except for Stora Alvaret in the south of Öland, the mean surface area of alvar is 57 ha (range 0.4-1055 ha) for the sites in Sweden and 111 ha (range 0.7-1261 ha) for the sites in Estonia.

Slope is almost zero and the drainage capacity low, so that wetlands with permanently or temporarily water-filled pools ("vätar") have developed in depressions in the ground.

Characteristic species among vascular plants are e.g. *Allium schoenoprasum* var. *alvarense, Anthericum ramosum, Apera interrupta, Arenaria gothica, Artemisia rupestris, Cerastium pumilum, Crepis tectorum* ssp. *pumila, Dasiphora (Pontentilla) fruticosa, Festuca rubra* ssp. *oelandica, Festuca ovina, Fumana procumbens, Globularia vulgaris, Inula ensifolia, Linum catharticum, Poa alpina, Saxifraga tridactylites, Sedum album, Silene uniflora* ssp. *petraea, Teesdalia nudicaulis* and *Thymus serpyllum;* on Öland also *Galium oelandicum* and *Helianthemum oelandicum* var. *oelandicum*. – Among lichens *Cetraria islandica, Cetraria nivalis* and *Thamnolia vermicularis,* and among bryophytes *Ditrichum flexicaule, Hypnum cupressiforme, Tortella inclinata* and *Tortella tortuosa* should be mentioned.

The vegetations in the wet or temporary wet depressions of wetland character include *Agrostis stolonifera, Baldellia ranunculoides, Crepis tectorum* ssp. *pumila, Eleocharis uniglumis* ssp. *sterneri, Euphrasia stricta* var. *gotlandica, Inula britannica, Plantago tenuiflora, Plantago (Littorella) uniflora, Ranunculus aquatilis* (and related species), *Taraxacum limnanthes, Teucrium scordeum* and *Veronica catenata*.

The Nordic system for classification of vegetation identifies a quite widespread *Festuca ovina-Tortella* spp. type and a less common *Helianthemum oelandicum* type (Påhlsson 1998). A more detailed analysis of the various plant communities is given by Rosén & Borgegård (1999).

In Estonia, three types are identified: A "dry thin soil layer type" (*Festucetum alvarense* type, soil layer <5 cm), a "dry deeper soil layer type" (*Avenetum alvarense* type, soil layer 5-30 cm) and a "wet alvar type" (*Molinietum alvarense* type; Pärtel *et al.* 1999, Ikonen 2004). The alvar areas in Estonia are mostly more heavily overgrown than the ones in south-east Sweden, to some extent related to an (on average) deeper soil layer, and with *Juniperus communis* (juniper) as a distinct element (Ekstam & Forshed 2002). Due to the still quite rapid land uplift (after glaciation) of 2.5-3.5 mm per year along the

eastern coastline of the Baltic Sea, primary alvar land may develop in the shorelines zones, with a typical vegetation developing over a period of around 400 years until scrub and tree overgrowth takes over (if left without human intervention; Pärtel *et al.* 1999).

In many of the alvars in northern Estonia characteristic plant species for alvar sites in the western part of the country are missing or infrequent. Characteristics for the northern sites are thicker and more fertile soils, with *Carex spicata*, *Lathyrus pratensis* and *Trifolium repens* as characteristic plant species (Pärtel *et al.* 1999). These northern alvars are more closely related to the small Russian alvars (Znamenskiy *et al.* 2006).

Precambrian flatrocks (6280b) with no or very thin soil-layer of limestone of precambrian origin. All sites in Finland belong to this subtype, with a concentration to the south-western parts of the country, including the archipelago areas and the Åland Islands in the Baltic Sea, with a mean size of 13 ha and a range between very small sites of less than 1 ha up to 210 ha. Further, this subtype is found at 14 sites in south-central Sweden, with a surface area of 8 ha (range 0.8-41 ha).

Characteristic species among vascular plants are e.g. *Androsace septentrionalis, Arenaria serpyllifolia, Artemisia campestris, Asperula tinctoria, Botrychium lunaria, Festuca ovina, Gentianella amarella, Geranium columbinum, Linum catharticum, Melica ciliata, Origanum vulgare, Potentilla tabernaemontani, Satureja acinos, Saxifraga tridactylites, Sedum album* and *Veronica spicata*, and among bryophytes e.g. *Ditrichum flexicaule, Schistidum apocarpum* and *Tortella tortuosa*.

Species that depend on the habitat

Birds: For some bird species listed in Annex I of the EU Birds Directive (79/409/CEE), calcareous flatrocks should be considered as important but not exclusive habitats:

- *Pluvialis apricaria* (Eurasian golden plover): With its characteristic liquid whistling calls, the golden plover symbolizes the alvar landscape. Outside the Scandes Mountains, the alvars together with raised bogs are the stronghold habitats for this species in the Nordic and Baltic countries. In the alvars on Öland, the average size breeding territory is 15-30 hectares, and the birds also use surrounding arable land for foraging (Länsstyrelsen Kalmar län 2005).
- *Circus pygargus* (Montagu's harrier): This raptor is a character bird for the alvars. Land with some scrub cover, e.g., of *Dasiphora (Potentilla) fruticosa* (shrubby cinquefoil) are preferred breeding habitats while remaining alvar areas as well as surrounding agricultural land are used for foraging.
- *Sylvia nisoria* (barred warbler): Alvar and similar environments are one of the main habitats of this species in the Baltic region. Here, it is linked to scrubby and overgrown areas with a mixture of birch, ash, rowan or whitebeam, plus single larger trees. On Öland the size of the breeding territories is 1-2 hectares (Länsstyrelsen Kalmar län 2005).
- *Lanius collurio* (red-backed shrike): This species is linked to various kinds of mosaics of open and scrubby areas and it has declined over large parts of Europe due to changed agricultural practices resulting in bush encroachment of scrubby pastures etc (e.g. Roos 2007). Alvar is one of the remaining stronghold habitats for this species, which is primarily found at edges of scrubby vegetation.

In addition, the alvars still host viable populations of various wide-spread bird species not listed in Annex I of the EU Birds Directive but with an unfavourable conservation in Europe due to recent declines in the agricultural landscape, including *Alauda arvensis* (Eurasian skylark) and *Oenanthe oenanthe* (Northern wheatear). The wetland depressions are frequently used as breeding sites for wader birds such as *Vanellus vanellus* (Northern lapwing), *Gallinago gallinago* (common snipe) and *Tringa totanus* (common redshank).

Invertebrates: The insect fauna includes a variety of species that have adapted to the dry conditions and lack of shade. To mention just a few from a long list, three species of grasshoppers deserve to be recognised: the rose-winged *Bryodema tuberculata*, the blue-winged *Sphingonotos pilleriana*, and *Omocestus haemorrhoidalis*. Further, several insect species are confined to only one host plant, e.g. three species of butterfly are dependent on *Gypsophila fastigiata*, which is very rare outwith the

calcareous flatrocks. Among endemics, *Scellus dolichocerus*, a roughly ½-centimetre large and long-legged fly feeding on mites living in bryophytes on the flatrocks, is note-worthy. Some of the water-filled pools and ponds are significant for their abundance of *Triops cancriformis*, a 3-5 centimetre branchiopod crustacean confined to water bodies free from fish. A common feature for most of the ponds holding *Triops cancriformis* is occurrence of *Eleocharis uniglumis*, often together with *Baldellia ranunculoides, Potamogeton gramineus* and *Ranunculus aquatilis* (Nilsson 2007).

Vascular plants: Among the rich flora of vascular plants connected to this habitat, four are listed in Annex II of the EU Habitats Directive (92/43/CEE):

- *Sisymbrium supinum:* This is a low-grown crucifer, 10-20 cm height, found on limestone flatrocks, wetland depressions etc., but which can also appear in a variety of early succession stages on calcareous ground. It is a weak competitor, favoured by moderate grazing and trampling by cattle (Länsstyrelsen Kalmar län 2000). The world distribution is restricted to Europe; with two core areas in southwest Europe (several sites in France) and around the Baltic Sea (primarily Öland and Gotland and in Estonia; e.g. Cederberg & Löfroth 2000).
- *Senecio jacobea* ssp. *gotlandicus* (alvar ragwort): This subspecies is endemic to Öland and Gotland, with a total of around 135 sites. It is found in open and herb-rich calcareous soils as well as in seminatural dry grasslands (habitat 6210). The ecology is poorly known, but it seems that this species at least temporarily benefits from a decrease in grazing pressure, although it is also susceptible to shading (Cederberg & Löfroth 2000, Länsstyrelsen Kalmar län 2000).
- *Thesium ebracteatum*: Semiparasitic perennial herb which is hardly noticeable due to its small greenish-yellow flowers and mostly non-branching shoots. The world distribution extends from Central-Europe to Siberia and Balkan. In Estonia, the species is restricted to the north-western parts of the country, where it is found in calcareous boreo-nemoral grasslands, wooded meadows and alvars, mainly in *Avenetum alvarense* (*sensu* Pärtel *et al.* 1999). The main threat to the species is cessation of traditional grassland management (Kuusk 2004).
- *Pulsatilla patens*: This is a herb with large bell-shaped violet flowers which appear in April or early May before the leaves emerge. Its preferred habitats are sparse pine forests of boreal and alvar habitat type and sandy slopes, but it is also found in some heath-alvars of the *Avenetum alvarense* type, where the calcareous soils are mixed with sandy material (Kalliovirta *et al.* 2003). Its main range remains in Central- and East-Europe and Siberia (Pilt & Kukk 2002).

In addition, another plant, endemic to Öland, *Artemisia oelandica* (alvar wormwood) is listed in Annex II of the EU Habitats Directive but it is primarily found in grasslands on thicker soils (e.g. habitat 6210). The species is known from around 75 sites. It is a weak competitor favoured by grazing and primarily dependent on vegetative propagation (e.g. Cederberg & Löfroth 2000).

Bryophytes: Two bryophyte species listed in Annex II of the EU Habitats Directive (92/43/CEE) are dependant on calcareous flatrock habitats:

- *Tortella rigens:* This bryophyte is found on calcareous flatrocks of both the alvar and precambrian subtypes. It is endemic to Sweden, where it is found in sites on limestone bedrock in various parts of the country, and in few sites in western Estonia (Pakri islands, Hiiumaa, Saaremaa). It occurs together with other bryophytes typical on limestone flatrocks and dry calcareous ground. It is favoured by moderate grazing but sensitive to intensive trampling (Cederberg & Löfroth 2000, Länsstyrelsen Kalmar län 2005).
- *Encalypta mutica:* This is a very rare but widespread bryophyte confined to various kinds of calcareous soils and with a few sites spread over northern Europe, Greenland and North America. It is recorded from single alvar sites on Öland and Gotland in Sweden and from Estonia.

In addition, several other rare and threatened species of insects, vascular plants (including several orchid species), lichens and fungi are linked or confined to alvar and other calcareous flatrock environments.

Related habitats

For the distinction of the Nordic alvar and precambrian flatrocks from similar habitats, some "rules of thumb" might be applied:

- Sites where the proportion of bare or only lichen-covered flatrocks exceeds 50% should be classified as *rupicolous calcareous or basophilic grasslands of the Alysso-Sedion albi* (*6110), or *limestone pavements* (*8240) if very rich in cracks.
- Sites where grass and herbs cover more than 50% of the surface might alternatively be considered as *semi-natural dry grasslands and scrubland facies on calcareous substrates* (6210). Soil thickness might be decisive, and often it is the subtype rich in orchids (*6210) that is the potential alternative. For sites characterized by mowing and not or only moderately affected by fertilizing, *lowland hay meadows* (6510) should be considered.
- Small permanent water pools and ponds (<1 hectare) must not necessarily be split out as separate habitats, while larger water bodies should be classified with reference to the relevant freshwater lake habitat. Pools and ponds with reeds of *Phragmites australis* or *Cladium mariscus* or with *Salix* spp. stands should always be classified with reference to relevant habitat, mostly *hard oligo-mesotrophic waters with benthic vegetation of Chara spp.* (3140, "alvar lakes") or *calcareous fens with Cladium mariscus* (*7210).
- *Alkaline fens* (7230) are distinguished from the wetlands created in depressions in the limestone bedrock by reference to typical plant species (see above under "subtypes identified"). If accumulation of tufa occurs, the site should always be classified as an alkaline fen.

The calcareous flatrocks mostly occur in a mosaic with related habitats, and for analyses of trends with reference to natural history and human impact as well as for determining management it is advisable to adopt a holistic perspective.

Ecological services and benefits of the habitat

Alvar is a habitat with a very restricted geographical distribution in temperate regions of the Northern Hemisphere, known only from northern Europe and minor areas in North America. With its species-rich plant and animal communities, including species that have developed various strategies in order to tackle the harsh environment linked to frosty winters and dry summers as well as some endemics, they make a unique contribution to the global biodiversity.

Alvars are also characterised by long-term human influence, and it is sometimes difficult (and perhaps also not particularly meaningful) to separate between the impact of natural and anthropogenic processes on the structure and composition of the animal and plant communities as experienced today. Humans may have had an impact over surprisingly long periods of time; in an Estonian study it was found that locations of Late Iron Age human settlement coincide with high current plant diversity in seminatural grasslands (Helm 2007).

The uniqueness of historical and on-going land-use in an unbroken continuity, unique nature values and a richness of prehistoric and historic remains, qualified the southern part of Öland, where alvar is a distinct feature of the landscape, for designation as a UNESCO World Heritage Site in 2000 (Lager *et al.* 2001).

Trends

The development of the alvars is described in brief below, primarily with reference to Öland, south-east Sweden (for details, see Königsson 1968, Rosén 1982, Ekstam & Forshed 2002, Forslund 2001, and more briefly by Schillander & Hultengren 1998 and Jansson 1999), although the main outline also applies for other areas. The presentation takes a wider scope than the calcareous flatrocks (i.e. FFH habitat *6280) in a strict sense, considering they occur mostly in a mosaic with related habitats.

With the land uplift following after the melting of the continental ice cap around 10,000 years ago a tundra landscape with an Arctic climate characterized by cold winters and very dry summers was established on the limestone flatrock habitat known as Nordic alvar of today. Some of the plants belonging to the Arctic-Alpine floristic element and still found today are survivors since that time. With a shift towards a more temperate climate, still with colder winters but also warmer summers than today, a more luxuriant vegetation of grasslands and (on thicker soils) deciduous forests was established, while the range of alvars was restricted to open patches with very thin soils. The first traces of human settlements, based on hunting and fishing, are from this time - around 8000 years ago.

Since around 6000 years ago, and with the change to a society based on cultivation and livestock husbandry, the alvars and coastal grasslands on Öland have been continuously used for grazing by domestic livestock. Since that time, the history of the alvars is a history of interactions between human impact and nature. Periods of openness of the landscape have alternated with a dominance of scrubland and (primarily) deciduous forest, where changes in grazing intensity have been a key factor, although areas with very thin soil layer have always remained open. As the human population grew, grazing became increasingly intensive and in addition, scrub was collected for fire-wood and for making tools. This resulted in an increase in the area of shrubless alvar land, though some parts with deep soils were turned into cultivated land. By the end of the 19th century the open area had reached its historically greatest extent. After large-scale emigration from Öland towards the end of the 19th century and the beginning of the 20th century, grazing influence and firewood collection decreased.

In Estonia, continuous animal husbandry and grazing can be traced back at least 4000 years, and there is also a tradition of controlled burning in order to facilitate cultivation or grazing, or to attract wild game such as moose *Alces alces,* which forage on the young shots which sprout after a fire (Ikonen 2004).

More recently, from the end of the 1950s, an era of heavy sheep use took place, mainly on Öland. This resulted in the overgrazing of some areas and drastic changes in the vegetation structure. At the beginning of the 1970s this turned into a more balanced sheep grazing system and from the 1980s onward both cattle and sheep grazing gradually decreased (Rosén 1982). By the 1960s the first "warnings" of scrub encroachment and risk of loss of nature values were heard (first concerning cattle grazed and marginal areas). By the time a LIFE Nature project for the restoration of overgrown alvars was initiated in 1995 (LIFE96NAT/S/003185, "Protection and restoration of parts of Stora Alvaret") less than 60% of the alvar areas in southern Öland were grazed (Rosén & Maarel 2000; Ekstam & Forshed 2002).

The trends, with an accelerating scrub expansion rate during the latest decades, are similar in Estonia (Ikonen 2004). In addition, large alvar areas have been excluded from grazing and afforested, primarily with pine trees (*Pinus sylvestris*), resulting in a drastic 60% decline of alvar and related grassland habitats during a period of 20-30 years during the latter half of the 20th century (Pärtel *et al*. 1999).

In addition to the long-term trends, it is important also to consider and understand the short-term impact of weather fluctuations between seasons on the structure and dynamics of the vegetation of alvars and related habitats, especially when interacting with grazing. In all alvar communities there is a process of continuous regeneration, described as the "carousel model" (Maarel & Sykes 1993). Very low summer precipitation in combination with high temperatures may result in a temporary but more or less total drying out of the field layer vegetation, with shrubs killed or injured by drought (Rosén 1982, 1995). At such times, animals prefer to graze the still green vegetation, such as *Sesleria caerulea, Carex* spp. etc. growing in soils with higher clay content, while the faster drying gravel and sandy soils with standing dry plants are ignored. Over the years, this dynamic results in shifts in grazing intensity between areas; with heavy grazing in some moist places in dry seasons while vegetation on thinner soils tend to be more heavily used during wet summers. As moist soils usually cover only small parts of the total area, there may be a lack of fodder during exceptionally dry summers.

To summarize: the alvar as experienced today is a product of a long period of interference between man and nature. There are nuclei of "natural" or "primary" alvar land where thin soil and drainage via cracks in the bedrock have made the establishment of any other kind of habitats impossible, but grazing and the clearing of scrub vegetation has led to a range of larger "cultural" alvar areas.

Threats

Grazing is a prerequisite for maintaining the nature conservation values linked to the alvars and other subtypes characterised by thin soils on calcareous flatrocks. Altered landuse will of course change the character of a site entirely, and various kinds of activities on surrounding land (e.g. gravel pits or limestone quarries) may also cause damage. External factors, such as fertilisers or acidifying air-borne pollutants may also have a negative impact (Naturvårdsverket 2005).

Abandonment of grazing or inadequate grazing regime

Total abandonment of grazing or an inadequate grazing regime is the main problem to tackle in order to assure the nature conservation values linked to the alvar. Low or no grazing pressure will have the following impacts (Rosén *pers. comm.*):

- There will be a limited effect on the main part of type 6280 as the soils in general are very thin and kept open irregularly by drought. However, in moist soil-filled fissures in the bedrock there will be an increase with grasses, e.g. *Sesleria caerulea* and sedges such as *Carex flacca*, as well as small shrubs like *Prunus spinosa*, *Rosa* spp. and a few others. If fissure systems are influenced by an influx of water, open to dense stands of *Dasiphora fruticosa* and eventually single junipers may develop.
- Where the soil is ca. 20-30 cm deep over fairly large areas, the development of juniper scrub may occur. If not grazed, the plant-cover will increase in height and density with a combination of *Festuca ovina, Helictotrichon pratensis, Filipendula vulgaris, Anthyllis vulneraria* etc. Dead plant material will slowly accumulate.
- In moist meadow areas, *Sesleria caerulea* will successively form tussocks; *Dasiphora fruticosa* increases and low-growing species like *Prunella vulgaris, Acinos arvensis* etc. will be shaded by an increase in litter.
- On deeper dry soils (borderlines to 6210), *Helictotrichon* spp. and *Phleum phleoides* together with *Filipendula vulgaris* will create too much shade for several small plants like *Linum catharticum* and *Antennaria dioica,* which disappear in litter and shade. Scattered junipers will expand and gradually dense scrub will develop, including *Prunus spinosa, Rosa* spp., *Berberis vulgaris, Crataegus* spp. with single pine and *Sorbus intermedia* trees. The bryophyte *Hypnum cupressiforme* will increase. Vascular plant regeneration, both by seeds and vegetatively, will be suppressed by bryophytes (Otsus 2004).
- A drastic decline of plant species will occur when the scrub cover reaches around 70% (Rejmánek & Rosén 1988). Fewer seeds are produced. Substances from the junipers create acidification of the soil. The seed bank in the soil decreases. Finally a pine forest might be established, combined with junipers and scattered deciduous trees. Soil heterogeneity due to invasion of woody species is also reported from Estonia (Helm 2007). The problem with juniper overgrowth is more pronounced in Estonia than on Öland and Gotland, primarily due to mostly thicker soil-layers (Pärtel *et al.* 1999).

For details, including explanations of the various reproductive strategies that make different species more or less dependent on or susceptible to grazing, see Ekstam & Forshed (2002).

Even if grazing is a key prerequisite for the management of calcareous flatrock habitats, inadequate grazing regimes may be negative with regard to nature values and the occurrence of species at a specific site (see above under "species that depend on the habitat" and below under "conservation management"). The use of fertilisers or supplementary feeding of livestock (e.g. in winter) may lead to external input of nutrients and have a negative impact on the flora, especially on weak competitors. Locally, trampling and abrasion, particularly in areas with very thin soil layers, and over-grazing may all have a negative impact (Naturvårdsverket 2005).

Impact of outdoor recreation

The very special landscape, combined with a rich flora and fauna, including several species that are never or only rarely found elsewhere, means that the calcareous flatrock attracts naturalists and other

kinds of tourists. At least locally, a high numbers of visitors may cause damage due to the wearing down of the thin soil layer and its vegetation (especially lichens and bryophytes), or disturbance on breeding birdlife. The potential risk of damage was demonstrated in an experiment: After being walked on only 25 times, the moss cushions in a moss community (on the bedrock) dominated by *Tortella tortuosa* were crushed and nine years were needed for recolonisation (Rosén 1984).

Climate change effects

Climatic changes are expected to result in milder and more humid climate conditions in northern Europe (e.g. IPCC 2007). This will involve shorter periods of frost in winter and a more humid summer climate than today. Both are factors that might have a substantial impact on conditions for plant and animal communities characterised by a variety of species-specific adaptations to survive in a climate characterised by regular frost in winter and dry summers. Increased forest growth might result in a more rapid encroachment rates in cases of zero or low grazing intensity

Some possible impacts on type 6280 which might result from climate change (primarily on Öland, Gotland and on some Estonian alvars) may include (Rosén pers. comm.):

- At sites with relatively thin calcareous soil, frost-induced soil movements and summer drought will keep large areas open; favouring species like *Helianthemum oelandicum, Thymus serpyllum, Globularia vulgaris,* small tussocks of *Festuca ovina, Festuca oelandica* and a number of small annual herbs.
- Decreased frequency of frost and moister conditions may favour grasses such as *Festuca ovina, Agrostis stolonifera* and *A. gigantea.* When forming comparatively dense or more closed vegetation, less favourable conditions for small annual species might occur. An expansion of mosses forming cushions might also occur.
- Where soil-filled fissures in the bedrock occur, shrubs like *Dasiphora fruticosa, Prunus spinosa, Juniperus communis* and *Rosa* spp. might establish and survive drought fluctuations better than today.
- In temporary pools and local depressions in the bedrock (where the soil is not very thin) *Carex* spp., *Agrostis* spp., *Sesleria caerulea*, *Dasiphora fruticosa* etc. and calcifilous mosses might develop a more dense vegetation which may turn to be less favourable e.g. for *Allium schoenoprasum* var. *alvarense, Crepis tectorum* ssp. *pumila , Sedum* spp. and others.
- The areas of deepest soil (borderline to habitat type 6210) will probably develop a more productive vegetation with a dominance of grasses and tall herbs, and thus less favourable for small-grown species.
- Established juniper and pine trees will not be as water-limited as today and the growth rate will increase, resulting in a faster expansion of juniper scrub and pine woodlands at the expense of open grassland vegetation. This problem might be more severe for the Estonian alvars with fairly deep sandy soils.

Changes to milder winter periods will presumably also favour all-year grazing of sheep and cattle. This will result in increased trampling effects and no recovery periods for the vegetation. A prolonged or permanent period of dung production in the field will favour nitrophilous species to increase and cause a decline in the present high species richness of the alvars. Invasive species like *Artemisia absinthum* and *Daucus carota* may be more frequent and more dominant. Already today such species are locally found in alvars, presumably supported by air deposed nitrogen.

For some of the northern alvars in Estonia (as well as for the limited areas in Russia) the changes might not be so drastic as their vegetation already is adapted to a more continental climate with higher precipitation and less specialised plants. The vegetation will probably become taller and small plants less frequent. Scrub encroachment will increase and so will woodland vegetation.

However, these expected scenarios might still involve short-term impact and regulation related to temporary periods of extreme drought.

2. Conservation management

General recommendations

For the management of alvars and other calcareous flatrock habitats it is important to keep in mind that they are results of a long history of interaction between man and nature. Although there are patches of "natural" alvar land where thin soil and drainage via fissures in the bedrock make the establishment of any other kind of habitats impossible, grazing is a basic prerequisite for the long-term maintenance of the nature conservation values for large areas. However, it is neither possible nor meaningful to relate the management objectives to fixed historical reference more or less distantly in the past. Rather, an approach to allow for a management that reflects various aspects of the natural history and landuse, and takes into account the variety of adaptations and strategies that have evolved among plant and animal species, might be considered (e.g. Ekstam & Forshed 2002). Maintenance of a variety of grazing regimes is crucial in this perspective.

Although grazing is the key concept for the recurring management of the alvars and other calcareous flatrock habitats, regular clearing may be a necessary complementary measure for assuring the basic requirement of openness. Also the clearing has some links to historical land use, so far as it included the collection of fire wood and material for tool-making. If to reopen an overgrown site for grazing, restoration in order to reduce overgrowth and overcome problems of internal fertilising is mostly a necessary initial measure. Specific requirements need to be considered on sites where viable populations of any threatened and rare species is a key objective.

It is advisable to do some research and as much as possible to document knowledge about the traditional land-use. Often, it is neither necessary nor possible to mimic the traditional techniques, but such knowledge might nevertheless help to understand the specific requirements that have to be met at a particular site, and to adjust the details in the management accordingly. Surveys and inventories of the various aspects of flora and fauna are recommended, if this kind of information is lacking, scant or not recently updated.

In addition to including detailed prescriptions about grazing and clearing in the management plans (or similar documents), it is also recommendable to prevent the use of fertilisers and biocides (pesticides as well as weed-killers), supplementary feeding of livestock, drainage, and the introduction of any species not spontaneously belonging to the animal or plant communities including non-native species (Naturvårdsverket 2005, etc). Top-soil treatment, ploughing for cultivation and afforestation (where soil depths make it possible) will of course destroy the habitat completely. (All these treatments are currently forbidden at alvar sites in Sweden.)

It is also necessary to keep control of and (if necessary) restrict activities on surrounding land that might have an indirect negative impact, e.g. lime and gravel pits.

*Note: For the detailed management planning at a particular site, it is mostly recommended that a holistic perspective be adopted where the calcareous flatrocks often occur in a mosaic with related habitats. The guidelines presented here refer to such a comprehensive approach, rather than to calcareous flatrocks (i.e. habitat *6280) in a strict sense.*

Active management

Grazing

Grazing is the traditional use of the alvar and other calcareous flatrock habitats, and it also the basic measure ensuring the maintenance of nature conservation and cultural heritage values linked to this kind of environment. But the grazing pressure has to be balanced and adjusted on a site-specific basis, with reference to the habitat requirements for specific species. The traditional livestock used at the alvars are cattle, sheep and horses. Livestock have traditionally been housed for winter - 4-6 months.

For nature conservation purpose, an average grazing intensity (pressure) of 1 "animal unit" per 5-6 hectares has been recommended for Öland (Länsstyrelsen Kalmar län 1997; adult cattle = 1.0-2.0 animal units, young cattle = 0.5 units, sheep (ewe with lamb) = 0.4 units, and horse = 0.8-1.5 units). The guidelines nevertheless allow for a large variation and flexibility (with a range of 3-10 hectares per animal unit). If thin soil areas predominate in mosaics with habitat types 6110 and 8240, a grazing intensity of 7-10 hectares per animal unit is more relevant. But it is important to allow for flexibility. In productive year, a few more animals could be used or the grazing period might be prolonged, while in extremely dry seasons animals might be taken to other grasslands earlier than planned, or be given extra fodder (outside the alvar area) to prevent suffering.

For Estonia, a substantially higher grazing pressure has been recommended with reference to sheep and considering that soil layers are usually thicker than on Öland (Ikonen 2004). With reference to the variety of figures, it is important to stress that the grazing pressure has to be decided with reference to the specific objectives set up for a particular site rather than on common standards in terms of animals per hectare. In this perspective the above given figures are to be regarded as indicative guidelines, rather than strict recommendations.

The kind of animals to be used, as well as the exact times of the season for grazing also has to be decided with reference to site and species-specific objectives (see also below, under "special requirements driven by relevant species"). It is also important to consider that today's cattle breeds are larger and heavier than the ones used traditionally. Grazing in winter should not be allowed.

The use of several kinds of grazing animals, either together or sequentially during the grazing season, should be considered with caution and on a site-by-site basis (even if related to local land-use traditions). It might sometimes be beneficial with reference to site-specific conservation objectives (e.g. Ekstam & Forshed 2002), but preferences for various plants by various kinds of livestock may also result in hardly any plants being left un-grazed. As a consequence, few or no flowers may be left to produce seeds for the future, and the insect fauna dependant on various flowers and structures might also suffer.

Experience relating to the establishment and maintenance of the infrastructure necessary for grazing, such as fences, gates, stiles, shelters, cattle pens and facilities for water-supply were gained in two LIFE-Nature projects on Öland (LIFE96NAT/S/003185, "Protection and restoration of parts of Stora Alvaret"; LIFE00NAT/S/007117, "Coastal meadows and wetlands in the agricultural landscape of Öland").

Complementary clearing

In situations when it is difficult to ensure a satisfactory grazing pressure, regular clearing may be a necessary complementary measure in order to meet specific requirements for individual species or to keep root and trunk shoots from cleared deciduous trees and scrub under control (see below, under "restoration by clearing" for further details).

Restoration by clearing

In most cases it is necessary to restore highly over-grown areas before they can be reopened for grazing. The main aim is to remove shade-producing overgrowth in order to allow the inflow of light necessary for the recovering of herbaceous vegetation on the ground. Preferably, clearing should be initiated before the critical level of around 70% scrub cover when a rapid decline in plant species is reached, and it might be more effective to prioritise less overgrown areas. Recent experiences show that reopening the land for grazing *before* the start of scrub clearance may help to make the restoration effective. If there is a substantial risk of problems finding enough livestock to carry out the grazing, the wisdom of initiating any restorative clearing at all should be considered. If not followed up with grazing, the removal of shrubs like *Prunus spinosa, Rosa* spp., *Dasiphora (Potentilla) fruticosa* and *Berberis vulgaris* will result in an even higher number of new shoots than before the scrub was removed. This is due to the release of accumulated nitrogen etc, which will necessitate further and

continuous complementary clearing in the future (see also below). However, *Juniperus communis* and *Pinus sylvestris* are killed by being cut, with no risk of regrowth.

To summarise some experiences and recommendations from a large-scale restoration program implemented on the southern parts of Öland in 1996-1999 (LIFE96NAT/S/003185, "Protection and restoration of parts of Stora Alvaret"; Länsstyrelsen Kalmar län 1996, Forslund & Lager 2000) and from recently adopted management plans for various alvar sites (primarily on Öland, see further Rosén & Maarel 2000; Rosén & Bakker 2005 and Rosén 2006):

- Often, the clearing has to be done in several stages, with the initial objective of halting further encroachment by starting from still open areas and clearing the most recently overgrown areas first. In the main, saplings of both deciduous and coniferous trees should be removed, while groups of old trees (e.g. trees characteristically shaped by wind) can be left to provide shelter from the winds for grazing livestock etc. Trees with large crowns, suitable for nesting raptors etc, should also be left.
- A major problem to be tackled after a break in grazing is the accumulation of nitrogen in the plant biomass as well as a build-up of litter. In the initial phase of the clearing of areas heavily overgrown with deciduous scrub, release of accumulated nutrients is an inevitable consequence and mostly the initial clearing has to be followed with repeated removal of rot and stump shoots. With repeated clearings at a few years interval not all nitrogen will be released at the same time, and this allows for a gradual regeneration of the field layer. On alvars, *Dasiphora (Potentilla) fruticosa, Prunus spinosa* and *Rosa* spp. may be particularly difficult to handle. The initial measures should be concentrated on halting further expansion, with these being followed up with further scrub removal.
- Clearing of junipers should be more judicious to leave old and large-grown bushes plus a variety of bushes of various sizes and shapes in order to provide good habitats for birds, insects etc. Vegetation in glades between the junipers usually survives drought periods and may provide fodder for the grazing animals during dry periods.
- Cleared bushes should be cut very close to the ground, in order to reduce harm to grazing livestock. Small and intermediate-sized junipers should be removed first as they expand their height and area faster than the bigger bushes (Rosén 1988).
- Cleared material should in the main be removed from the site, if possible without unacceptable damage to the ground by vehicles. Alternatively, burning can be done at a limited number of predetermined locations, preferably on recently cleared patches where grass vegetation has still not recovered, and in late winter-early spring or late autumn. Burning on metal plates placed on the ground or using mobile trailers specifically prepared for this purpose has been tested with positive results. Burning must never be done directly on bare flatrocks.
- Clearing should not be done during the bird breeding season between mid-April and June.

Locally, it might be necessary to adjust the clearing to cultural heritage values (e.g. stonewalls) and prehistoric remains; for the latter, archaeological expertise should be consulted.

A 7-years field experiment in Estonia indicated that the restoration of alvars and other kinds of species-rich grasslands on limestone bedrock do not require the additional input of diaspores of grassland species, provided that the local species pool is still intact, although transplantation of sods is a potentially important method in case of impoverished local species pools (Pärtel *et al.* 1998).

In the 1996-99 LIFE Nature project on restoration of alvar sites on Öland (LIFE96NAT/S/003185), various techniques were tested and evaluated and it was found that manual clearing was the most effective in the long-term from a conservation perspective, although time-consuming in the short term. It was also found that burning and bush pulling are not to be recommended, even if they seem to be quick and effective methods in a short-term perspective. The experience of the project can be summarised as follows (Forslund & Lager 2000):

Table 1. Different methods, from a conservation perspective, carried out during the LIFE Nature project (LIFE96NAT/S/003185) in Öland (Forslund & Lager 2000)

Method	Advantages	Drawbacks	Comments
Manual clearing (incl. motorised equipment)	- Can be used on land with susceptible vegetation. - No damage from vehicles. - Makes a high degree of selectivity possible. - Waste easy to collect and destroy. -Easy access, e.g. where stones and tussocks and along stonewalls. -Can be done all the year around (but disturbance to breeding birds must be considered)	- Time-consuming	Considering long-term nature conservation benefit, this is often the most effective method.
Mechanical clearing	- Large capacity, time-effective. - Easy to maintain previous clearing effects. - Whole scrubs and bushes can be collected in one unit. - Machines can be adjusted to be used also on land with much of stones and tussocks.	- Not to be used on land with susceptible vegetation - Not suitable on land with much of tussocks - Low efficiency on stony land. - Low precision. - Risk for damage from vehicles. - Limited access to wet areas. - Collection of waste time-consuming.	Of very limited value in alvar habitats, considering the overall low precision, risk for damage and that manual clearing often is necessary as a complement to get acceptable results with reference to nature conservation benefit. On highly overgrown land, time and conservation effective, however.
Burning	- Easy and quick method	- To be done only during a limited period during late winter and early spring. - No selectivity. - Difficulties to keep the fire limited to the target area. - Often bushes are burnt and dead but not completely destroyed, which make grazing more complicated (and also a less attractive element in the landscape). - the feet of grazing animals can easily be wounded by the unburned basal parts of the shrubs. - Burning on dry soil may totally destroy the humus later. - Unwanted fertilising effects. - Usually to be complemented with manual clearing.	**→ NOT TO BE RECOMMENDED**
Bush pulling (mechanically, using a tractor)	- Small problems with unwanted fertilising effects (the whole bushes are removed) - Waste easy to collect and handle. - Less problems with root shoots for some species, e.g. *Prunus spinosa* and *Crataegus* spp. than with other methods.	- Often remaining damage on the ground. - Not to be used on land with susceptible vegetation or rare plant species. - Risk for damage from vehicles.	**→ NOT TO BE RECOMMENDED**

In addition, spreading juniper chips on the ground has been tested but found not to be recommendable. Junipers are known for their very slow decomposition rate and full recolonisation of a chip layer of 10 cm thickness by grassland vegetation has been found to take over ten years.

Other relevant measures

Channelling of visitors and vehicles

Alvar and other calcareous flatrock habitats are extremely susceptible for wear, and at least locally, it might be necessary to channel visitors to certain paths (following already present tracks or small roads) in order to reduce negative impact by trampling on vegetation, or to restrict the public access to minimise the risk of disturbance on breeding birdlife.

The use of motorised vehicles should be kept at a minimum, whether for livestock husbandry or nature conservation (incl. clearing), and it should also be concentrated on pre-existing roads and tracks. Away from roads and tracks, vehicles should be limited to land with an intact vegetation cover or on flatrocks without bryophytes and lichens and preferably on frozen ground and only used when necessary for management and restoration purposes. Areas with dense coverage of bryophytes and lichens should always be avoided.

Monitoring

The monitoring of e.g. vegetation structure or population changes of vascular plants, insects or birds in flatrock habitats involves some challenges related to the dynamics resulting from the interactions between effects of grazing and weather fluctuations between seasons. E.g. short-term fluctuations of large magnitude may hide more long-term trends that are essential to detect for decisions of changes and adjustments of the management and with reference to site-specific as well as species-specific conservation objectives. Taking into account experiences gained from monitoring of vegetation and plant communities in alvars, e.g. in order to follow up changes after restoration by clearing or changes in the grazing regime, yearly recordings in permanent plots are recommended (Rosén 1982, 1995, Rosén & Bakker 2005). For characteristic or rare plants species (including species listed in Annex II of the EU Habitats Directive), as well as for invasive taxa, complementary species-specific monitoring programs should be used. A reliable method is an annual count of individuals within permanent study plots.

In Sweden, the following criteria are proposed for the evaluation of the conservation status of a specific site (e.g. Naturvårdsverket 2005):

- The surface area (in hectares) to meet the definition of 'Nordic alvar or precambrian calcareous flatrock'.
- The percentage of well-managed surface area.
- Minimum percentage of monitoring study plots with vascular plants characteristic for the habitat.
- Minimum number of breeding pairs of typical bird species, e.g. *Numenius arquata* and *Pluvialis apricaria*.

However, repeated surveys with only 6-years interval of various parameters, as recommended by The Swedish Environmental Protection Agency (Naturvårdsverket 2005) are not adequate in the light of the above referred experiences.

Special requirements driven by relevant species

Often, it is necessary to adjust details in the management of a calcareous flatrock area in order to meet specific habitat requirements of rare or threatened species. This might sometimes involve decisions about compromises or priorities between alternative conservation objects and some fine-tuning of the proportions between scrubby and heavily managed areas. Some of these difficulties might be

overcome if possible to adopt large-scale landscape perspective that allows for a variety of site-specific priorities for particular animal and plant species.

For the detailed planning of the management it is thus useful to have access to recent information about the occurrence of species that have to be considered. Below, some specific considerations are outlined, primarily for relevant species listed in Annex I of the EU Birds Directive and Annex II of the EU Habitats Directive, although similar kinds of adjustments might be necessary also for other rare and threatened species, e.g. with reference to national or regional red-lists.

Birds:

In the main, ground-nesting wader-birds such as *Pluvialis apricaria* and *Vanellus vanellus* benefit from grazing (as found at surveys linked to restorations done within the LIFE-Nature project on restoration of alvar sites on Öland 1996-99 (LIFE96NAT/S/003185, Ålind & Lindell 2001), but for some bird species misdirected restoration may have a negative impact:

- *Circus pygargus* (Montagu's harrier): Although an overall positive population trend has been recorded for this species in Europe during the latest decades (BirdLife International 2004), the population breeding at alvars on Öland has decreased by around 40%, from 40-45 pairs in the mid-1990s to 23 pairs in 2004 (Rodebrand 2007), and the decline can at least partly be related to misdirected restoration and management in terms of destruction of preferred nesting sites in connection to clearing of *Dasiphora fruticosa* scrub. Obviously, the necessity to adjust management to the requirements of this species must be taken into account in the preparation and revision of management plans and similar documents.
- *Sylvia nisoria* (barred warbler): This warbler may suffer from heavy clearing of scrub and it might be necessary to make site-by-site choices between the habitat requirements of this species and management objectives related to floristic values. But the species may also be negatively affected by severe scrub encroachment (Svensson & Waldenström 2007), so a fine-tuning of the site-related management might be necessary.
- *Lanius collurio* (red-backed shrike): The species often responds positively and quickly to removal of shrubs and trees in overgrown grassland habitats of various types but also suffers from too over-clearing. 10-15% of a grazed area should be left covered with junipers and other scrub (e.g. *Prunus spinosa*, *Rosa* ssp., *Crataegus* ssp; e.g. Roos 2007).

Invertebrates:

Management which affects pools and ponds and their surroundings has to consider the specific conservation values linked to these habitats, especially with reference to the mostly species-rich aquatic fauna including brachiopod crustaceans (primarily *Triops cancriformis*, Nilsson 2007). The kind of pool that seems to be preferred by brachiopods has a good water-holding capacity and a comparatively thick layer of precipitated lime on the bottom. Trampling by cattle seems to have a positive impact. Introduction of fish will completely wipe out the brachiopod crustacean populations because of predation.

Vascular plants and bryophytes:

Many of the plant species that suffer from heavy shading recover quite quickly after scrub clearing and the re-starting of grazing, but for a variety of species the management has to be adjusted to particular requirements that sometimes necessitate a fine-tuning of the management, e.g. a moderate grazing pressure in order to avoid encroachment while still keeping the risk of damage due to trampling by cattle to a minimum.

Among plants species listed in Annex II of the Habitats Directive, experiences and guidelines can be summarised:

- *Sisymbrium supinum* is one of the many species that can be categorised as weak competitor linked to early succession stages on calcareous ground and favoured by moderate grazing and trampling by cattle (Länsstyrelsen Kalmar län 2005).

- *Senecio jacobea* ssp. *gotlandicus* (alvar ragwort) has a poorly known ecology but it seems to be at least temporarily favoured of a decrease in grazing intensity and may flourish for a temporary period of some years on land left abandoned or with low grazing pressure, but it is also susceptible to heavy shading (Cederberg & Löfroth 2000, Länsstyrelsen Kalmar län 2000).
- *Thesium ebracteatum*: The species is dependant on continuous extensive management of grasslands. The decrease in abundance relates to the increase in scrub cover in abandoned grasslands.
- *Pulsatilla patens*: This is rather light-demanding herb and therefore suffers when open areas get overgrown. A thick layer of bryophytes decreases its germination and establishment success. This species is facilitated by moderate disturbances like livestock trampling.
- *Tortella rigens:* This bryophyte, like many other bryophytes and lichens typical to limestone flatrock habitats, is favoured by moderate grazing but sensitive to intensive trampling (Cederberg & Löfroth 2000, Länsstyrelsen Kalmar län 2005).

Cost estimates and potential sources of EU financing

Cost estimates

Restoration costs for clearing of overgrown calcareous flatrock areas may differ substantially between sites, depending on the degree of encroachment, thickness of soil etc. Some idea can be given by reference to previous experiences:

- In the LIFE-Nature project LIFE02NAT/S/007118, "Restoration of alvar habitats on the island of Stora Karlsö", 158 ha of overgrown alvar and calcareous grasslands were manually cleared from scrub, mainly junipers on land with very thin soil layer, using motorised equipment. The cost was around €2700 /ha and the work-efficiency 0.057 ha/person/day. The cost could at least partly be related to high wear of saw blades because of the extent of areas with very thin or no soil layer.

- A preliminary assessment of the cost of clearing overgrown alvar, meadow and grassland habitats on Öland (October 2007) is of the same magnitude, i.e. around €3000 /ha.

- For grazing of alvar, the current approximate level (September 2007) of annual compensation within the agri-environmental scheme in Sweden is around €90 /ha.

The Nordic alvars and Precambrian flatrock is a kind of habitat that, if not used for grazing, is mostly left abandoned without any alternative non-agricultural activities. Thus, it is presumably only rarely that compensation payments have to be considered for income foregone when the management has to be adjusted to achieve conservation objectives.

Potential sources of EU financing

Among the diversity of sources for EU funding, the following funds might primarily be of interest for the management of alvars and other calcareous flatrock habitats:

- The European Agricultural Fund for Rural Development (EARDF): This fund has the potential to cover several management activities that might be relevant for calcareous flatrock habitats, although the measures have to be shown to be necessary in the National Strategy Plans and set out in the related Rural Development Plans (RDPs) in order to be implemented at the national level. However, the costs of grazing calcareous flatrocks are mostly eligible for agri-environmental subsidies within this program. To some extent, necessary infra-structure, such as fences and shelters, may also be eligible under this program. LEADER projects offer the opportunity to implement the same type of measures, but designed for and tailored to the local level, and may be therefore be designed to implement the management of sites in the Natura 2000 network.

- The European Regional Development Fund (ERDF), The Cohesion Fund and Interreg: These funds might be relevant in single cases although activities related to Natura 2000 sites mostly need to be integrated in a broader development context, and for ERDF also related to productive investments (e.g. infrastructure). However, the Interreg approach is more flexible, but need a transnational objective and partnership. Different geographical levels are defined and all of them have their specific rules, eligibility criteria and objectives.

- The Financial Instrument for the Environment (LIFE+): The 'Nature' component of LIFE+ supports best practice and demonstration projects contributing to the implementation of the Birds and Habitats Directives but only exceptionally outside Natura 2000 sites. The 'Biodiversity' component is for demonstration and innovation projects outwith Natura 2000 sites which contribute to the objectives of the Commission Communication 'Halting the loss of biodiversity by 2010 – and beyond'. Both the 'Nature' and 'Biodiversity' components emphasise on concrete non-recurring management actions (at least 25 % of the budget) and when needed compensation payments for restrictions in commercial land-use are eligible under 'Nature'. Recurring management is not eligible under LIFE+.

For the identification to what extent management measures required for a specific site are eligible for financial support from various EU funds, further consultation of the "Financing Natura 2000 Guidance Handbook" (Torkler 2007) is recommended;
http://ec.europa.eu/environment/nature/natura2000/financing/index_en.htm

Furthermore an IT-tool is available on the EC web site:
(http://ec.europa.eu/environment/nature/natura2000/financing/index_en.htm).

Acknowledgements

This model has been prepared by Mats O.G. Eriksson (MK Natur- och Miljökonsult HB) and Ejvind Rosén (Uppsala University Ecological Research Station).

Following persons have contributed with particularly important information and inputs for the elaboration of the management model: Ms. Susanne R. Forslund (Kalmar County Administrative Board, Kalmar, Sweden) and Dr. Merit Otsus (Estonian University of Life Sciences, Institute of Agricultural and Environmental Sciences, Estonia).

Gwyn Jones (European Forum on Nature Conservation and Pastoralism, UK) revised the final draft.

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