Technical Report 2008 20/24

NATURA 2000

MANAGEMENT of Natura 2000 habitats
Alkaline fens
7230

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. 7230 Alkaline fens

This document was prepared in March 2008 by Viera Šefferová Stanová, Ján Šeffer and Milan Janák, DAPHNE-Institute of Applied Ecology, Slovakia

Comments, data or general information were generously provided by:

Michal Hájek, Masaryk University of Brno, Czech Republic
Ab Grootjans, University of Groeningen, Netherlands
Lesław Wołejko, University of Agriculture, Szczecin, Poland
Francis Muller, Fédération des conservatoires d'espaces naturels, France
Mara Pakalne, Latvian Fund for Nature, Latvia
Mats Eriksson, MK Natur Och-MiljöKonsult, Sweden

Coordination: Concha Olmeda, ATECMA & Daniela Zaghi, Comunità Ambiente

ISBN 978-92-79-08332-7

Šefferová Stanová V., Šeffer J. & Janák M. 2008. Management of Natura 2000 habitats. 7230 Alkaline fens

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

Contents

7230 | Alkaline fens

Cottongrass and Davall's sedge are dominant plants on calcareous fens.
Photo: Viera Šefferová Stanová

72. Calcareous fens

EUNIS Classification:

D4.1 Rich fens, including eutrophic tall-herb fens and calcareous flushes and soaks

Summary

Alkaline fens are mires occupied by peat- or tufa-producing small sedge and brown moss communities developed on soils permanently waterlogged with calcareous water supply, and with minimal water level fluctuation. They are generally species-rich both in terms of mosses and flowering plant species. Alkaline fens have been selectively drained in the past and have become very rare in most of EU countries and have a high conservation priority.

Formerly, hydrological systems that provided natural fens with a large supply of base-rich groundwater were able to stabilize nutrient poor fen vegetation for many centuries, without any management by man. However, during the past few centuries, almost all fens have been slightly drained and changed into low-productive meadows and pastures that cannot be maintained without management.

A significant proportion of fens are managed by conservation mowing - purely for habitat management. Mowing is carried out by hand mowing on a small scale and with light machinery adapted to the sensitive environment of fens, such as small and light mowers, pedestrian-driven mowing machines, or with specially adapted of tyres (low pressure, twinned wheels). Cut biomass is then gathered and removed from the site. As a minimal management, mowing every second year or also with longer intervals of 3-5 years is judged to be sufficient.

Moderate grazing on fens can be recommended as an alternative conservation strategy to mowing. But optimal grazing conditions have to be developed to minimize the unwanted effects of foraging and trampling. Reduction in species richness and changes in species composition and species traits may occur. The grazing intensity has to be determined carefully. Managers in France recommend an average pressure of between 0.2 and 0.8 Cattle Unit/ha. In Scotland, fens should be accessible to stock during the driest months of the summer. They should be grazed for at least two weeks each year.

In northwest Europe public pressure increases for the restoration of fens, which were heavily damaged by drainage and agricultural pollution. Large projects for the restoration of fens are appearing mainly in northern Germany, the Netherlands and Switzerland.

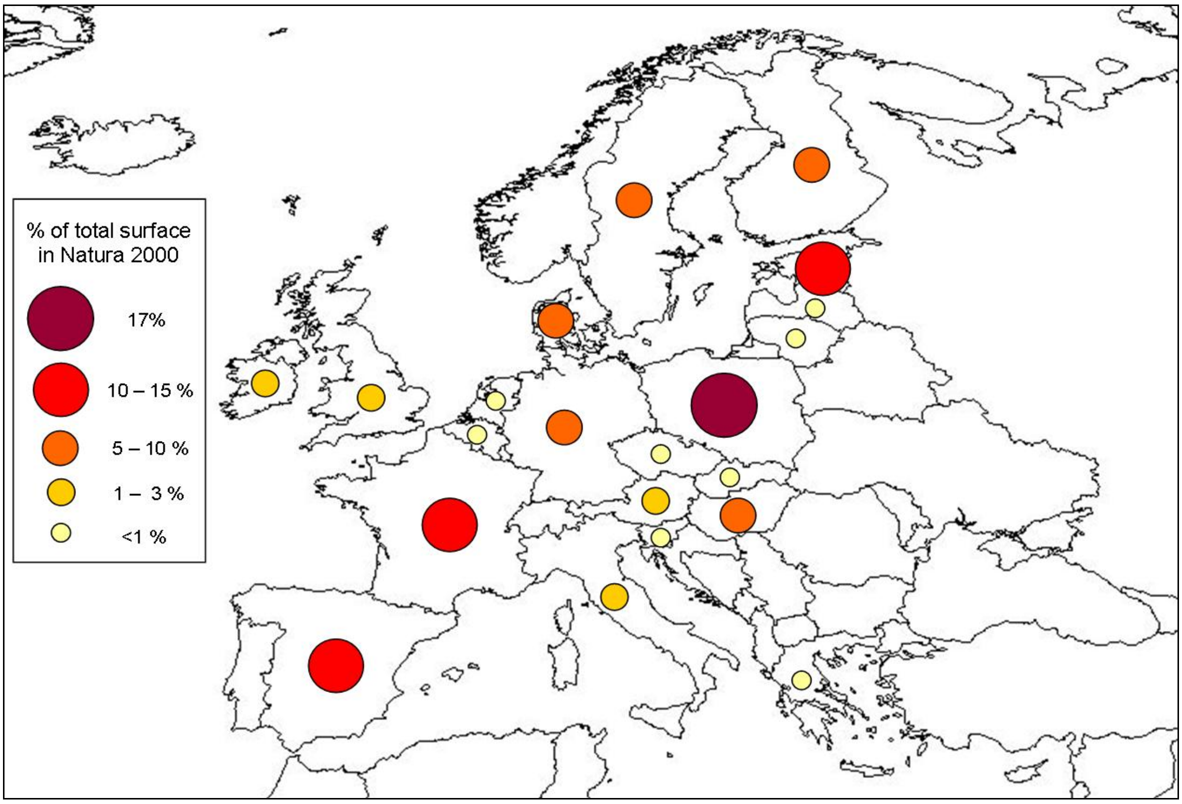
Without appropriate management, natural succession will lead to scrub and woodland forming. Cutting scrub by hand is one solution, and this practice is still utilised. For some sites, this is the only workable option, but it is extremely labour intensive and so only suitable for small areas. Low ground pressure excavators, cutting machines and portable incinerators have all been developed and are enabling large areas of scrub to be restored to fen.

1. Description of habitat and related species

Alkaline fens are mires of small sedge and brown moss communities on soils permanently waterlogged, with a calcareous water supply, minimal fluctuations in the water level and with peaty substrate.

Distribution

Alkaline fens occur in most bio-geographical regions and in 23 EU countries. The largest designated surface area (more than 60%) is in the Boreal and in the Continental biogeographical region, with 30% of the total in Poland and Estonia. Although the final list of sites have not been agreed for either country, alkaline fens can also be found in Romania and Bulgaria.



Percentage distribution of the total surface of Alkaline fens in Natura 2000

Alkaline fens 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
Boreal	832	46,291	32.5
Continental	731	41,320	28.9
Atlantic	207	19,879	13.9
Alpine	316	17,166	12.0
Mediterranean	60	10,216	7.2
Panonic	65	7,880	5.5
Biogeographical region	Nº of sites	Estimated surface in Natura 2000 (ha)	% of total surface in Natura 2000
Poland	56	24,233	17.1
Estonia	113	20,122	14.1
France	180	16,886	11.8
Spain	55	15,592	10.9
Sweden	440	13,726	9.5
Finland	307	11,192	7.8
Denmark	113	9,244	6.5
Hungary	64	7,879	5.5
Germany	488	7,646	5.4
Italy	128	4,929	3.5
Ireland	35	2,809	2.0
Austria	44	2,127	1.5
United Kingdom	49	1,633	1.1
Slovenia	10	1,264	0.9
Latvia	22	1,209	0.8
Lithuania	24	1,058	0.7
Slovakia	53	760	0.5
Belgium	7	222	0.2
Greece	6	166	0.1
Netherlands	8	56	0.04
Czech Republic	10	20	0.01
TOTAL	**2,212**	**142,753**	**100**

Main habitat features, ecology and variability

Alkaline fens are mires of peat or tufa-producing small sedge and brown moss communities, which have a high water table, a calcareous water supply and minimal water level fluctuation. In many cases, the dividing line between rich fen (peat-forming) and fen meadow is fuzzy, and the two often occur alongside each other. Generally, they are species-rich both in terms of moss and flowering plant species.

The vegetation in the best-preserved mires has a mosaic-like structure of calciphilous plant communities, pools, springs, pioneer communities and peat-forming moss-sedge communities belonging to the *Caricion davallianae* alliance (Wolejko *et al*. 2005).

Caricion davallianae is a community of open low-growing small sedge vegetation. It is characterised by:

- an usually prominent "brown moss" carpet formed *by Campylium stellatum, Drepanocladus cossonii, Cratoneuron commutatum*, *Caliergonella cuspidata*, *Ctenidium molluscum*, *Fissidens adianthoides*, *Bryum pseudotriquetrum* and others,
- a grasslike growth of *Schoenus nigricans*, *S. ferrugineus*, *Eriophorum latifolium*, *Carex davalliana*, *C. flava*, *C. lepidocarpa*, *C. hostiana*, *C. panicea*, *Juncus subnodulosus*, *Trichophorum cespitosum*, *Eleocharis quinqueflora*, and
- a very rich herbaceous flora including *Tofieldia calyculata* (in northern Europe *Tofieldia pusilla*), *Dactylorhiza incarnata*, *D. traunsteinerioides*, *D. russowii*, *D. majalis* ssp. *brevifolia*, *D. cruenta*, **Liparis loeselii*, *Herminium monorchis*, *Epipactis palustris*, *Pinguicula vulgaris*, *Pedicularis sceptrum-carolinum*, *Primula farinosa*, *Swertia perennis* (EC 2007).

Vegetation units in alkaline fens have similar physiognomy. Because there is a wide distribution range of alkaline fens, their species composition changes depending on the geographical region, altitude and water chemistry. The floristic and faunistic differences between biogeographical regions may be significant.

Ecological requirements

Mire development is determined by water: the amount of water available and its chemical composition affects the morphology and surface pattern of a mire as well as its floristic composition, the productivity of its vegetation, the distribution of microtopes and the accumulation of peat (Damman 1995). Two fundamental processes are prerequisites in the formation of mires: a positive water balance and the accumulation of peat (Mitsch & Gosselink 2000). Both groundwater regime and quality play a crucial role in determining whether fens are formed. Fens can be subdivided on the basis of hydrology into topogenous and soligenous. In topogenous fens the ground water level is high due to the local relief – water movement is often slow. They include basin fens and floodplain fens. Soligenous fens are largely the result of flowing surface water. They include mires associated with springs, mountain flushes, valley mires, and water tracks and ladder fens in blanket and raised bogs.

Rich fens receive a significant groundwater component that is rich in base cations (principally calcium, but also magnesium and potassium), but poor in nutrients (nitrogen and phosphorus). The base cations enter the water as it travels over or through calcareous bedrocks such as limestone. These fens are therefore restricted to areas with significant calcareous geological deposits. The pH is also high, ranging from 6 to 8.5 across most of the continent, but in northern Europe occasionally as low as 5.5 (Airaksinen & Karttunen 1999).

Groundwater levels in undisturbed basiphilous fens are usually high and oscillate close to the mire surface, sometimes seeping out and filling small depressions and ponds (Wolejko *et al*. 2005).

Variability

In countries such as Poland (Wolejko *et al.* 2005) and Slovakia (Stanová & Vachovič 2002), rich fens are represented by *Sphagno warnstorfiani-Tomenthypnion* communities. These are dominated by calcium-tolerant peat mosses and sedges. Peat forms rapidly where there is a sufficient water supply on calcareous bedrock. Typical dominant mosses include *Tomentypnum nitens, Helodium blandowii, Paludella squarrosa, Sphagnum warnsdorfii, and Sphagnum teres*.

This community is not differentiated in most West European countries due to the difficulty of distinguishing it from *Caricion davallianae*, as *Carex davalliana* is dominant in both vegetation units. The main differences are in the composition of the moss layer, and the terrestrial snail composition (Hájek et al. 2006).

In Poland (Wolejko *et al*. 2005) selected plant associations from the *Caricion nigrae* and *Caricion lasiocarpae* alliances were also included into basiphilous mires.

The French Natura 2000 handbook (Gaudillat & Haury 2002) mentions also *Hydrocotilo vulgaris-Schoenion nigricantis*, which occurs in France in regions with Atlantic trends. Species composition is typical for occidental regions, with strong Atlantic influence. In northern Europe, a variety of sub-types have been identified, with reference to the proportions between *Carex* spp. and various herb varieties, and the amount of shadow created by birch, pine and spruce trees (Påhlsson 1998, Airaksanen & Karttunen 1999).

Species that depend on the habitat

Bryophytes are ecologically important and dominant in alkaline fens. They respond more quickly to a lowering of water levels than do vascular plants, since they lack vascular tissue for the transportation of water from greater depths. Characteristic rich fen bryophyte species which are very sensitive to changes in hydrological conditions include *Scorpidium scorpioides, Drepanocladus cossonii, Pseudocalliergon trifarium* and *Campylium stellatum*. They therefore also serve as good indicators of altered hydrology, water chemistry and trophic status (Mälson & Rydin 2007).

Butterflies are one of the most noteworthy invertebrate groups dependent on fens. This is especially true of *Coenonympha oedippus* (false ringlet), and *Lycaena dispar* (large copper). *Maculinea teleius* (scarce large blue), *Maculinea nausithous* (dusky large blue), and *Euphydryas aurinia* (marsh fritillary) are associated with habitats transitional into fen meadows.

Coenonympha oedippus can be found in France, through Northern Italy and Austria, to Hungary (Kudrna 2002). In most European countries it is considered as rare and very endangered. In Slovakia, *Coenonympha oedippus* is considered to be extinct (Kulfan & Kulfan 2001) while in Poland it can be found in three locations in the eastern part of the country and hence is considered as critically endangered (Buszko 2007). Its habitats are fens in river valleys. The food plants of the caterpillars are not known, although grasses (*Poaceae*) and sedges (*Carex sp.*) have been mentioned (Higgins & Riley 1970).

Typical dragonflies present in fen habitats include *Leucorrhinia pectoralis* (large white-faced darter dragonfly), *Coenagrion ornatum* (ornate damselfly), and *Coenagrion mercuriale* (southern damselfly). *Dolomedes plantarius* (fen raft spider) is a characteristic spider of fen habitats.

Other typical fauna are molluscs, including whorl snails. *Vertigo geyeri* (geyer's whorl snail) can be found in the moist base of small sedges (e.g. *Carex viridula*) or bog-rush, while *Vertigo angustior* (narrow-mouthed whorl snail) occurs mainly in plant litter, and *Vertigo moulinsiana* (desmoulin's whorl snail) on stalks, even 1.5m above the ground.

Fens also host a number of threatened bird species. The most important is *Acrocephalus paludicola* (aquatic warbler), Europe's rarest songbird. Its population has declined significantly in Europe as a result of the loss of suitable fen mire habitats – an estimated 95% were lost during the last century. It breeds across a highly fragmented range in Hungary, Poland, Belarus, Ukraine, Russia, Germany and Lithuania, in lowland sedge fen mires with water less than 10 cm deep (BirdLife 2007). Poland is its most important stronghold within the European Union, supporting 85% of the EU population (MoARD 2007).

Liparis loeselii (fen orchid) is a small-sized orchid, which requires low-growing vegetation; a high content of lime in the soil (pH >6) and easy access to mobile ground water (e.g. Cederberg & Löfroth 2000). The existence of early habitat succession stages seems to be a key factor in its survival. On many sites, this demand is met through mowing or grazing (but not over-grazing), while along the coast of the Baltic Sea the species can also be found on fens in early succession stages on land undergoing post-glacial isostatic uplift (Sundberg 2006). The species is dependent upon a constant hydrological regime; when temporary changes in the water regime, such as flooding or a drop in the water level, occur, the species does not flower and can survive in a vegetative stage. When the changes are permanent, the species disappears after 3 or 4 years. The number of individuals decreases after even short-term flooding (Jersáková & Kindlman 2004).

Related habitats

A fen is often a mosaic of different habitats ranging from open-water, through small sedge vegetation, wet and mesotrophic grasslands, reed-beds and tall sedges, to semi-terrestrial birch and alder woodland. The complex of habitats that can occur within a fen contributes to the rich diversity of plants and animals. The following communities may form part of the fen system:

*Calcareous fens with *Cladium mariscus* and *Caricion davallianae* (7210)**.** This type comprises the more species-rich examples of great fen-sedge *Cladium mariscus* communities, particularly habitats enriched with *Caricion davallianae,* along with sites which have a mixture of closed, species-poor *Cladium* beds, which at their margins transform into species-rich small-sedge mire vegetation.

Molinia meadows on calcareous, peaty or clayey silt-laden soils (*Molinion caeruleae*) (6410). Its subtypes on neutro-alkali to calcareous soils with a fluctuating water table are relatively species-rich, and are characterised by the presence of *Caricion davallianae*. An increase of *Molinia caerulea* can be observed in calcareous fens following drainage.

Large herbs dominate *Calthion* meadows, while grasses and sedges are of secondary importance in many of its communities. These habitats are found on the alluvia of small streams, near springs and in seepage areas, where soil is moist throughout the year, and usually well supplied with nutrients, and may occur on the edges of, or in mosaic with, fens.

Fennoscandian mineral-rich springs and spring fens (7160). Borderline cases in terms of identification, which may occur in northern Europe: a different vegetation composition (EC 2007) and a lower content of base cations in the groundwater, the springs, and the spring fens, are conclusive.

In the extreme north of Europe, smaller areas of alkaline fen may be embedded in larger areas of aapa mire (*7310), or in blanket bogs (*7130) in the British Isles.

Tall sedges (*Magnocaricion*) and reed beds (*Phragmition*) may form a part of the fen system.

*Alpine pioneer formations of *Caricion bicoloris-atrofuscae* (7240) is a type of flush mire, constantly flushed by cold, base-rich surface seepage, that only occurs at high altitude, and which is associated with alkaline fens in Europe's high mountains.

Ecological services and benefits of the habitat

Fens act in a number of different ways to regulate the environment. These functions include water purification, flood prevention, and carbon storage, which have become increasingly important since the recognition of global warming. Peatlands are one of the major global carbon stores and play a key role in controlling the levels of carbon dioxide in the atmosphere and thereby mitigating climate change.

Like bogs, the peat in fens contains a very informative record of the past. Much of this is organic material that has not been preserved elsewhere. This information can be used as a reliable record of past environmental conditions, and may also contain valuable information about our ancestors' way of life.

Trends

The plant communities characteristic of the habitat can be either undisturbed or influenced by human activities. These ecosystems are very sensitive to changes in hydrology and hydrochemistry in the wider area. For example, in Estonia the main trends in the distribution of communities of *Caricetum davallianae* over the last 35-40 years were evaluated and they were found to have decreased by more than 50 % (Paal 2005). In the United Kingdom, it is estimated that 95-98 % of species-rich fens existing in 1940 have been lost. Similar losses have been reported in France and the Netherlands (Middleton *et al.* 2006).

The following root causes of biodiversity loss were identified.

Drainage for intensive agriculture and forestry. Peatlands have been subject to artificial drainage for centuries. This drainage has been in response to demands for agricultural land, forestry, peat for horticulture and energy, and flood prevention (Holdena *et al*. 2004). Past drainage of surrounding areas has lowered water tables and led to the drying out of even the remaining fen habitats. Large-scale or local drainage schemes were particularly successful in the lowlands, where the majority of fens have been drained and transformed into arable land with limited potential for restoration. Due to the fact that the drainage infrastructure is in some cases relatively recent, the majority of drainage schemes are still in operation. Afforestation has also contributed to the drying out of fens.

In southern Sweden, the remaining alkaline fens are mere fragments of their former selves. Substantial areas have been affected by drainage. During the 19th century this was mainly to create more agricultural land, while during the 20th century it was primarily to increase the productivity of commercial forests. In northern Sweden (e.g. the counties of Jämtland and Norrbotten), larger areas of intact alkaline fens can still be found (Naturvårdsverket 2003, Sundberg 2006). In a recent nation-wide inventory in Sweden, disturbed hydrology was reported on two thirds of the almost 1600 alkaline fen sites with high nature conservation values identified, although for some of the sites the disturbance was marginal (Sundberg 2006).

Human induced change in hydrological conditions in the recharge area (water level drop, change in the direction and volume of groundwater flow). Drainage activities change the routes water takes within the hydrological system and result in the mixing of different water sources. This usually means that the influence of groundwater decreases while that of rainwater increases. This in turn affects the fen's vegetation composition. Another problem is the knock-on effect on protected sites of damage to hydrological systems in neighbouring areas, caused by a lack of hydrological understanding in land use planning. The effects on the vegetation of soligenous mires can be severe: the encroachment of woody species; reduction in the rate of peat formation, and, in extreme cases, peat mineralisation and the invasion of nitrophilous species (Wolejko *et al.* 2005).

Abandonment of traditional management practices. Traditional fen management practices consisted, in most countries, of mowing and light grazing. In Poland (MoARD 2007), small sedge-moss communities were mown in a traditional manner, every 1 or 2 years, depending on the area's accessibility and wetness. In Germany, such areas were subject to traditional, moderate, land use, such as late autumn mowing without fertilization (Stammel *et al.* 2003). The cut vegetation was usually used as livestock bedding (litter). Hand mowing was used successfully to manage fens for generations. From the 1950s onwards, machines replaced hand mowing and habitats which are of marginal importance for agriculture were abandoned. For example, in the famous Biebrza National park in Poland, authorities are facing a huge and difficult task to stop and reverse succession on 20,000 ha of abandoned fens (Bokdam *et al.* 2002).

Similar trends have been observed in other parts of Europe. For example in northern Sweden, mowing and the use of fens for the production of winter feed for livestock ceased during the first half of the 20th century, resulting in overgrowth and the formation of tussocks (Elveland 1978, Sundberg 2006).

In some Central European countries, the lack of management was caused by nature conservation policy, which was influenced by a paradigm that promoted the exclusion of human activities from strictly protected areas. This happened from the 1960's to the 1990's. This policy ignored the importance of farmers and their traditional low-intensity practices in maintaining habitats. The subsequent lack of management caused a rapid succession of grass or tussock-forming sedge communities, followed by scrub and tree encroachment, resulting in the loss of biodiversity.

Nutrient enrichment. The main source of pollution tends to be fertilisers and herbicides applied by farmers, leading to the eutrophication of fen waters and changes in plant communities. Fens are very sensitive to eutrophication and many sites are affected by it.

Water abstraction. Excessive water abstraction from aquifers dries up or reduces spring flows, lowers water tables and affects water quality. Abstraction also affects the natural balance between ground water and surface water, with their different hydrochemistries.

Threats

Alkaline fens have been selectively drained in the past and have become very rare. The abundance of species occurring in these mire types implies that these mires have a high conservation priority (Raeymaekers 2000).

Drying out

Mires that suffer from hydrological dysfunction following drainage are quite common. The lowering of the water table leads to the ground drying out slowly, and to drastic changes in its physical and chemical properties (Dupieux 1998). In general, mires can react to a lowering of the water table in three ways (Van Diggelen *et al.* 1998):

1. The system can adjust to a minor lowering through a reduction in the peat volume.
2. If the fall in the water level is more significant, and it is not possible to compensate with a reduction in peat volume, there may be a net inflow from alternative water resources (precipitation or surface water), at least in times of water shortage, and this may cause acidification or eutrophication and is likely to increase the degree of fluctuation in the water table.
3. If the lowering of the water level is even more significant, the process of refilling from other water sources cannot compensate for the reduction in groundwater, leading to the desiccation and mineralisation of the peat.

Draining the fen's surroundings increases the loss of groundwater; this may lead to both a reduction and compression of the existing peat. In these conditions, mire species, which form the basis of the peat forming process, will not find favourable conditions and will slowly disappear, to be replaced by other species more adapted to these drier conditions. These are mostly common species with a low biological value. Finland's remaining rich fens are in danger of being destroyed in the near future due to drying up because of ditching in the surrounding areas (Lindholm & Heikkilä 2005).

Chemical processes

Eutrophication of surface-water and/or groundwater is one reason for the endangering of fens. Nutrients filtering in from agricultural soils and waste water lead to an increase in the availability of phosphates and nitrates. Strongly competitive species such as *Phragmites australis* (reed) and *Glyceria maxima* (reed sweet-grass) progressively take over in these locations. This type of eutrophication, by importing nutrients, is labelled as 'external' in order to distinguish between it from the 'internal' mobilisation of nutrients (Lamers *et al*. 2001) caused by changes in the composition of the water. In Dutch fens this latter phenomenon – a result of the influx of alkali surface water into fens during the summer months – has been recorded. Alkalinisation increases the decomposition of organic material (mineralisation), which leads to an increase in the available nutrients.

Desiccation can also stimulate decomposition and mineralisation. Grootjans *et al*. (1986) demonstrated that nitrogen increases as a result of long-term desiccation. The availability of phosphorous decreases, however, because the capacity of the soil to bind phosphorous grows during the dehydration process as a result of the oxidation of iron compounds. These opposing effects on the availability of the two nutrients, together with the lack of water, cause a shift in the composition of the vegetation. Grasses replace characteristic sedge species.

Vegetation changes

The vegetation composition of mires influenced by man is, in general, deemed to be an excellent indicator of the intensity and duration of disturbance (Dierssen 1992). Changes are characterised by:

- decrease or disappearance of species with weak competitive capability and low ecological amplitude
- invasion by, or increase of, ubiquitous and nitrophilous species with strong competitive capability and, often, with broad ecological amplitude.
- in drained fens there is a conspicuous reduction in fen plants, which obtain moisture from groundwater, while meadow species (which are not dependent on this resource) appear in greater numbers and, after a certain amount of time, increase the overall species diversity of the habitat (Dierssen 1992).

In the absence of mowing, litter accumulates and negatively influences the species richness of a fen. High quantities of litter cause a decrease in the number of vascular plant species and a decrease in bryophyte biomass. In the long-term, the accumulation of litter or the biomass of vascular plants causes a decline in the richness of bryophyte species (Bergamini *et al.* 2001).

Deterioration of sites

Even today, when the importance of calcareous fens has been recognized across Europe, many important sites continue to be damaged by development, mainly, but not exclusively, in the new Member States.

One of the most important Balkan wetland complexes lies below the Pirin Mountains near the towns of Razlog and Bansko in Bulgaria. The area covers a territory of ca 5 square kilometres, and the part with the most valuable spring fens covers ca 1.5 square kilometres. It has been designated as a Natura 2000 site. Over the last several years, extraordinarily high levels of investment from all of Europe came to the region for the development of a tourist centre. So far, the complex has only destroyed some smaller springs, but right now a new hotel is being constructed at the very border of the most important part of the Krusheto locality, where the largest and best-preserved fen sites occur (Hájek 2007).

One of the most unique travertine spring fens in Europe, the *Močiar* Nature Reserve in Slovakia, was heavily damaged in 2005. The mayor of a nearby village decided to excavate a bathing pool, impounding the spring water supplying the fen. This pond drains the water away from the fen, so that half of the site has no water supply. Appropriate restoration measures have not yet been implemented, even though the site is legally protected.

Climate change effects

Peatlands contribute to the fight against climate change by storing large amounts of carbon. Global warming affects peatlands mainly through spatial and temporal changes in the water balance. Increased evapotranspiration, altered precipitation and increased frequency of extreme events (droughts) result in deeper water table levels during the growing season. The impacts of hydrological changes on the ecosystem are mediated through autotrophic (vegetation) and heterotrophic (microbe) communities (http://www.peatsociety.org/user_files/files/laine.doc).

Van Dam and Beltman (1992) believe that negative changes in fenlands will be caused by eutrophication due to an increased supply of allochthonous water.

2. Conservation management

General recommendations

Hydrological systems that provided natural fens with a large supply of base-rich groundwater were able to stabilize nutrient poor fen vegetation for many centuries, without any management by man. However, over the past few centuries, almost all fens have been slightly drained and changed into low-productivity meadows and pastures that cannot be maintained without management (Kotowski 2002 in Middleton *et al.* 2006).

Management is needed to maintain open-fen communities and their associated species richness. Without appropriate management, natural succession will lead to the formation of scrub and woodland. A significant proportion of fens are managed by conservation mowing - mowing purely for habitat management.

However, the conservation status of fens is also highly dependent on the impact of external factors, such as land-use on surrounding land and the deposition of airborne pollutants. To some extent, the negative effects of these kinds of impacts can be tackled by measures carried out on the site, such as by intensified mowing or grazing, or the clearing of overgrowth related to the fertilising effects of air-borne nitrogen compounds, but restrictions on land use on surrounding areas must also be considered. This may include control of ditching activities on agricultural land and in commercial forests and restrictions on the use of fertilisers and so on.

In northern Sweden, fen sites that have not suffered any negative impacts from drainage activities are left for so-called "free development", with reference to historical land-use. However, the need for management has to be decided on a "site-by-site" basis. For alkaline fens in the isostatic uplift zone along the Baltic coast, a favourable conservation status can be maintained for long periods of time without any intervention (Sundberg 2006).

Active management

Mowing

Mowing is an important management tool, and it has proven successful in maintaining species richness, particularly in fens that have been mowed annually for centuries. At present, mowing is carried out with light, usually small, machinery adapted to the sensitive fen environment, such as pedestrian-driven mowers. Tyres are frequently specifically adapted (low pressure, twinned wheels). Cut biomass is then gathered and removed from the site. This method, particularly the collecting and disposing of material, is very labour intensive. Management recommendations for this habitat type (Háková 2003) in the Czech Republic are:

Table 1. Management recommendations for alkaline fens in the Czech Republic by Háková 2003.

Optimal Management		**Alternative Management**
TYPE OF MANAGEMENT	Mowing with removal of fresh or dry biomass.	Mowing with removal of fresh or dry biomass.
SUITABLE INTERVAL	Once every 1-2 years, or twice a year, or without mowing.	Once every 1-2 years, or twice a year.
MIN. INTERVAL	Once every 3-5 years, or without mowing.	Once every 3 years.
EQUIPMENT		
1. SUITABLE	Hand mowing by scythe or brush cutter.	
2. POSSIBLE		Pedestrian-driven mowing machines.
3. UNSUITABLE	Livestock, heavy mowing equipment, fertilization, use of lime.	Livestock, heavy mowing equipment, fertilization, use of lime.

The use of fertilizers and grazing is not recommended for calcareous fens. If the site is located within a grazed area, the fen should be fenced off. Habitats usually adapt to management. Only extremely wet sites with a dominance of moss communities can cope with lack of management or could be managed infrequently – at intervals of 3 to 5 years, for example. The optimal time for mowing is late summer, when the sites are not as wet as in spring or early summer.

The use of pedestrian-driven mowers is only possible during drier periods in drier grassland areas. In very wet and tussock forming communities, eg. *Sphagno warnstorfiani-Tomenthypnion,* the use of pedestrian-driven mowers is not recommended (Háková 2003). Hand mowing is often a preferred form of management on very small reserves. This is not possible on larger areas. Specially-adapted mowing machines that do not damage the soil are needed.

In Sweden, mowing is the primary recommendation for the management of alkaline fens. Mowing every second year is usually judged to be sufficient and even recommended on sites with orchids and other vascular plants with biennial life cycles, rare molluscs, and ground-nesting birds. For low-productivity fens, mowing on a longer cycle of 3-5 years is acceptable. The recommended equipment includes scythes and brush cutters. Cut plant material must be removed from the managed area (Sundberg 2006).

Within agri-environmental packages in Poland (MoARD 2007), management recommendations for mowing in small sedge moss communities include:

- mowing every year between 15th July and 30th September;
- an obligation not to mow more than 50% of the area in any year, and alternating the areas mown; mowing of the whole area is allowed only once every 2 year;
- mowing height 5-15 cm;
- mowing technique: in a manner which prevents the destruction of the plant and soil structure, and a ban on circular mowing from the outside towards the inside of an agricultural plot;
- the obligation to remove or stack the cut biomass within no more than 2 weeks after mowing (except in justified cases);
- prohibition on fertilising and grazing

The use of heavy equipment destroys the plant and soil structure of fens. A prototype harvester, specially designed for wetland conditions was developed in the United Kingdom as part of the LIFE-funded New Wetland Harvest project (LIFE97ENV/UK/000511). This project, which started in 1997, involved the development of a low ground pressure machine that was able to cut, collect and remove material from the fens. Unlike conventional harvesting machinery, the fen harvester can negotiate marshy terrain without sinking into the soft surface, and can cut large areas of fen, including small areas of scrub. The harvested material is chopped into tiny pieces and blown down a high-pressure air-filled pipeline. This means that the material can be removed from the fen to a lorry without making repeated journeys over fragile habitat (http://www.broads-authority.gov.uk/managing/land/fen/management/fen-harvester.html).

Grazing

Moderate grazing on fens can be recommended as an alternative conservation strategy to mowing. But optimal grazing conditions have to be developed to minimize the unwanted effects of foraging and trampling. When endangered species are involved, the response of these species to grazing has to be investigated prior to making a decision whether or not to introduce it. Grazing can be recommended as an alternative form of land use to mowing or abandonment, but a reduction in species variety and changes in species composition and species traits may occur (Stammel *et al.* 2003).

In France, extensive grazing is often considered to be the most natural management method, which permits the softest and the most beneficial ecological impact, since herbivores are a part of the managed ecosystem, in some respects re-creating past conditions, when these ecosystems were managed by large wild herbivores. Since the conditions in peatlands can be quite difficult (low temperatures, waterlogged soil, acidity, low nutritive value of vegetation…), the animals used often belong to traditional hardy breeds, which are well adapted to these conditions, for example, Highland cattle from Scotland; the ' Bretonne pie noire', a small breed of cattle from Brittany; Highland or the Konik Polski ponies; Camargue horses or Solognot and Shetland sheep. These animals prevent litter from accumulating by grazing, and then trampling vegetation and litter. The grazing intensity has to be determined carefully; a good balance has to be found between under- and overgrazing. Usually, an average pressure of between 0.2 and 0.8 LU/ha is recommended in the literature. Starting with a lower pressure and increasing it if it turns out to be insufficient, is recommended (Dupieux 1998).

In Scotland, fens should be accessible to stock during the driest months of the summer. They should be grazed for at least two weeks each year. Poaching should be controlled. Light poaching helps to maintain species diversity but heavy poaching can encourage the establishment of agricultural weeds such as *Cirsium arvense* (creeping thistle) and should be avoided. As a guide, the frequency of hoof prints should be no more than would occur through the occasional crossing of the grass or fen area by livestock (Scottish Natural Heritage 2005).

In Sweden, grazing is mostly regarded as a "second-best choice" for the management of alkaline fens. There are reports that high grazing pressure may have a negative impact on rare species, including *Vertigo geyeri*, although other species (e.g. ground beetles) may benefit. This means that grazing has to be carefully adjusted to the specific conditions and species composition at each site, but in general an extensive level of grazing is recommended. On smaller sites, grazing every second year, or over a very short period during the season, is recommended (Sundberg 2006).

If grazing is used as a management technique, it should aim to create a diverse structure of short vegetation and taller tussock areas where grasses and herbs can flower and set seed - the flowers will provide nectar and pollen for insects. In this respect, cattle are preferable to sheep. It is very important not to overgraze sites, and rotational grazing should be considered where possible, as livestock trampling and dung inputs, while beneficial for some invertebrates on a small scale, can be damaging in excess.

Cattle trampling creates open conditions and small patches of bare peat required by many species and maintaining a trampled berm along the margins of ditches can be useful, but if excessive, it is likely to be detrimental to the plant sources of food of insects such as leaf beetles.

In Europe, cattle do not generally graze in natural fens, but they do use slightly drained fen meadows http://www.buglife.org.uk/conservation/adviceonmanagingbaphabitats/fens.htm

Restoring of qualitative and quantitative hydrological conditions

Knowledge of the hydrological conditions is necessary for the preservation of the structure and function of wetlands. In north-west Europe there has been increasing public pressure for the restoration of fens, which were heavily damaged by drainage and agricultural pollution. Large projects for the restoration of fens have appeared mainly in northern Germany, the Netherlands and Switzerland (Brülisauer & Klötzli 1998; Grootjans *et al*. 2002; Klimkowska *et al*. 2007).

When evaluating the potential for the ecological restoration of small and fragmented sites, the whole hydrological system must be taken into consideration. The main reasons for degradation can usually be found outside protected areas. Groundwater flux is a major factor in the formation of fens, and vegetation changes inside reserves are interconnected with hydrological factors outside (Diggelen *et al*. 1995). In order to stimulate the formation of peat, groundwater levels should be increased to soil surface level and fluctuations of the water column should be minimised (Pfadenhauer 1991).

Restoration of these drained sites consists of blocking or filling in the ditches responsible for the draining of the site. These ditches are first described (slope, width, depth) and mapped, and the groundwater should also be studied (monitoring of its level and fluctuations). The method usually implemented consists of inserting a series of regularly spaced dams in the ditches. These dams act as impermeable barriers that retain the water upstream: the flow is slowed down, and the water level increase in the ditch enables an increase in the water table. These interventions are very often labour intensive: the number of dams which need to be constructed can be important on sites with a dense ditch network. These dams can be difficult to construct and need a careful survey to ensure their effectiveness (Dupieux 1998). Some details on the construction of blocks, in order to ensure a long-term function with a minimum of maintenance, are summarised by Sundberg, based on experience in Sweden (2006).

If surface water is used to compensate for a deficit in groundwater, problems can occur due to a lowering in the concentration of iron compounds (Lamers *et al.* 2001). In general, oxygenated surface water contains low concentrations of iron. High concentrations of iron are however found in anoxic groundwater. This has a great significance for fens because iron binds to phosphates, which are then not available to plants. Infiltration of surface water into the fen can thus cause internal eutrophication.

Flooding with surface water during the summer can be particularly harmful for species-rich fens and may result in the rapid growth of tall grasses (Middleton *et al*. 2006).

Removal of the top soil layer

An alternative to raising the water table is the removal of the top layer of soil. This technique is appropriate in small, isolated areas that have been influenced by excess transport of nutrients and changes in the water regime (Brülisauer & Klötzli 1998). The depth to which the top layer of soil should be removed depends on the concentrations of nutrients in the different soil horizons. Removal of the soil to a depth of approximately 30 cm should - in the majority of cases - be sufficient (Pfadenhauer 1991). Diggelen *et al.* (1998), working in the Netherlands, removed the top layer of the soil down to a depth of 50 cm in nine locations with different hydrological regimes, soil-nutrient contents and with different degrees of species isolation. By stripping off the topsoil they lowered the nutrient content of these soils, which had until then been used for intensive agriculture. The results showed an increase in biodiversity in all the locations.

Scrub and woodland removal

Restoring fens that have been invaded by scrub and woodland is something of a technical challenge. Fens are wet and often treacherous places where large machinery can quickly become stuck and cause significant damage to this fragile environment.

Cutting scrub by hand is one solution, and this practice is still employed. For some sites, this is the only viable option, but it is extremely labour intensive and hence it is only suitable for small areas. As the scale of fen restoration has increased, new machines have been developed to tackle larger scrub removal operations. Low ground pressure excavators, cutting machines and portable incinerators have all been developed and are already enabling the restoration of large scrubland areas into fens.

However, even large-scale scrub clearance, should not result in a complete absence of woody species from the fen. All fen restoration projects leave a proportion of scrub within the fen to provide singing, roosting and nesting areas for birds, and an important habitat for invertebrates (http://www.broads-authority.gov.uk/managing/land/fen/management.html).

Willow will be particularly beneficial, but also elm, ash, lime and maple. The litter produced contains calcium citrate, a form of calcium easily available to molluscs, which also helps to maintain a high pH. Coniferous trees, especially spruce, might, on the other hand, have an acidifying effect (Sundberg 2006).
The initial clearing of a heavily overgrown fen usually has to be followed by repeated removal of basal regrowth of various species of deciduous trees.

Restoration management

Mowing in late season is the primary technique for preserving species diversity and species composition. However, this is not necessarily the most effective means of restoration management on abandoned meadows currently dominated by grass. Management at the start of the season is, in this case, highly effective (Huhta *et al.* 2001). It should reduce the grasses' ability to compete.

Mowing of *Phragmites communis* (common reed) or *Molinia* spp. is most effective at the start of flowering. Most of the food reserves produced during that season are removed in the aerial portion of the plant, reducing the plant's vigour. This approach may eliminate an entire colony if carried out annually over several years.

The abandonment of management of Swiss fen meadows has reduced their plant species diversity and the health of some typical fen species. Results from mowing experiments have demonstrated a rapid recovery of fen plant communities irrespective of the length of time since abandonment (up to 35 years). Restoration of the pre-abandonment plant community is likely to be successful if the site (in terms of its hydrology, nutrient status) remains intact and if common habitat specialists are still present in the vegetation and/or seed bank (Billeter *et al.* 2007).

Other relevant measures

Turf pond creation

Other techniques, such as turf pond creation, have also been used to restore fen habitats. Shallow peat diggings, or turf ponds, were dug in the Broads during Victorian times. Some were dug to provide fuel, while others may have been cut as a way of clearing the fen to improve the quality of the reed and sedge harvest. When these turf ponds were allowed to be re-colonised, they proved a rich source of diverse vegetation, and today the most species-rich areas tend to be found where turf ponds were once dug http://www.broads-authority.gov.uk/managing/land/fen/restoration.html.

Reducing the impact of external land use

In Sweden a series of recommendations have been proposed to reduce the negative impact from surrounding land on alkaline fens (Sundberg 2006). For example, any kind of drainage activities, including the maintenance of existing ditches, should be avoided within 200 meters of the fen. In the case of clear-cutting in surrounding forests, a zone of 20 meters should be left unfelled around the fen. The construction of roads should be avoided in the catchment area upstream of a fen.

Special requirements driven by relevant species

The butterfly *Coenonympha oedippus* (false ringlet) is threatened mainly by habitat destruction, the invasion of fens by willow and birch, drainage, grass burning in spring and illegal collecting. Conservation measures should focus on suppressing the succession of trees and shrubs, and on protecting, and where necessary restoring, the fen's water regime to prevent it drying out. Combating illegal collecting of false ringlet specimens is necessary (Buszko 2007). Extensively mown meadows are suitable for rare butterflies. Invasion of reeds and other competitive plants should be prevented.

Populations of rare dragonflies such as the *Leucorrhinia pectoralis* (large white-faced darter dragonfly) are usually threatened by habitat destruction, eutrophication of water bodies, and unsuitable habitat management. These adverse activities especially include peat extraction, draining, changes to the water regime, excessive nutrient enrichment from agricultural runoff, and overgrowing by shrubs and trees. Conservation measures include the preservation of the fen's natural water regime, and, where necessary, its restoration with the aim of stabilising the water level. Any active management, such as mowing, reed cutting or shrub removal, should be done regularly but spread over several years. Overgrown water pools, where the species used to be found, should be deepened, creating at least 5-10 m^2 of open water, which should also be exposed to the sun. The removal of adjacent scrubs should also be considered (http://www.nature.cz/natura2000-design3/web_druhy.php?cast=1805&akce=karta&id=6).

Whorl snails require an undisturbed water regime, with the groundwater table located near the surface, and short vegetation with non-intensive grazing or mowing (Šteffek & Vavrová 2005). High grazing pressure and lack of species-specific adjustments have been reported to have a negative impact of local populations of *Vertigo geyeri* (Sundberg 2006). Grazing decreases the total densities of molluscs and substantially reduces the densities of the rare *Vertigo moulinsiana* snail. However; due to the patchy nature of grazing *V. moulinsiana* can survive at reasonably high densities in patches of ungrazed vegetation within the grazing area (Ausdena *et al.* 2005).

Water extraction, including from underground aquifers, is a major problem at many fen sites and can result in the drying out of fens and the loss of emergent marginal vegetation. Preventing the fen surface from drying out ensures a continuity of the habitat for *Dolomedes plantarius* (fen raft spider). However, if this is to be considered, the source and the quality of water would need to be monitored (http://www.buglife.org.uk/conservation/adviceonmanagingbaphabitats/fens).

The most important threats to *Acrocephalus paludicola* (aquatic warbler) are the loss of breeding habitat owing to drainage for agriculture and peat extraction, as well as the damming of floodplains, unfavourable water management and the canalisation of rivers. Habitat degradation is widespread wherever traditional fen management has ceased, enabling the development of unsuitable overgrown reed beds, scrub or woodland. Uncontrolled fires in spring and summer pose a direct threat to birds and nests, and can destroy the fen's upper peat layer (BirdLife 2007). Favourable management techniques therefore include non-intensive grazing (less than 1 fully grown cattle/ha), combined with mowing, which also helps to suppress reed and shrub growth. Grazing by horses, goats or sheep is also employed for example in the Woliń National Park in Poland (Dylawerski 2004).

For *Liparis loeslii* (fen orchid), management involves a balance between the definite need for mowing or grazing, and the fact that the species might also suffer from too intensive management or trampling by cattle (Sundberg 2006). Specific measures can be applied on sites which are being overgrown by competitive grasses, e.g., *Molinia* spp. Tussocks of grasses can be removed selectively, which allows the creation of small depressions with a higher level of underground water.

Cost estimates and potential sources of EU financing

Hay production in the peat zone is not economically competitive with other sources of winter forage. This means that nature conservation has to pay for the mowing, both on private and public land. Traditional haymaking with mowing machines (mowing, reaping and sometimes dumping of unmarketable hay) costs roughly €300-500/ha per year in the Netherlands. Revenues from marketed hay may reduce these costs (Bokdam *et al.* 2002), but there is not much of a market for material harvested from fens. The main limiting factors are therefore high costs and a lack of funding to compensate for market failure. A secondary factor is the lack of adequate machinery.

Traditional hand mowing by volunteers or employees using scythes may offer a solution for small areas. Hand mowing by local farmers sponsored by the WWF/Biebrza National Park coalition cost €315/ha. These public projects are of high importance in maintaining a good relationship with the local populations (Bokdam *et al.* 2002).

For the management and restoration of alkaline fen sites in Sweden, some indicative costs are (Sundberg 2006):

- Recurring management qualifies for subsidies from the European Fund for Rural Development (EARDF) agri-environmental scheme. Machine mowing, including the obligatory removal of the mown material, is compensated at a rate of around €450/ha. Scythe mowing attracts approximately €700/ha, if done on an annual basis. These amounts do not cover the full labour costs, which can be as high as €2700/ha.
- For blocking ditches, the total cost of the construction of one dam is roughly €1600 including planning, material and labour (including time for the transportation of material and equipment to the location).
- The cost of clearing overgrown land is assessed to be roughly €1000-1100/ha, with substantial variation either side of this estimate depending on the volume of the cleared scrub, ground conditions, etc.

The prospects of financial support or subsidies in the future are promising in Poland. The mosaic of private and state owned land can be an advantage in obtaining funding from Agri-environmental schemes. The amount of agri-environmental payment for small/sedge communities (MoARD 2007) is €307.4/ha. Payments were determined according to the following criteria:

Income foregone
1. income lost due to the extension of production
2. income lost on fattened animals

Additional costs
3. appropriate mowing techniques
4. removal or storage of cut biomass

Among the diversity of sources for EU funding, the following funds might primarily be of interest for the management of alkaline fens habitats:

- The European Agricultural Fund for Rural Development (EARDF): This fund has the potential to cover several management activities that might be relevant for alkaline fens 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 alkaline fens 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 needs 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 focus 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+.

Concerning potential sources of EU financing, a Guidance Handbook (Torkler 2007) presents the EU funding options for Natura 2000 sites in the period 2007-2013 that might be available at the national and regional level. Furthermore an IT-tool is available on the EC web site:
(http://ec.europa.eu/environment/nature/natura2000/financing/index_en.htm).

Acknowledgements

This management model has been elaborated by Viera Šefferová Stanová, Ján Šeffer and Milan Janák (DAPHNE Institute of Applied Ecology, Slovakia), with contribution from Mats Eriksson (MK Natur Och-MiljöKonsult, Sweden), covering experiences from Scandinavia.

We are particularly grateful to Michal Hájek (Masaryk University Brno, Czech Republic), Ab Grootjans (University of Groeningen, Netherlands), Lesław Wołejko (University of Agriculture, Szczecin, Poland), Francis Muller (Fédération des conservatoires d'espaces naturels, France) and Mara Pakalne (Latvian Fund for Nature, Latvia) for their useful inputs and suggestions in the elaboration of this document.

Gwyn Jones (European Forum for Nature Conservation and Pastoralism) revised the final draft.

3. References

Case studies and practical examples

Broads Authority, Wetland Harvest Project. http://www.broadsauthority.gov.uk/managing/land/fen/management/fen-harvester.html (15 September 2007).

European and national guidelines

Airaksinen O. & Karttunen K. (eds.) 1999. Natura 2000 handbok över de finska naturtyperna. Finnish Ministry of Environment, Helsinki.

Cederberg B. & Löfroth M. (eds.) 2000. Swedish animals and plants in the European network Natura 2000. ArtDatabanken, SLU, Uppsala (in Swedish, summary in English).

European Commission, 2007. Interpretation Manual of European Union Habitats - EUR27. DG Environment. July 2007.

Gaudillat V. & Haury J. (coord.) 2002. « Cahiers d'habitats » Natura 2000. Connaissance et gestion des habitats et des espèces d'intérêt communautaire. Tome 3 - Habitats humides. MATE/MAP/MNHN. Éd. La Documentation française, Paris, 457 p. + cédérom.
http://natura2000.environnement.gouv.fr/habitats/cahiers.html

Háková, A. (eds.) 2003. Zásady péče o nelesní biotopy v rámci soustavy NATURA 2000. Ms. Agentura ochrany přírody a krajiny ČR.

MoARD - Ministry of Agriculture and Rural Development of Poland. 2007. Rural Development Programme for 2007-2013. Annex 10. Detailed description of agri-environmental packages and the calculation of the amount of agri-environmental payment.

Mitsch W. J. & Gosselink J.G. 2000. Wetlands, 3rd edition, John Wiley and Sons, New York.

Naturvårdsverket 2003. Natura 2000, art- och naturtypsvisa vägledningar: 7230 Rikkärr. Naturvårdsverket, Stockholm (available via www.naturvardsverket.se).

Påhlsson L. (eds.) 1998. Vegetationstyper i Norden, 3rd ed. TemaNord 1998:510. Nordic Council of Ministers, Copenhagen.

Scottish Natural Heritage 2005. East Scotland Grassland Management Scheme. Fens and fen meadows. http://213.121.208.4/about/ab-pa09h4.asp (19 September 2007).

Shirt D.B. 1987. British Red Data Book: 2 Insects. Nature Conservancy Council, Peterborough, 402 pp.

Stanová V. & Valachovič M. (eds.) 2002. Katalóg biotopov Slovenska. DAPHNE – Inštitút aplikovanej ekológie, Bratislava, 225 p.

Torkler P. (ed.) 2007. Financing Natura 2000 - Guidance Handbook. European Commission. Available at: http://ec.europa.eu/environment/nature/natura2000/financing/index_en.htm.

Articles and other documents

Aldous A. 2001. Integrity Assessment for Wetland Ecosystem Targets. http://conserveonline.org/docs/2002/01/integrity_example2.pdf

Ausdena M., Halla M., Pearsonb P. & Strudwick T. 2005. The effects of cattle graying on tall/herb fen vegetation and molluscs. Biological conservation, Vol. 122/2: 317-326.

Bergamini A., Pauli D., Peintinger M. & Schmid B. 2001. Relationships between productivity, number of shoot and number of species in bryophytes and vascular plants. – J. Ecol. 89: 920–929.

Billeter R., Peintinger M. & Diemer M. 2007. Restoration of montane fen meadows by mowing remains possible after 4–35 years of abandonment. Bot. Helv. 117: 1 – 13.

BirdLife International 2007. Species factsheet: *Acrocephalus paludicola*. Available at: http://www.birdlife.org

Bokdam J., Braeckel A. van, Werpachowski C. & Znaniecka M. 2002. Grazing as a conservation management tool in peatland. Report of a Workshop held 22-26 April 2002 in Goniadz (PL). http://inbo.be/docupload/2134.pdf (18/09/2007.

Brülisauer A. & Klötzli F. 1998. Notes on the ecological restoration of fen meadows, ombrogenous bogs and rivers: definitions, techniques, problems. Bulletin of the Geobotanical Institute ETH, 64: 47-61.

Buglife – the Invertebrate Conservation Trust. 2007. Managing Priority Habitats for Invertebrates. Fens. ' series has been funded by the Department for Environment, Food and Rural Affairs as a resource for land managers and advisors.
http://www.buglife.org.uk/conservation/adviceonmanagingbaphabitats/fens.htm (15 September 2007).

Buszko J. 1993. Atlas motyli Polski. I. Motyle dzienne (Rhopalocera). Grupa IMAGE, Warszawa, 269 pp.

Buszko J. 2007. *Coenonympha oedippus* (Fabricius, 1787). Polska czerwona ksiega zwierat – Bezkregowce. Available at: http://www.iop.krakow.pl/pckz/opis.asp?id=99&je=pl

Conservation status assessment for the species S1013 *Vertigo geyeri* - Geyers whorl snail. In: Second report by the United Kingdom under Article 17 on the implementation of the European Community Directive on the Conservation of Natural habitats and on Wild Fauna and Flora (92/43/EEC).

Dam H. van & Beltman B. 1992. Effects of climatic change on chemistry and vegetation of. peatlands, with special reference to interaction with atmospheric to interaction with atmospheric deposition. Wetland Ecology and Management. Vol. 2: 63 – 68.

Damman A. W. H. 1995. Major mire vegetation units in relation to the concepts of ombotrophy and minerotrophy: a worldwide perspective. Gunneria 70: 23-34.

Dierssen K. 1992. Peatland vegetation and the impact of man. In: Bragg, O.,M., Hulme, P.D., Ingram, H.A.P. & Robertson, R.A. (eds.). Peatland Ecosystems and Man: an Impact Assessment. University of Dundee and International Peat Society, pp: 213-223.

Diggelen R. van., Grootjans A.P. & Wierda A.K. 1995. Hydro-ecological landscape analysis: a tool for wetland restoration. Z. f. Kultutechnik und Landentwicklung, 36: 125-131.

Diggelen R. van., Bakker J. & Klooker J. 1998. Top soil removal: new hope for threatened plant species? In: Cooper, A., & Power, J., (eds.) Species Dispersal and Land Use Processes. Proceedings 6th annual conference International Association for Landscape Ecology (IALE UK), pp. 257-263.

Dylawerski M. 2004. Wodniczka (*Acrocephalus paludicola* Vieillot,1817) w Wolińskim Parku Narodowym. Available at: http://www.aquaticwarbler.net/download/Feb_2004_Poland_Abstracts_II.pdf

Dupieux N. 1998 - La gestion conservatoire des tourbières de France : premiers elements scientifiques et techniques. Espaces Naturels de France, programme Life Tourbières de France, 244 p.

Elveland J. 1978. Skötsel av norrländska rikkärr. Studier av vegetationsförändringar vid olika skötselåtgärder och annan påverkan. Naturvårdsverket PM 1007.

Grootjans A.P., Schnipper P.C. & Van der Windt H.J. 1986. Influence of drainage on N-mineralisation and vegetation response in wet meadows II. *Cirsio-Moninietum* stands. Acta Oecologica/Oecologia Plantarum 7: 3-14.

Grootjans A.P., Bakker J.P., Jansen A.J.M. & Kemmers R.H. 2002. Restoration of brook valley meadows in the Netherlands. Hydrobiologia 478, 149-170.

Hájek M. 2007. News from Bulgaria: Most important spring fen complex under threat. *IMCG Newsletter*, no. 3, s. 34-35.

Hájek M. & Háberová I. 2001. Scheuchzerio-Caricetea fuscae. In: Valachovic M. (ed.), Rastlinné spolocenstvá Slovenska. Mokradná vegetácia. Bratislava: 185-274.

Hájek M., Horsák M., Hájková P. & Díťe D. 2006. Habitat diversity of central European fens in relation to environmental gradients and an effort to standardise fen terminology in ecological studies. Perspectives in Plant Ecology, Evolution and Systematics 8 (2006): 97–114.

Higgins L.G. & Riley N.D. 1970. A Field Guide to the Butterflies of Britain and Europe. Collins, London, 384 pp.

Holdena J., Chapmana P.J. & Labadzb J.C.2004. Artificial drainage of peatlands: hydrological and hydrochemical process and wetland restoration. Progress in Physical Geography 28,1: 95–123.

Hutha A.P., Rautio P, Tuomi J. 2001. Restorativ emowing on an abandoned semi-natural meadow: short-term and predicted long-term effects. j. Veg. Sci. 12: 677-686.

Jersáková J. & Kindlmann P. 2004. Zásady péče o orchidejová stanoviště. Kopp nakladatelství České Budějovice.

Klimkowska A., Diggelen R. van, Bakker J.P. & Grootjans A.P. 2007. Wet meadow restoration in Western Europe: A quantitative assessment of the effectiveness of several techniques. Elsevier, Biological Conservation 140, pg. 318-328.

Kudrna O. 2002. The distribution Atlas of European Butterflies. Oedippus 20, 343 pp.

Kulfan M. & Kulfan J. 2001. Red (Ecosozological) List of Butterflies (Lepidoptera) of Slovakia. In: Baláž D., Marhold K. & Urban P. (eds.), Red List of Plants and Animals of Slovakia, Nature Conservation Vol. 20 (Suppl.): 134-137.

Laine, J. Climate change affects carbon exchange processes in northern peatlands http://www.peatsociety.org/user_files/files/laine.doc (15 September 2007).

Lamers L.P.M., Smolders J.P. & Roelofs J.G.M. 2001. The restoration of fens in the Netherlands. In L.P.M. Lamers: Tackling biochemical questions in peatlands. PhD thesis, Katholieke Universiteit Nijmegen, 160 p.
Lindholm T. & Heikkilä R. 2005. Mires in Finland, their Utilization and Conservation. Stapfia 85, zugleich Kataloge der OÖ. Landesmuseen Neue Serie 35, 233-246.

Mälson K. & Rydin H. 2007. The regeneration capabilities of bryophytes for rich fen restoration. Biological Conservation 135: 435–442.

Middleton B., Grootjans A., Jensen K., Venterink H. O. & Margóczi, K. 2006. Fen Management and Research Perspectives: An Overview. In: Bobbink R., Beltman B., Verhoeven Jos T. A. & Whigham D., F. (Eds.) Wetlands: Functioning, Biodiversity Conservation, and Restoration. Ecological Studies, Vol. 191, pp. 247-268.

Paal J. 2005. Estonian mires. Stapfia 85, zugleich Kataloge der OÖ. Landesmuseen Neue Serie 35, 117-146.
Pfadenhauer J. 1991. Massnahmen zur Pflege und Entwicklung von Feucht- und Nasswiesen. Biotopfflege Biotopentwicklung, 1, 32-39.

Raeymaekers G. 2000. Conserving mires in the European Union. European Communities, 90 pp.

Stammel B., Kiehl K. & Pfadenhauer J. 2003. Alternative management on fens: Response of vegetation to grazing and mowing. Applied Vegetation Science 6: 245-254.

Šteffek J. & Vavrová Ľ. 2005. Pimprlík mokraďový (*Vertigo angustior*). In: Polák P., Saxa A. (eds.): Priaznivý stav biotopov a druhov európskeho významu. ŠOP SR, Banská Bystrica: 408-409.

Šteffek J. & Vavrová Ľ. 2005. Pimprlík močiarny (*Vertigo geyeri*). In: Polák, P., Saxa, A. (eds.): Priaznivý stav biotopov a druhov európskeho významu. ŠOP SR, Banská Bystrica: 409-410.

Šteffek J. & Vavrová Ľ. 2005. Pimprlík bruškatý (*Vertigo moulinsiana*). In: Polák P., Saxa A. (eds.): Priaznivý stav biotopov a druhov európskeho významu. ŠOP SR, Banská Bystrica: 410-411.

Sundberg, S. 2006. Åtgärdsprogram för bevarande av rikkärr inklusive arterna gulyxne *Liparis loeselii* (NT), kalkkärrsgrynsnäcka *Vertigo geyeri* (NT) och större agatsnäcka *Cochlicopa nitens* (EN). Naturvårdsverket Report 6501.

Wheeler B.D & Proctor M.C.F. 2000. Ecological gradients, subdivisions and terminology of north-west European mires. J. Ecol. 88:187-203.

Wolejko I., Herbichowa, M. & Potocka J. 2005. Typological differentiation and status of Natura 2000 mire habitats in Poland. Stapfia 85, zugleich Kataloge der OÖ. Landesmuseen Neue Serie 35, 175-219.

World Conservation Monitoring Centre 1996. *Coenonympha oedippus*. In: IUCN 2007. 2007 IUCN Red List of Threatened Species. Available at: www.iucnredlist.org (13 September 2007).