an increase in management intervention (mowing, grazing, cutting, burning and turf removal) in order to maintain habitat quality.

The 'fixed dune' situation is an intermediate stage in the model proposed by Brouwer *et al.* (2005). The management choice is either to intensify the management or accept the gradual move towards an ecologically and geomorphologically stable situation. There are biodiversity and landscape considerations here; the dynamic dune is richer in biodiversity of different scales and is also a 'wilder' landscape. On the other hand, some older stable dunes preserve medieval landscapes and the agricultural fields associated with early settlement patterns. A wider regional or national context may be an important consideration in developing a vision for the site. Managers need also to remember that dunes are often cultural landscapes, formed through centuries of interaction with local land uses. This cultural link can also perceive blown sand as a threat and communities are often divided in their views on the desirability of mobile sand.

Large scale destabilisation can be an effective management tool but runs the risk of losing populations of species which depend on habitat mosaics. The opposite to this approach might be considered to be 'eco-gardening'; creating and maintaining patches of bare sand where large-scale dynamics are absent. There is no simple solution and some of the results of recent experiments are discussed under restoration actions.

Active management

Grazing

Extensive year-round grazing is probably the most appropriate management technique across most of the fixed dune resource from the lush dune grasslands of the Atlantic fringe to the more sparsely vegetated grey dunes of the Continental and Mediterranean climates. Dune systems will have been influenced by native herbivores (rabbits, hares, deer etc.) and by a wide range of domestic grazing animals dependent on local tradition. In most areas, without this activity (probably combined with scrub cutting –see below), there would be a gradual move towards scrub and wooded habitats.

Grazing can be used both as a recurring management tool and as a restoration tool with different grazing regimes applied for different objectives. Several reviews and guidance documents on grazing of dunes have been published (Oosterveld 1985, van Dijk 1992, Boorman and Boorman 2001, Oates *et al.* 1998).

These experiences conclude that grazing animals such as cattle and sheep, especially the mixture of animals, for example in Belgium (Provoost *et al.* 2002), can be used to counteract grass and scrub encroachment. Browsing animals such as goats are effective in countering the development of scrub and have been used in restoration projects. The effect of grazing depends on the mechanism which has led to the current state. If it is the result of reduced grazing pressure then it should be possible to return the habitat to its former condition. But in the case of existing dense shrubland, grazing alone is not successful, and at first scrub removal is necessary (van Dijk 1992). If however there has been an accumulation of organic matter the vegetation will remain more dense. This is also true for areas of high Nitrogen deposition.

Where organic matter has accumulated it may be necessary to combine grazing with another measure such as turf stripping or to intensively graze the site for a short period. Sometimes, however, there can be a difficulty in seeking to 'overgraze' using agri-environment funding as levels are often pre-determined by national policy.

Grazing is returning once again in northwest Europe as the main management tool to maintain the open character and diversity of sites. In south Sweden sandy fields and dunes were traditionally used as low productivity pastures (Appelqvist *et al.* in press) Today attempts are being made to reinstate grazing. To some extent the grazing is seen as a double-edged sword: grazing seems to stimulate lateral shoot formation in grasses thus creating dense grass swards and reducing the number and sizes of patches with bare sand. The view in Sweden is that ideally grazing should be carried out in a way that allows the animals (preferably of different species) to roam freely over a large area to create a mosaic of well grazed patches as well patches with taller vegetation. The grazing pressure should be moderate in the summer but can be higher in the autumn and winter (Appelqvist *et al.* in press).

The success of grazing management will depend on the type of grazing (single species or mixed), the breeds selected, grazing density, seasons etc. Grazing management is partly a trial and error approach, subject to the vagaries of seasons, but, as a management tool, must also be a long-term decision.

A positive spin-off from conservation grazing is that often it is the traditional (and rare breeds) which are most effective at tackling the coarse vegetation. The Forum for the Application of Conservation Techniques (FACT 2003) gives ratings for each species in terms of their ability to tackle scrub. Organisations exist in the UK, the Netherlands and France to promote the use of rare breeds in conservation (e.g. GAP 2001).

Table 2: Some examples of species used in conservation projects on fixed dunes drawn from the experience in the United Kingdom

Site	Species /breed	Stocking rate	Seasons	Comments
Ainsdale Sand Dunes, England (Kimpton, pers. comm.)	Herdwick Sheep	2 sheep /ha. c. 0.3 LU/ha	Winter (October-April)	Controls *Hippophaë rhamnoides* and birch. Existing stands of scrub must be cut and cleared.
Newborough Warren, Wales (Sandison 2005)	Welsh Mountain Ponies	1 pony /3-4 ha c. 0.25 LU/ha	Year round	Maintains short grass sward. Does not control scrub.
Sandscale Haws, England (Burton 2001)	Herdwick sheep Swaledale Mule sheep Friesian /Hereford cattle	c. 300 sheep on c. 250ha. In winter. 150 ewes and lambs in summer 60-70 cattle	Winter and summer sheep flocks Cattle grazed all year	Combined grazing creates tight, closed, species-rich sward. Some supplementary feeding in winter
St. Aidens dunes, Northumberland (Redgrave, pers. comm.)	Exmoor ponies	2 ponies /8 ha. 0.25 LU/ha	Winter grazed (October-March)	Grazing maintains matrix of short (species-rich) and rough dune grassland
Sandwell & Pegwell Bay National Nature Reserve (Swandale, pers. comm.)	Exmoor ponies	8 ponies /8 ha. I LU /ha.	Winter-grazed	Grazing on ancient dune pasture. Grazing only partly effective in controlling scrub.
Whiteford Burrows National Nature Reserve, south Wales (Musgrave, pers. comm.)	Welsh mountain ponies	50-60 ponies on c. 150 ha.	All year-round	Problems with sheep encroaching from adjacent common land

Note: The use of livestock is measured in generalised European Commission livestock units (LU) where cattle over 2 years old and horses are 1 LU, cattle up to 2 years old are 0.6 LU and sheep are 0.15 LU. In practice different breeds have different mature live-weights and conservation grazing schemes often use medium and small breeds. Additional guidance will be given through the individual agri-environment schemes.

For conservation grazing the main decision lies between year-round low intensity grazing or more intensive seasonal grazing. Boorman and Boorman (2001) propose that dune grassland can be maintained at low levels of grazing (0.06 -0.3 LU/ha) but a higher intensity will be required for restoration projects.

Grazing projects need to be supported by monitoring both to detect whether the desired effects are being achieved but also to check whether the action is having a negative effect on sensitive species such as reptiles, butterflies and some plants.

It is now possible to evaluate the success of some of the early schemes. In 1985 extensive cattle grazing was introduced to the Eiland van Rolvers part of the Amsterdam Water Supply dunes (van Til 2006). Cattle grazing initially led to a varied vegetation with blow-outs, dune grasslands and open dune scrub, but could not prevent woodland development in dune slacks. Also, by the 1990s the coverage of coarse

grasses and scrub began to increase, probably enhanced by a decline in the rabbit population. The grazing did not have a clear impact on ground beetles and butterflies, but had a negative effect on bird species which depended on *Phragmites australis* (common reed) in slacks for breeding. Grazing had positive effects on plant species, macrofungi, dung chafers, grasshoppers and dragonflies. The studies concluded that grazing with large herbivores was successful, but that rabbits play an indispensable role in the maintenance of the coastal dune landscape.

Attempts to reinstate rabbit populations are difficult especially where the vegetation has grown coarse. In the 1980s rabbits were released on the Murlough National Nature Reserve in Northern Ireland but it was necessary to bring sheep on to the site (at 1.6 sheep/ha/yr) to create the conditions suitable for the expansion of the rabbit population (Oates *et al.* 1998).

Some studies (e.g. Nijssen *et al.* 2001) show how grazing, introduced to control *Calamogrostis epigejos* could have a negative impact on the very open *Corynephorus canescens* grasslands (intolerant of trampling) by replacing this with a *Festuca* spp. dominated grassland. This more closed sward would give a cooler micro-climate and could eliminate heat-loving species such as some carabid beetles (ground-beetles). It is suggested that these sensitive open vegetation sites may have to be fenced off from grazing pressure (Nijssen *et al.* 2001). More studies on the effects of grazing on fauna are required and care needs to be taken when setting up extensive grazing schemes.

In Belgium grazing has been introduced to maintain open areas after mechanical scrub control and to prevent scrub encroachment. (Provoost *et al.* 2004). The preliminary evaluation is that vegetation composition responds to grazing in a rather slow manner – over decades rather than years. Short-term effects have been studied through detailed projects on diet, habitat use and behaviour for different species (e.g. Konik and Shetland pony, donkey and Scottish Highland cattle). The results confirm that all domestic herbivores are mainly grass eaters (70-80% of their diet is composed of grasses and sedges) and they prefer to graze in grasslands. Diet is affected by season. During the winter and early spring cattle and donkey browse *Ligustrum vulgare* and *Salix repens*. But browsing pressure is insufficient to push back or to prevent scrub encroachment. *Hippophaë rhamnoides*, the most common scrub species, is hardly touched by the herbivores.

Grazing experiments in Belgium have shown that rough vegetation, dominated by *Calamagrostis epigejos*, which succeeds in patches of decayed scrub, is controlled and the impact of grazing is significant. In most cases the biomass of the dominant grass species collapses and after 3-4 years several stress-tolerant dune grassland species occur (Provoost *et al.* 2004). Colonisation by dune species is promoted by both the trampling effects of grazing animals and by seed dispersal through dung.

The overall conclusion seems to be that the benefits of grazing will outweigh negative side-effects, but that for many sites more attention should be given to maintaining rabbit populations and that grazing alone will not counter all the problems associated with scrub development.

Burning

There is increasing interest in burning as a management tool on calcareous dunes. The technique has been applied with success on the more acidic dunes in Denmark (mainly of habitat type 2140) and is being trialled on calcareous dunes in the Netherlands through the LIFE-Nature project 'restoration of dune habitats along the Dutch coast'

The Danish experience is that burning dune heath in a mosaic pattern of small irregular patches (burning of small patches of 0.1-1 ha on a 5-15 year rotation) is a very efficient management tool, also in undulating terrain (Final report LIFE-Nature project LIFE02/NAT/DK/8584). To control the fire a narrow firebreak is cut with a tractor-mounted mulcher. Following this, a small counter-fire is started on the lee side of the belt before the actual fire is started on the windward side. The shape of the burned areas is undulating in order to create a more natural look. Burning mainly takes place in February and March, outside the bird breeding season. Delays can be experienced with weather. The reported cost was about €70/ha.

A study of the restoration of lichen diversity following a wildfire on the island of Terschelling in 1993 (Ketner-Oostra *et al.* 2006) found that fire alone will not change dunes dominated by grasses into open

lichen-rich grasslands where there remains high Nitrogen deposition. In the years immediately after the fire, recovery of fixed dune vegetation was promising but the dominance of coarse grasses returned since the original factors which had developed the coarse grassland were still there:

- Nitrogen deposition in combination with available phosphates in the soil.
- The impact of acidification on the soil micro-organisms which influence the growth of *Ammophila arenaria.*
- Litter decomposition and soil formation during succession.

The recommendation from this study is that after fire, burned vegetation should be cleared and that fresh sand, either imported, or by re-activation of blowouts should be used to encourage the restoration of the fixed dunes.

There is a need for further studies on the value of burning as a management tool for the conservation of fixed dunes. It is a practice which would appear to present most opportunity in the calcium-poor dunes of the Wadden Sea area (Vestergaard and Alstrup 2001).

Mowing

Mowing as a recurring management practice is more commonly associated with dune slacks. Mowing of dune grasslands has been used in Belgium (Provoost *et al.* 2004) and on the Danish dune heaths (Final report LIFE-Nature project LIFE02/NAT/DK/8584). In Denmark tractor-mounted harvesters were used to mow vegetation as an alternative to grazing or burning. The reported costs were about €330/ha.

Managers at the Braunton Burrows dune site in south west England had to resort to attempts to mow the fixed dunes after negotiations to continue grazing failed (Breeds and Rogers 1998). Breeds and Rogers (1998) give details of a series of experiments with different types of equipment, none of which would replace grazing in an ideal situation. The main problem was the scale of the operation. In 1995/1996 140ha of dune grassland were mown but volunteers and staff could only remove 24ha of cut material. Problems affecting such work were using machinery in sand, uneven terrain, trenches and steep slopes and hidden hazards. Overall, after 10 years of work, the results did not compare favourably to grazing. The mechanical control was expensive and caused side effects such as compaction of the ground. Failure to remove the cuttings would lead to soil enrichment and burning on site caused problems with neighbours. The removal of cuttings off site would require a disposal area (Breeds and Rogers 1998).

Elsewhere, the mowing of 'semi-rough' is part of the management of 'links' (dune) golf courses and maintains fixed dune grassland in favourable condition. Many golf courses lie within the Natura 2000 network; the fine-tuning of normal management practices could help to conserve significant areas of fixed dune grassland and dune heath.

Sod-cutting

There is increasing interest in sod-cutting (also referred to as turf-cutting or turf-stripping) both as a restoration tool and a recurring activity. From a restoration perspective it can be used to remove the build up of below-ground biomass stimulated by Nitrogen deposition.

Recent experiments at the Amsterdam Water Supply dunes (van Til and Kooijman 2007) have developed a technique of shallow sod-cutting, removing a 5cm layer of topsoil. Cutting led to an increase in species such as *Viola tricolor* ssp *curtsii* (wild pansy*), Saxifraga tridactylites* (rue-leaved saxifrage), *Lotus corniculatus* (bird's-foot trefoil) and *Phleum arenarium* (sand cat's-tail) and a decrease in coarse vegetation such as *Rosa pimpinellifolia* (burnet rose) and *Calamagrostis epigejos*. The study also found an increase in grasshoppers in response to cutting and overall the action stimulated an increase in rabbit numbers, from low numbers up to 60/ha.

Further study will show whether the apparent benefits to the flora and fauna are short lived or sustainable. The technique may work because it avoids the pitfalls of taking off too much soil (and losing much of the seed-bank) and because it is applied in a patchwork so that there is little risk to populations of animals and plants which can colonise from nearby habitat.

Soil removal is often associated with scrub removal actions but the large volumes involved can be expensive to move and there is a risk that it may encourage further scrub invasion. However, if the problem being addressed is the build up of nutrient-rich top-soil then the action may be appropriate.

Soil reversal

A more disruptive technique which has potential benefits is deep ploughing and turning over the soil to some depth. In Sweden dune stabilisation activities have led to extensive vegetation cover followed by leaching of cations such as calcium and an acidified top layer of the dunes. This is perhaps more noticeable in the Swedish dunes as the sand mainly originates from siliceous bedrocks such as gneiss and granite and thus the soil pH was already relatively low.

To bring sand with a higher pH back to the surface an experiment has tested the use of different types of mechanical excavators to create relatively deep pits (2-3 metres deep). In areas with difficult terrain and steep slopes smaller diggers with caterpillar tracks have been used compared to larger wheeled excavators on flatter areas. Any additional disturbance which leads to blowout development is also welcomed.

To create patches of bare sand, the top layer of sand and turf including the vegetation was placed at the bottom of pits and the sand from the bottom layer placed on top, mimicking the effects of sand drift and presenting an opportunity to remove the rather extensive organic material. The initial results look promising (Bengtsson, pers. comm.): flowering plants are colonising the bare patches of sand and in some patches large colonies of sand-living insects, especially beetles and wasps, have become established after a short period of time. The management is relatively cheap; a large digger can produce several pits in one day on flat ground.

Topsoil inversion as a potential restoration technique for highly eutrophic hind-dune grassland has been trialled at Talacre Warren in north Wales, United Kingdom. The technique involved using a specially adapted plough to invert the soil profile, burying 30cm of topsoil under approximately 50cm of subsoil (Jones, pers. comm.)

Scrub cutting

Scrub is a natural component of dune systems and is a resource which has been exploited for centuries. However, since the 1950s many dune systems have recorded an invasion of scrub. Reasons include reduction in grazing pressure, loss of rabbit populations, water abstraction (especially for slack areas), nitrogen deposition and the loss of dynamics. The rapid and massive colonisation by *Hippophaë rhamnoides* recorded for the Belgian dunes (Leten *et al.* 2005), dunes of north France (Lemoine 2005) or for Germany (Isermann *et al.* 2007) may well be a normal process in lime-rich dunes in northwest Europe. This gives a management dilemma; to maintain species-rich open dunes or to accept natural scrub and woodland.

Policies for scrub management should be developed on a site by site basis. For Belgium, in some areas a strict policy of scrub eradication is developed to maintain the '19th Century' landscapes. At other sites a compromise is reached between pattern-orientated management (where intervention maintains the mosaic of habitat types) and process-orientated management where succession is accepted.

Experience of scrub control in Belgium gives the following best practice advice (Leten *et al.* 2005);

- Whether cutting of scrub is carried out by hand or machine it is important to remove and process coarse woody debris.
- Stumps, fine organic matter and topsoil should also be removed.
- There will need to be follow-up work and evaluation.

The conclusion is that cautious removal of scrub and litter and the introduction of extensive year-round grazing may be successful in restoring and maintaining fixed dune habitats. Various techniques have

been used for the removal of scrub from manual cutting to the use of tractor-mounted flails and adapted arms of tracked excavators. Details can be found in Leten *et al.* 2005.

Scrub control in north France (Dune Marchand, Dune Dewulf and Dune du Perroquet) started in 1988 with the manual cutting of *Hippophaë rhamnoides*, *Ligustrum vulgare* and *Salix repens* (Lemoine 2005). In what is described as 'eco-gardening' patches of low scrub were cut manually and later mechanically over an area of 9ha. From this a larger programme of scrub clearance was developed using tractors and mechanical flails to cut and chip thickets of scrub up to 3.5m tall (Lemoine 2005).

For the United Kingdom examples of scrub management for *Hippophaë rhamnoides* are described in The Scrub Management Handbook (FACT 2003). This provides guidance to selecting management options.

Removal of invasive species

The most common 'problem' species of fixed dunes in northwest Europe is *Hippophaë rhamnoides*. It is native to most of northwest Europe including the east coast of the United Kingdom. Where it has been introduced as part of 19th Century dune stabilisation problems, often in association with conifer plantations (e.g. west coast of England) it has become highly invasive, especially in young slacks and open dunes. Management prescriptions have been developed in projects from the United Kingdom, Netherlands, France and Belgium.

Rosa rugosa (Japanese rose) is a widespread problem on many North Sea and Baltic dune systems. It became popular in the early 20th Century as an ornamental shrub and has been widely planted. In Germany, Jutland and in the Baltic it was also planted to stabilise dunes. The plant spreads both by vegetative propagation and by seed. Expansion of *Rosa rugosa* reduces species richness for example due to shading (Isermann 2007a, 2007b). In Sweden attempts to eradicate *Rosa rugosa* have been carried out using excavators (Bengtsson, pers. comm.). First experiments used a type of bailer attachment which uprooted the bushes but allowed the sand to fall back to the ground. The material was piled up for burning. However, in the following year it was clear that a lot of the root system had been left in the ground; the regrowth had to be treated by hand. The technique was improved by using larger machinery to take out more of the root system resulting in less problems with re-growth (but still some problems). The technique also had the advantage of more disturbance to the soil.

Removing of *Rosa rugosa* and other coarse vegetation has also been carried out using a large sifting machine normally used to separate roots and other organic material from agricultural soil. Sand and plant material were removed by a front loader and tipped into the sifting machine. The clean sand was then returned to the dune area by the front loader resulting in more bare sand patches and some sand drifting. The techniques look promising (Bengtsson, pers. comm.).

The invasion of the exotic moss *Campylopus introflexus* is a particular concern on the more acidic dunes of the Wadden Sea area where it threatens the lichen-rich fixed dunes (van der Meulen *et al.* 1987, Biermann and Daniëls 1997, Ketner-Oostra and Sýkora 2004, Hassel and Söderström 2005). In Denmark and The Netherlands removal of the moss carpet has been attempted.

In The Netherlands at a scale of 200 m^2 sod-cutting by hand was used to regenerate the natural lichen-rich *Corynephorus* vegetation, but after few years *Campylopus* was again dominant. The species was also dominant five years after fire. Management measures will be less successful until existing atmospheric nutrient deposition reduces. Moreover, chemical control with the herbicide Asulox was not successful (Rowntree *et al.* 2003). Furthermore, rabbits not only distributed *Campylopus* pieces stuck to the animals, but also created open areas by scraping, which could be colonised by the moss, because the moss often established at disturbed sites. Natural sand accumulation from more seaward dunes (with higher lime content) could be a natural measure against the spread of the moss (van der Meulen *et al.* 1987)

Restoration activities

General guidance can be found in the web-based resource 'Coastal Habitat Restoration –Towards Good Practice' (Doody and Pamplin 2003).

Removal of plantations

Probably the most significant interference with natural dune evolution across Europe has been the planting of non-native woodlands, principally conifer plantations. The main reason for afforestation, in countries such as Poland, Denmark, Sweden and the Netherlands, was to stop long-standing problems caused by sand-drift and the 'wandering dunes'. For this reason the hardy, but uneconomic, *Pinus mugo*, was used in Denmark along with *Pinus contorta*. The potential for commercial plantations came later.

In France the focus was on finding a productive use for the vast areas of Les Landes and here plantations of native *Pinus maritima* were used. The trees were the basis for the turpentine industry. Elsewhere smaller scale woodlands have been planted to reduce sand-drift, find a productive use for dune 'wastelands', to shelter agricultural land and as cover for hunting.

A number of LIFE projects have addressed the issues concerning dune forestry and the conservation of fixed dunes. In France the focus has been to ensure that a zone of grey dunes is retained between the mobile dunes and the productive forests. In the United Kingdom the focus has been on issues concerning direct loss of habitat, fragmentation and the impact on the water-table, and in the Netherlands there is interest in re-structuring the plantations to replace parts of the forest with native 'dune woodland'.

The largest effort in pine removal has been in Denmark, through the project 'Restoration of Dune Habitats along the Danish West Coast' where the encroachment of self-sown trees has been tackled on some 5000 ha of fixed dune and dune heath where over 500 ha of dense overgrowth (self-sown woodlands) has been removed and 390 ha of plantations have been removed and the dune habitats restored.

The costs for these actions (Final report LIFE-Nature project LIFE02/NAT/DK/8584) are €2320/ha for conversion of forest stands to open dune, €1210/ha for dense over-growth (tree encroachment of up to 50 years old) and €228/ha for the removal of scattered self-sown trees.

The best practice guidelines, developed largely for dune heath habitats, are also applicable to the removal of plantations from fixed dunes.

- Clearing of invasive exotic conifers should take place as soon as possible. The longer the trees develop the more difficult restoration will be.
- Clearing of conifers should always include the removal of all above-ground biomass, including the litter layer of needles and cones. The material should be collected on site and either burned on selected spots or chipped and removed from site.
- The manual removal of self-sown young conifers will be necessary every year for the first three years following clearance. Thereafter the manual removal will need to continue every few years until the seed bank is exhausted.
- In some areas extensive grazing (mainly by sheep, but also in some cases cattle) is recommended to maintain the open vegetation.
- The heavy equipment used should have wide, preferably smooth, tyres, using as few routes as possible and avoiding damage to the more sensitive humid dune slack communities. Heavy equipment can, however, be used to good effect to break up dense scrub to allow access to cattle.
- Fire spots should be carefully selected and should not be on grey dune habitat. It may be necessary to transport the cuttings to fire sites. Fire sites should be re-used, if necessary, in follow-up clearance.

Mechanical uprooting of pine trees has been tested in Sweden with good results (Bengtsson, pers. comm.). An excavator with a large gripping device has been used to pull out the whole tree including the roots. The method has been trialled on trees with a relatively small DBH (diameter at breast height) (c. 15-

30 cm) but probably can be used on larger trees as well. The uprooted trees are chipped and removed from site. The disturbance created by the techniques also provides patches of bare sand. An area of 2.5 ha was cleared in 120 hours at a cost of c. €2600/ha. The result was a nitrogen-poor dune habitat with large patches of bare sand restored in a few weeks rather than the much less interesting clear-cut vegetation that would have been the result from just felling the trees (Bengtsson, pers. comm.).

At Ainsdale Sand Dunes National Nature Reserve in the United Kingdom conifer removal has been followed up by sheep grazing (Simpson and Gee 2001). However, there are now concerns that sheep grazing produces a rather uniform, low vegetation and the site managers will introduce an experiment using Shetland cattle (a hardy, small breed) in an attempt to develop more structure and open up areas of bare, and blowing sand (Kimpton, pers. comm.)

The removal of conifers should be combined with either litter-raking or top soil removal (van Til *et al.* 2007). In an experiment in the Amsterdam Water Supply dunes different treatments were applied to the removal of a 60-year old *Pinus nigra* stand. The treatments were control, tree-cutting, tree-cutting with litter raking and tree-cutting with top soil removal. The best restoration was achieved with top soil removed. This eliminates the litter layer, increases pH and reduces the nitrogen content of the soil. If litter raking is used a further reduction of tall grass cover could be achieved by additional seasonal grazing by cattle or sheep.

Large scale destabilisation

Large-scale destabilisation and disruption of dune systems can allow a new habitat mosaic to form with, at least for a period, more open conditions and representation of younger stages of dune and slack succession. Projects which aim to create areas of bare sand have been carried out in the Netherlands (Arens *et al.* 2005, Arens and Geelen 2006) and France (Lemoine 2005). The main idea for restoring dune mobility is that natural processes will take control, creating new dune valleys with opportunities for pioneer species whilst destroying mature vegetation through burial (Arens *et al.* 2005). However, restoration of dune mobility in the fixed dune zone is difficult and even after 10 years it cannot be determined whether the technique is successful (Arens *et al.* 2005). The removal of vegetation and soil leads to a sudden and dramatic increase in aeolian dynamics but re-stabilisation from root remnants counters dune mobility. Also a 'pavement' of eroded (dead) roots prevents further erosion. The experiments in the Netherlands will be monitored for several decades (Arens and Geelen 2006).

Other relevant measures

Positive management of golf courses and military sites

A significant proportion of the fixed dune resource in the United Kingdom lies within the boundaries of golf courses and military sites, many of which were established in the 19th century. The undeveloped nature of the golf course 'roughs' and training areas has made these sites important for nature: many are included within the Natura 2000 network. Managers of these sites have worked closely with nature managers to share skills and develop conservation programmes (Simpson 2000, Simpson *et al.* 2001b) and management bodies, advisors and specific non-governmental organisations promote good practice. An overview of golf and the environment can be found on www.golfenvironmenteurope.org.

Recreation management

In all countries there is concern about the impact of recreation of fixed dune habitats but also an understanding that light pressure can be beneficial in maintain areas of open sand. In Denmark, for example, serious erosion is reported at 50% of fixed dune sites and erosion is noted at a further 33%. Of the 50% of reported cases erosion was considered to have a negative effect whilst in 20% erosion was considered positive. The number of paths networks is increasing, occasionally resulting in breaches in the dunes and blowouts.

The control of recreation pressures is commonly a feature of management projects in southwest and Mediterranean Europe where there is less of a history of control on dune activities, continuing pressures

for development and the need to educate the visitors. In France LIFE projects have addressed grey dune conservation and sustainable tourism (e.g. LIFE95ENV/F/676).

In many sites the monitoring of recreational use is important to assess the impact of access and to plan annual programmes of maintenance.

Monitoring of habitat quality

Article 17 of the Habitats Directive requires Member States to submit regular reports on the condition of Natura 2000 sites and progress towards favourable conservation status. Whilst each Member State will set out its own targets for habitat quality these must allow an overall assessment of conservation status to be made by the European Commission every six years. In the United Kingdom the Common Standards Monitoring Guidance for national Sites of Special Scientific Interest is used as a basis for compiling reports under Article 17. The guidance for sand dune habitats, including fixed dunes, is published on www.jncc.gov.uk (JNCC 2004). For fixed dune grassland the following targets should be met:

- Bare ground or sand present, but no more than 10% total area
- 30-70% of sward to comprise species-rich short turf, 2-10 cm tall
- Flowering and fruiting of dune grassland frequent
- Typical species to be present
- Non-native species no more than rare
- Scrub/trees no more than occasional, or less than 5% cover
- Tree invasion from adjacent plantations rare

Special requirements driven by relevant species

There are concerns linked to the spread of grazing schemes and the potential impact on populations of reptiles. Although reptiles have undoubtedly benefited from the landscape mosaic created by traditional grazing some care needs to be taken to avoid known breeding sites. Intensive grazing can also reduce the micro-diversity of the vegetation and the habitat for reptiles such as *Lacerta agilis* and *Coronella austriaca* (smooth snake).

Guidance on habitat management for *Lacerta agilis* in the United Kingdom (Moulton and Corbett 1999) gives advice on management operations to avoid unintentional damage or disturbance to the species. Although whole site conservation is supported, management for *Lacerta agilis* in the United Kingdom is targeted to 'foci', known, stable, breeding and foraging areas. Most of these sites are well known so scrub removal can be targeted to maintaining the optimal conditions for the species and grazing projects and other initiatives can be made aware of the specific interest in parts of the site.

At some Swedish sites with *Lacerta agilis*, continuous mowing or grazing has been recommended in order to reduce overgrowth and to maintain patches with bare soil (Berglind 2007).

In the United Kingdom management work for *Bufo calamita* is focused on both the aquatic and terrestrial habitat. Terrestrial habitat has to be open, un-shaded with extensive areas of un-vegetated or minimally vegetated ground (Beebee and Denton 1996). Adult and juvenile *Bufo calamita* require this kind of terrain for hunting invertebrate prey which they do by active pursuit. They also need bare ground for burrowing. Management effort for the terrestrial habitat has been directed to the restoration of over-fixed dunes, creation of new yellow-dune habitat and maintenance of suitable dune habitat. (Beebee and Denton 1996)

In Sweden, grazing has been recommended in order to avoid overgrowth of sites with breeding pairs of *Anthus campestris*. There are also proposals to clear a zone inside the dunes from trees and scrub, as a complementary measure in order to restore the kind of dry heath on sandy soil that characterised the breeding habitats for this species in earlier days (Naturvårdsverket 2003, Elfström 2007).

In Estonia, at the Häädemeeste wetland complex, dune slopes were cleared of planted *Pinus mugo*, moss and lichen cover to improve the conditions for sand-dwelling insects, reptiles and bird species (Eglīte 2005).

Cost estimates and potential sources of EU financing

Specific cost features for the habitat

Management costs will vary depending on the objective for management. Funding for both the sustained management and the restoration of dune systems may be available through national agri-environment schemes and other national funding initiatives for nature conservation. Dune habitat management could also be linked to wider projects concerned with access, interpretation and eco-tourism. The EU Natura 2000 funding manual can be used to explore some of these possibilities.

Most Member States will have prepared specific funding packages for nature conservation and Natura 2000 sites and have an opportunity to set some priorities for the use of EU funds.

In England, for example, agri-environment funding is available to support the introduction and maintenance of grazing regimes on sand dunes (http://www.defra.gov.uk/funding/schemes/hls.htm). Support is also available for the creation of coastal sand dunes on arable land and grassland. Land that lies behind a sand dune and is currently arable, set-aside or grassland may be suitable to allow the roll-back of the dune system inland.

The prescription for fixed dunes is to manage by light grazing to control excessive growth of vegetation. Cover of scrub should be less than 5% and bare ground between 5%-15%. No supplementary feeding or application of fertilizers is allowed. The restoration option gives 5 -10 year periods in which to reach favourable or recovering condition.

Annual payments under the Environmental Stewardship Scheme are £140/ha (ca. €200/ha) for the maintenance of sand dunes, £200/ha (ca. €285/ha) for the creation of sand dunes on grassland and £320/ha (ca. €460/ha) for the creation of sand dunes on arable land. Other options, including access, may attract additional payments. Permissive open access, for example, could attract an additional £41/ha (ca. €60/ha).

Member States have opportunities to develop targeted management schemes for habitats and species. In Scotland the *Natural Care* programme has developed a conservation scheme for the management of dune, machair and dune slacks at two sites on the islands of Shetland. The aim of the scheme is to provide financial support to land managers to help maintain and improve the conservation value of the sites and to maintain natural processes. The scheme is based on achieving targets for favourable condition without prescribing the actual grazing pattern or number of livestock: local knowledge and experience is considered to be important. The five year management prescriptions also include payments to control rabbit numbers and invasive weeds.

Payment rates are £85/ha (ca. €120/ha) for grazing management, 90% of the costs of rabbit control up to a maximum of £100/ha (ca. €140/ha) and £200/ha (ca. €285/ha) for initial weed control (with follow up treatment at £50/ha, ca. €70/ha). One-off payments are given for writing the management plan and for rabbit-proof fencing and gates and traps. Rabbit numbers are a problem on these grasslands and the Natural Care scheme can make additional payments over and above the land owners duty to control rabbit as part of cross-compliance with General Environmental and Agricultural Condition (GAEC).

A case study of conservation management on the Dunes de Merlimont (Dermaux and Viellé 2007) gives details of the costs of establishing grazing systems, restoration and management of dune grassland, humid dune slacks and fixed dunes. Annual costs for mowing and removal of material from dune grasslands are given as €600-750/ha, for a farmer to take material as hay €150/ha and to pay a farmer for grazing €70/ha but with costs decreasing over time.

Relations with potential sources of EU funds

Management measures for Natura 2000 were defined in the annexes of Communication from the Commission on Financing Natura 2000 (COM 2004-0431 and its working documents).

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 are, in principle, 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).

Among the diversity of sources for EU funding, the following funds might primarily be of interest for the management of 2130:

- The European Fund for Rural Development (EARDF): This program has a potential to cover several management activities that might be relevant, although the measures have to be covered in the National Strategy Plans and related measures Rural Development plans (RDPs) in order to be eligible on a national basis. Furthermore Leader+ funds have to be studied on a national basis.

- 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. However, the Interreg approach is more flexible but needs a European objective and partnership. Different geographical levels were 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 practise 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 contributing 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). Recurring management is not eligible under LIFE+.

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