Grazing for nature conservation management of coastal sand-dunes, with special reference to the Sefton Coast, north Merseyside, UK

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Introduction

Coastal dunes are a relatively rare habitat in Britain and Europe, renowned for their rich fauna and flora. A good example is the Sefton Coast dune system in north Merseyside, UK. Extending for over 15 km between the estuaries of the Mersey and Ribble, it is the largest duneland in England (2100 ha) and one of the most biodiverse in Northwest Europe, supporting over 3500 insects (Smith, 2023) and more than 1250 higher plants (Smith, 2021). Many of these are sand-dune or heathland species that occur rarely in other habitats. For centuries, perhaps thousands of years, suitable conditions for these specialists were maintained by dune dynamics mediated by natural processes, such as changes in sand-supply, storm events and the actions of wild grazers but also by human activities, including livestock grazing, Rabbit (*Oryctolagus cuniculus*)-warrening, harvesting of natural products, like Marram (*Ammophila arenaria*) and turves, and even small-scale arable farming. However, since the 19th century, attempts to stabilise coastal dunes, including the introduction of trees and shrubs, conifer forestry, the collapse of Rabbit populations due to disease, abandonment of livestock grazing and an increase in infrastructure, including golf courses and built development, contributed to a rapid increase in vegetation and loss of bare sand (Howe *et al.*, 2012; Provoost *et al.*, 2011; Smith, 2009; 2012). For many decades the problem was exacerbated by aerial deposition of nitrogen from intensive agriculture, transport and industry. Levels above a critical threshold of about10 kg ha^{-1} yr^{-1} are recognised as a threat to low-nutrient habitats, such as heathlands, bogs and coastal dunes (Bosanquet, 2021; Jones *et al*., 2004). These changes have affected dune systems throughout Western Europe and in other parts of the world, as well as in Britain (Provoost *et al.*, 2011). Delgado *et al*. (2019a) showed that the Sefton dune system lost over 80% of its bare sand between 1945 and 2015, while Smith (2012) found that the proportion of bare sand on frontal dunes in what is now the Cabin Hill National Nature Reserve (NNR), Sefton, fell linearly from 40% in the early 1960s to less than 5% in 2015 (Figs. 1; 2).

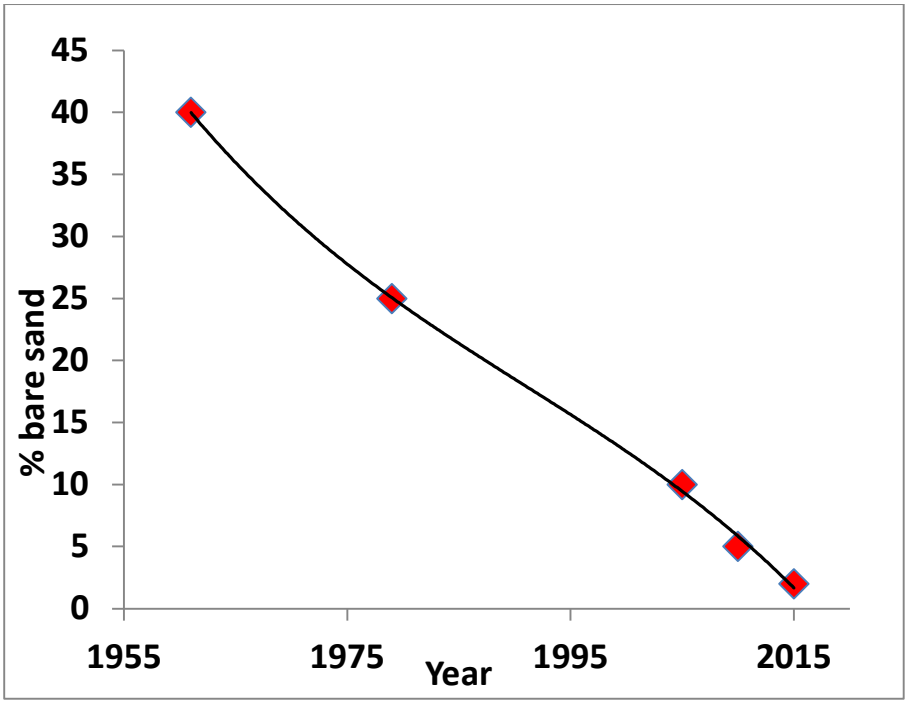

Figure 1. Decline in % bare sand on Cabin Hill NNR frontal dunes, 1960-2015

Figure 2. Cabin Hill NNR frontal dunes in 2013 showing lack of bare sand

Figure 3. Scrub on Birkdale Sandhills Local Nature Reserve, 2015

Analysis of aerial photographs found that scrub cover in a sample of representative dune areas on the Sefton Coast increased six-fold between 1945 and 1985 (Smith, 2009) (Fig. 3). Much of this was Sea Buckthorn (*Hippophae rhamnoides*), which was introduced by the manorial estates in the 1890s (Savidge *et al*., 1963) and has been spreading since the 1950s (Holder, 1953). More recently, the rapid growth of Japanese Rose (*Rosa rugosa*) (Smith, 2019a), Grey Willow (*Salix cinerea*) (Smith & Kimpton, 2008), Traveller's-joy (*Clematis vitalba*) (Smith, Jarvis & Jarvis, in press) and Broad-leaved Everlasting-pea (*Lathyrus latifolius*) (Smith, 2020a) have attracted mounting concern, while several other potentially invasive plants, such as Pampas-grass (*Cortaderia selloana*), have been recognised (Smith, 2020a). It has been argued that these trends are a direct threat to the unique biological assemblages found on British coastal dunes, most of which are protected by Site of Special Scientific Interest (SSSI) and Special Area of Conservation (SAC) designations, many being managed in National Nature Reserves (NNR) or Local Nature Reserves (LNR) (Creer *et al.*, 2020). Alternatively, Delgado-Fernandez *et al*. (2019b) contends that, under prevailing climatic conditions in Northwest European, dune systems would be expected to support dense vegetation and that their historic mobile condition was due to human activities. In their opinion, these features should be allowed to 'evolve' naturally but with control of

recreational pressure on frontal dunes to facilitate coast protection.

Many site managers have responded to a perceived threat to biodiversity from vegetation overgrowth by employing techniques to halt and/or reverse the increasing stability and lack of dynamism in their duneland holdings. These methods include tree and scrub removal, turf-stripping, mowing and larger-scale attempts to re-mobile parts of dunes using heavy machinery (Jones *et al*., 2021). It was recognised in the 1980s that grazing with livestock was important to the survival of specialist dune flora and fauna (Doody, 1989; Oosterveld, 1985). Accordingly, stock was introduced (or re-introduced), with the aim of opening up coarse vegetation, preventing scrub invasion, encouraging Rabbits and creating bare sandy patches. The results of such grazing interventions seem to be mixed, some studies reporting improvements in habitat condition, while others have seen less favourable outcomes. This article seeks to review some of the evidence for and against the benefits of grazing on coastal dunes, with particular reference to Sefton.

History of dune grazing in Sefton

Evidence of pre-historical grazing in the Sefton dunes is limited to footprints of large mammalian herbivores in hardened silts, dated to the late Mesolithic/Neolithic (5400-2300 BC) and exposed by erosion on Formby shore (Burns, 2014; Roberts, 2014). They include prints of the now globally extinct Aurochs (*Bos primigenius*), accompanied by those of Red Deer (*Cervus elephas*), Roe Deer (*Capreolus capreolus*) and Wild Boar (*Sus scrofa*) (Fig. 4)

Figure 4. Pre-historic human and animal footprints in hardened silts at Formby Point

It is not known what impact these herbivores had on dune ecology but this and other processes must have been sufficient to maintain suitably open habitats for specialist biota, such as Natterjack Toads (*Epidalea calamita*) and Sand Lizards (*Lacerta agilis*). They are thought to have arrived in the area about 9500 years ago, as they re-colonised Britain following the end of the last glaciation (Smith, 2009). Domestic cattle footprints have also been found in Iron Age sediments at Formby Point, Sefton (Plater *et*. *al*., 1993). In more recent times, coastal dunes were often viewed as 'waste land' (Rooney & Houston, 2009), one of few economic values to local communities being as a resource for grazing by livestock. Many large dune systems, including Sefton's, had commercial Rabbit-warrens that operated for centuries, Rabbit fur and meat being valuable commodities (Lewis, 2008). Documents relating to farmed warrens in the Sefton dunes go back to at least the 17th century. Poaching was evidently a major problem, reflected in an Act of Parliament 1765 enabling anyone convicted of Rabbit poaching to be whipped, fined, imprisoned or transported for seven years (Smith, 2009). Direct evidence for historical stock grazing is fragmentary but it is reasonable to assume that duneland was grazed by cattle and, especially, sheep for long periods. Thus, in the early Middle Ages, Sefton's Richard de Ainsdale granted a *sheal* (shepherd's or herdsman's hut) in a place known as Stardale. A sheepfold and shepherd's house, situated on the eastern side of the village, are also mentioned in 1190-1216 (Philpott, 2008). Lewis (2008) states that, until the 16th or 17th centuries, animals were grazed in common on the dunes, Court Books for Formby and Ainsdale setting out regulations for grazing sheep on the commons. Similarly, records for Sandscale Haws, Cumbria, suggest that, since the 12th century, these dunes were used for sheep and possibly cattle grazing but information is limited (Pye *et al*., 2020).

As it was becoming uneconomic, livestock grazing on the Sefton dunes had all but died out by the 20th century, a small area at Cabin Hill being grazed by cattle and horses until the 1980s (personal observations). Concerns about vegetation overgrowth led NNR managers to re-introduce livestock in the early 1990s. From 1992, the eastern part of Cabin Hill NNR was winter-grazed by about 50 Herdwick sheep, five Shetland cattle being occasionally added from 2010/11. The sheep were joined by seven English Longhorns in the 2022/23 winter (Fig. 5). At Ainsdale Sand Dunes NNR, winter-grazing by 30 Herdwicks began in 1990 in a 10 ha plot (Atkinson & Houston, 1993). This was subsequently extended to about 95 ha, including areas cleared of pine plantation and scrub as part of a 'dune

restoration project'. This area supported 200 Herdwicks and, sometimes, the five Shetland cattle. Simpson (2002) described how the grazing improved the terrestrial habitat for Natterjack Toads, helping to promote a population increase. Winter grazing on the nearby Ainsdale Sandhills LNR began in 1999 with 25 Herdwicks in a 7.2 ha fenced plot. An adjacent 32 ha area was grazed from 2012 by 13-22 'heritage breed' cattle: Redpolls, Shorthorns or Belted Galloways. A 64 ha enclosure on Birkdale LNR was similarly winter-grazed by 11-13 cattle, these projects being funded by Higher Level Stewardship. However, none of them included frontal dunes, where former open mobile dunes became increasingly invaded by dense Marram (*Ammophila arenaria*) and False Oat-grass (*Arrhenatherum elatius*), the latter species being known to proliferate in the absence of grazing (Rodwell, 2000).

Figure 5. English Longhorn, Cabin Hill NNR, October 2022

Modern grazing studies

Rabbits

Boorman (1989) reported on the influence of grazing on 48 UK sand-dune sites; the dominant grazer was the Rabbit, though sheep and cattle played an important role on about

one third of sites. He found that grazing intensity had fallen, leading to the development of coarse vegetation and scrub, concluding that controlled grazing regimes, together with long-term monitoring, was necessary to maintain species diversity in dune grasslands.

Houston (1992) reviewed the early literature that describes the importance of Rabbits as dune grazers (Fig. 6; 7). This small herbivore has been described as a 'keystone species' in many British grassland, heathland and dune habitats (Bell *et al.*, 2021; Potter & Hosie, 2001); its grazing and burrowing have the effect of engineering ecosystems, inducing spatial heterogeneity and maintaining successional stages with high numbers of plant and invertebrate species in fixed-dunes and the drier parts of slacks (Bravo *et al.*, 2008; Houston, 2008a, b; Kirby, 1992; Smith & Lockwood, 2011). Collapsing Rabbit warrens (Fig. 8) can open up the dune surface to wind erosion, creating blowouts (van der Hagen, 2022; van der Hagen *et al*., 2020). The loss of a 'keystone' can result in unforeseen and damaging changes to ecosystem function and biodiversity (Payne, 1995).

Due to disease, the Rabbit has declined drastically since the mid-1950s, one result being the domination of previously floristically-rich vegetation by a few grass and shrub species (Sumption & Flowerdew, 1985). Early changes in dune vegetation following the introduction of myxomatosis were described by White (1961) at Blakeney Point, Norfolk. The disease arrived in 1954; Rabbits soon being wiped out. There followed a rapid growth of grasses, while mosses and the area of bare ground declined. Other species that were affected included Common Ragwort (*Jacobaea vulgaris*), which was much reduced as Rabbit activity declined, while Sea Bindweed (*Calystegia soldanella*) increased, the latter having previously been eaten by the Rabbits. Similarly, the effects of the almost complete disappearance of Rabbits at Newborough Warren NNR, Anglesey in 1955, included a great increase in the growth of most grasses and sedges, a reduction in dicotyledonous herbs, especially low-growing and rosette species and no change or a slight increase in the moss flora (Ranwell, 1960). Garson (1985) reported that, since the arrival of myxomatosis, Rabbit populations had fluctuated widely on Holy Island, Northumberland, adversely affecting the floral diversity of dune-slacks during both booms and crashes. These rapid changes created a management challenge, as an intermediate level of grazing was desired. Edmondson (1991) investigated the impact of Rabbits on dune-slack vegetation at Ainsdale NNR. Within exclosures installed in 1974, there was clear evidence of accelerated succession leading to increased vegetation height, reduced species-richness and an increase of grasses over forbs.

Also, Rabbit grazing prevented Creeping Willow (*Salix repens*) from reaching a size required to dominate other components of the vegetation.

Figure 6. Rabbit warren, Falkland's Way dunes, Ainsdale, March 2021

Figure 7. Rabbit-grazed dune grassland, on former arable field, Formby Point, March 2019

Figure 8. Collapsed Rabbit warren in fixed-dunes, Ainsdale NNR, January 2022

From the 1960s, Rabbits were patchily distributed on the Sefton dunes but played an important role in keeping vegetation short, especially in the slacks. However, in 2009, there was a major outbreak of myxomatosis, numbers plummeted and corpses littered the ground (personal observations). This had a noticeable effect on slack vegetation with, for example, Grass-of-Parnassus (*Parnassia palustris*) declining in some slacks as sward height increased Smith & Deed, 2014). Coarsening of vegetation and scrub invasion inhibited re-colonisation by Rabbits, as they avoid taller swards once established (Drees & Olff, 2001). The latter authors showed that Rabbits have a strong preference for dry places with sparse, short vegetation, which they maintain by constant nibbling. van der Hagen (2022) found that Rabbits preferentially graze the nutrient-rich seedlings of shrubs and trees, including Sea Buckthorn, and that, in the absence of Rabbits, these young sprouts survive to form scrub and, eventually, woodland. Oosterveld (1985) also recognised the importance of Rabbits in maintaining variation in the pattern and composition of dune vegetation. He showed that larger grazers, such as horses, improved habitat conditions for smaller herbivores, including Rabbits. Due to disease, Rabbit numbers at Sandscale Haws, Cumbria, have been low since the 1990s but localised areas of bare sand and pioneer habitat were created by Rabbit activity in the fixed-dune grasslands (Pye *et al.*, 2020).

Using grazing exclosures on the dunes of Norderney, Germany, Isermann *et al.* (2010) studied the effects of Rabbits and other environmental factors on floristic diversity. She found that grazing diversified habitats, slightly supported total species-richness and enhanced heterogeneity of species composition. The highest species-richness was achieved at intermediate levels of grazing pressure. Grasses were preferentially grazed year-round. This research confirmed that grazing is one of the main factors maintaining the composition of dune vegetation.

In south-eastern Australia, increasing cover of dune vegetation coincided with a significant decline in Rabbit numbers. Rabbit density was found to be the primary factor leading to rapid vegetation growth and stabilisation of dune fields. Other factors, such as changes in rainfall, aeolian sediment transfer, land-use practices and the introduction of invasive plants played a limited to negligible role (Moulton *et al.*, 2019). Not all studies find that Rabbit grazing is beneficial for biodiversity. Thus, Garcia-de-Lomas *et al.* (2023) showed that following removal of the invasive shrub, White-flowered Broom (*Retama monosperma*), from coastal dunes in south-west Spain, exclusion of Rabbits increased species-richness and diversity in grey dune vegetation.

Livestock and Rabbits

The combined role of livestock and Rabbits in controlling scrub in slacks was investigated during a 36-year study on Ainsdale Sand Dunes NNR by Millett & Edmondson (2013). Using exclosure plots, they demonstrated a clear succession to scrub where grazing did not take place. Grazing by Rabbits and sheep reduced the cover of woody plants, while increasing both grass and herb cover and species-richness. In general, sheep grazing accelerated the impact of Rabbits. However, although it retarded succession in a valuable way, grazing did not entirely prevent this process taking place, leading the authors to suggest that disturbance to create new habitat, followed by grazing, may be a more successful strategy. Similarly, Smith & Lockwood (2011) proposed that the interaction between winter sheep-grazing and year-round Rabbit-grazing was a major factor in the increase of a rare plant, Field Gentian (*Gentianella campestris*), on part of Ainsdale NNR. Rabbits maintained a low vegetation height, while the sheep helped to prevent litter build-up during the winter and browsed competitive Creeping Willow. Both grazers provided sufficient ground disturbance

to encourage Field Gentian seedling establishment in bare patches (Fig. 9).

Ford *et al.* (2017) compared plots that were ungrazed, Rabbit-grazed or fully grazed (ponies, cattle and Rabbits) in fixed-dune grassland at Newborough Warren NNR. Fully grazed grassland supported a higher plant species-richness than ungrazed land, especially for forbs. Predatory Coleoptera (beetles) and Araneae (spiders) were more abundant and species-rich on fully-grazed grassland. However, nectar-feeders, as a proxy for pollinators, did not differ in species-richness or abundance with grazing intensity.

Herron (2014) found that livestock grazing on sand-dunes in Northern Ireland reduced vegetation height and biomass while controlling scrub such as Gorse (*Ulex europaeus*). However, Rabbits had 2.6 times the effect of cattle on sward height. Variation in Rabbit numbers by several orders of magnitude made impacts on vegetation difficult to predict. Seasonal cattle grazing had no effect on community composition but year-round Rabbit grazing, especially close to warrens, skewed plant composition towards unpalatable species, creating spatial variation in community composition.

Figure 9. Field Gentian habitat at Ainsdale NNR grazed by sheep and Rabbits, September 2009

Restoration of Rabbits

Evidently, the ideal would be to restore Rabbit numbers in dunelands where they have declined or disappeared. However, this seems to be difficult to achieve in practice. Thus, following changes to vegetation attributed to the loss of Rabbits at Murlough NNR, Co. Down, attempts were made to re-introduce this grazer between 1985 and 1989. Unfortunately, viable populations were not established, probably because the sward was too tall. From 1987, sheep, cattle and, eventually, Exmoor ponies were used to manage the habitat, the latter producing the most satisfactory results (Oates *et al.,* 1998).

The potential for translocating Rabbits to a Dutch dune system was evaluated by Drees *et al*. (2009). Mortality before release was minimised by reducing stress during trapping, handling and transportation, tall vegetation was mowed and artificial burrows were provided at the receptor site. However, 91% of the translocated Rabbits were found dead within a few days, mostly predated by Red Fox (*Vulpes vulpes*). Translocation attempts elsewhere also experienced high mortality in the first few days after release. Thus Calvete *et al*. (2009) reported that, since myxomatosis, about half a million Rabbits were restocked annually in France and the Iberian Peninsula. Survival of marked individuals over the first ten days was less than 3% and most of the tagged Rabbits in their study were dead within three months. These deaths were attributed to disease and predation, the latter especially by Red Fox. Several related studies showed that translocation success could be improved by providing artificial warrens and increasing food availability (Catalan *et al.*, 2008; Cabezas & Moreno, 2007).

Bell *et al.* (2021) described methods to encourage Rabbit recovery in acid grassland of East Anglian 'Brecks'. They stressed the importance of brush piles and south-facing banks to protect Rabbits from predation and encourage the construction of warrens. This also allowed younger individuals to disperse and establish new social groups, thereby increasing the rate of population recovery. However, this project did not address the coarsening of vegetation that prevents recolonisation once Rabbits have been lost. Mowing is another management technique that could produce short vegetation suitable for Rabbits but there are few examples in the literature. Romeril (1989) describes how mowing to control coarse grasses on dune grassland in Jersey, Channel Islands, also led to an increase in Rabbit activity.

Livestock

Wideranging studies suggest that the best way to conserve coastal dune habitats is by conservation grazing, designed to counteract vegetation overgrowth, support a desired range of specialist flora and fauna and restore favourable condition (Denning *et al*., 2024). Unfortunately, most modern breeds of livestock do not cope well with the low-quality herbage on dunes; therefore, use of 'traditional' or 'heritage' breeds is desirable (Fig. 10). Also, success depends on availability of suitable breeds, staff to undertake daily visits to check animal welfare, the provision of water-sources and, until recently, the requirement for stock-proof fencing and handling pens. Livestock are also susceptible to dog attacks. Fencing is expensive, visually intrusive, difficult to install on undulating topography and risks fencing out other areas than need grazing. It may also attract local opposition, sometimes leading to fence-cutting, so effective engagement and communication with site users is important (Denning *et al*., 2024). Conventional fencing can now be replaced by 'virtual fencing' that combines GPS with an audio cue and electrical stimulus. Although challenging to set up and monitor, this technology is cheaper than fencing and has been shown to be successful for cattle and sheep (Marini *et al.,* 2018). It has not been trialled for ponies and has only just started to be used on the Sefton dunes.

Figure 10. Belted Galloway cattle on Ainsdale Sandhills LNR, December 2021

Houston (2008a, b) reviewed several publications on grazing by livestock on coastal duneland, finding that its benefits outweighed the few negative side-effects. He concluded that grazing had been the most important form of land management for maintaining the open character of fixed dunes and dune-slacks, especially in northern countries. Conservation grazing was partly a 'trial-and-error' approach and should be a long-term commitment. However, grazing alone did not counter all the problems associated with scrub development (Oosterveld, 1985). Where dense scrub was already present, it should first be removed (van Dijk, 1992). Furthermore, where soil organic matter has accumulated, turf-stripping or short periods of intensive grazing may be necessary to restore the habitat.

Cattle

Cattle can cope with taller grasses and are the least selective of the main grazers used on duneland. Advantages include their ability to browse and de-bark woody plants and force their way through scrub. However, they are prone to graze near water sources and tend to herd together, sometimes creating issues of poaching and compaction. Breeds commonly used are Highlands, Galloways, Welsh Blacks, Dexters, Shorthorns and English Longhorns, all being tolerant of poor-quality forage and not requiring supplementary feeding (Denning *et al*., 2024; Nugtereu, 2023). A disadvantage is the need for ear-tagging and regular testing for Bovine TB. The site manager must also provide cattle movement records.

Using permanent plots and exclosures, Aptroot *et al*. (2007) studied the role of cattle in maintaining plant species-richness in humid dune slacks on the Wadden island of Vlieland. They concluded that cattle grazing could stall succession towards shrubby vegetation but, to maintain the full range of typical slack species, additional management was needed. This could include mowing, if topography allowed, while to retain pioneer specialists, turf-stripping may be required. Kooijman (2004) compared four Dutch coastal dune systems where mowing was applied for seven years with nine that were grazed by cattle for at least five years. Both treatments successfully countered tall-grass encroachment. Mean above-ground biomass was reduced at all sites, while available light at the soil surface and species richness both increased. She further concluded that soil acidification and ongoing succession were retarded to some extent.

Winter grazing for about 11 years by 'heritage' breed cattle (Fig. 10) achieved the desired condition on the fixed-dunes on Ainsdale Sandhills LNR but did not prevent scrub

invasion, mainly by Sea Buckthorn, birch (*Betula* spp.) and willow (*Salix* spp.), in the slacks (personal observations). The increasing dominance of these shrub and tree species led to Sefton Council removing them mechanically from 18 slacks in the LNR during the 2020/21 winter, followed by similar work in other slacks in 2023/24 (Fig. 11).

Figure 11. Heavy machinery uprooting scrub in Ainsdale LNR slacks, February 2021

Sheep

Sheep are selective grazers that tend to avoid tall and coarse vegetation, though when there is little choice, they will generally graze whatever is available, including woody plants and invasives. Hardy breeds, such as Hedrideans and Herdwicks, are preferred. They are more agile than cattle and will graze steeper slopes, creating patchy short grassland. A downside is that sheep may target summer flowers and will, therefore, often be more suitable for winter grazing. Areas of dense bramble should be cleared to prevent sheep getting tangled. On publicly accessible sites, such as the Sefton dunes, sheep are highly susceptible to dog attacks, especially during pregnancy (Hoffmann *et al.*, 2005; Nugtereu, 2023).

Despite vegetation management by sheep-grazing for about 20 years on Cabin Hill NNR, Sefton (Fig. 12), Smith (2012) reported that bare sand patches had become almost entirely overgrown; areas of Creeping Willow had expanded, while larger willow spp. increased in frequency and stature. He attributed these changes partly to ecological

succession following disturbance caused by sand-winning in the 1950s, the almost complete loss of a formerly large Rabbit population since 2000 and ongoing aerial deposition of nitrogen. In recent years, clearance of larger willows in the Cabin Hill NNR grazing enclosure was supplemented by mowing drier parts of slacks and fixed dunes dominated by dense Creeping Willow and coarse grassland. It was hoped that this, coupled with winter sheep-grazing, would restore the previously diverse open vegetation and might even encourage the return of Rabbits. A recent increase in Roe Deer (*Capreolus capreolus*) sightings and footprints (personal observations) may add to grazing and browsing pressures both here and elsewhere on the Sefton dunes.

Figure 12. Herdwick Sheep on dune grassland, Cabin Hill NNR, February 2014

Ponies

Many dune managers prefer to use ponies or horses, if available (Fig. 13). They are less selective than sheep and, not having a rumen, require a higher intake of vegetation than cattle or sheep. Also, their dung is less nutrient-rich. They create short-grass pasture but have less impact on shrubs than other grazers. Suitable breeds include Highland, Exmoor, Dartmoor, Dales, Fell, Shetland, New Forest and Welsh Mountain (Denning *et al*., 2024; Nugteren, 2023).

Other mammalian grazers and browsers

Being browsers rather than grazers goats are suitable for the control of scrub and trees. However, they are difficult to fence in. Perhaps because of challenging husbandry issues, goats have not often featured in dune grazing projects. However, Bullock & Kinnear (2010) reported on a three-month pilot study using goats to control birch and willow scrub in a dune-slack at Tentsmuir Point NNR, Fife. A high stocking density of 32 goats/ha reduced scrub biomass by almost 50%, while there was little impact on the ground and herb layers. They concluded that goats may be suitable for scrub control where the main conservation interest is in ground or herb layers and where hand removal or herbicide treatment is unacceptable. In recent years, goats have been used occasionally on Freshfield Dune Heath Nature Reserve, Sefton, to browse Gorse (*Ulex europaeus*) and birch scrub (Fig. 14) but no quantitative data are yet available to judge their effectiveness.

Donkeys were trialled in Flemish dune nature reserves by Hoffmann *et al*., (2005). These animals spent 16-27% of their time in scrub but grazing pressure was minimal. They did not move through dense scrub patches, so their actions were mainly restricted to the edges. One bonus from using donkeys was that the invasive Wood Small-reed (*Calamagrostis epigejos*) formed a high proportion of their diet. In a 100 ha Flemish dune nature reserve, Couvreur *et al.* (2005) donkeys roaming over the whole reserve dispersed the seeds of 20% of the higher plants.

Figure 13. Welsh Mountain ponies in North Wales

Figure 14. Golden Guernsey goat browsing Gorse, Freshfield Dune Heath, March 2017

Perhaps the most inventive dune grazing project so far attempted is the introduction, since 2007, of the European Bison (*Bison bonasus*) to Kraansvlak dunes, part of the Zuid-Kennermerland National Park in The Netherlands. Living in association with Konik ponies and Highland cattle in a rewilding project, the bison survived and bred well, without supplementary food, at a density of about 1/15 ha. Preliminary results indicated that they reduced woody plant cover. It is hoped Bison will help suppression of scrub encroachment, while maintaining grassland/scrub/woodland mosaics (Cromsigt *et al.*, 2017).

Van der Spek (2024) described the effects of Fallow Deer (*Dama dama*) on the Amsterdam Waterworks Dunes in the Netherlands. Numbers of deer increased exponentially after 2000, reaching a peak density of about 200/km^2 in 2016. Large impacts on vegetation and vegetation structure, due to grazing and trampling, were recorded. Characteristic dune plants, including rare species, declined “alarmingly”. There were also adverse effects on monitored fauna, including butterflies, moths, bees, hoverflies, as well as some mammals and birds. Management to reduce the Fallow Deer population to more sustainable levels was underway.

Mixed livestock types

Several studies advocate a mixture of livestock types, for example sheep with cattle, these being more successful than a single type. In Sweden, the view was that grazing animals should move over large areas, creating a mosaic of well-grazed patches interspersed with taller vegetation. Grazing pressure should be light to moderate in the summer but can be higher in autumn and winter, this being adjusted to take account of palatable biomass. Boorman & Boorman (2001) advocated low levels of grazing, namely 0.06-0.3 livestock units (LU)/ha, to maintain dune grassland but a higher rate for restoration projects. Jones *et* al. (2021) thought that 0.1 to 0.3 LU/ha/yr would be a reasonable level. However, Edgar *et al*. (2010) warned that stocking rates often used for conservation management may have adverse effects on reptiles. Anything above 0.2 LU/ha produces large patches of very short vegetation lacking structure and removing tall stands required for cover and prey. However, controlled grazing can benefit reptiles by limiting the spread of shading scrub, diversifying vegetation structure and creating areas suitable for basking amongst denser stands. Edgar *et al.* (2010) recommended that small sites (≤5 ha) supporting reptiles should not be grazed. Special care was needed where Sand Lizards are present. Thus, Moulton & Corbett (1999) claimed that grazing animals can be highly damaging to habitats used by Sand Lizards and that grazing should be avoided on 'foci' of this species. Natterjack Toads require short, open vegetation for foraging (Smith & Skelcher, 2019), thereby creating a potential conflict of management aims if both Sand Lizards and Natterjacks occupy the same site, as in the Sefton dunes.

In a long-term study at Sandscale Haws, Cumbria, Pye *et al.* (2020) reported that livestock grazing over several decades played an important role in controlling the development of scrub and coarse grassland but had a limited impact on the extent of bare sand. Furthermore, sheep and cattle preferred to graze the dry dunes, resulting in standing crop increasing in the slacks, as was seen in the Sefton dunes. However, as noted earlier, large areas of Sefton frontal dune are not grazed by livestock. Here, tall Marram and the Marram-False Oat-grass community have become increasingly dominant (Fig. 15). Because of the build-up of dead material, this vegetation is susceptible to fire during droughts. Thus, in March 2013, about 11.5 ha of frontal dune at Ravenmeols LNR/Cabin Hill NNR were burned in a destructive fire (personal observations) (Fig. 16).

Figure 15. Ungrazed frontal dunes dominated by dense Marram at Birkdale Sandhills LNR, December 2021.

Figure 16. Aftermath of a large burn, Ravenmeols LNR, April 2013

At Meijendel, The Netherlands, year-round grazing by Galloway cattle and Fjord horses was introduced in 1990 at one unit per 12-18 ha and the results monitored. After five years, Bonte *et al.* (1999) found that the grazed plots showed an increase in species-richness and a decrease in cover of Wood Small-reed and Sand Sedge (*Carex arenaria*). Tall grass vegetation largely disappeared while areas of open sand, sand with moss and lichens and low grass vegetation increased. However, van der Hagen (2022) and van der Hagen *et al.* (2020) continued monitoring for 19 years using aerial photographs. They reported no significant impact of grazing on measured areas of bare sand, grassland or shrubland; ungrazed areas showed the same changes as in those that were grazed. Factors implicated in these unexpected results included the earlier planting of Marram for dune stabilisation, changes in temperature, rainfall and amounts of nitrogen deposition from the atmosphere, the collapse of Rabbit populations due to disease and ecological succession. It was concluded that removal of long-lived indigenous trees, such as Hawthorn (*Crataegus monogyna*) birch and oak (*Quercus* spp.) would be needed to maintain 'priority' dune grassland habitat.

Plassmann *et al*. (2010) reviewed the effects of long-term management by grazing by cattle, sheep and/or ponies for 16 years on sand-dune vegetation at Newborough Warren NNR, Anglesey. Grazing brought about a shift from a tall-grass-dominated, species-poor community to more species-rich vegetation in dry dunes but did not change community types in slacks where hydrology and moisture regime seemed to be more important than grazing in determining vegetation composition. Also, cattle and ponies preferred a drier habitat, while winter flooding would tend to reduce or prevent the grazing of slacks. However, grazing enhanced the frequency of indicator species of conservation interest in both habitat types. Year-round grazing seemed to create more heterogeneity than seasonal grazing but beneficial effects would only be valid at low to medium stocking densities. There was a strong Rabbit population of about 45/ha in the grazed plots, results suggesting that the Rabbits exerted more grazing pressure than ponies. Their experiments indicated that grazing could not fully counteract the effects of atmospheric nitrogen deposition, though Kooijman & Smit (2001) found the opposite, concluding that grazing on The Netherlands dunes could mitigate the effect of increased N-deposition to a large extent.

FitzGibbon *et al.* (2005) reported on a seven-year grazing trial in a 27 ha duneland plot at Braunton Burrows NNR, Devon, involving a mix of cattle and sheep at densities

ranging from 0.12 to 0.49 LU/ha/day. The breeds used included Devon Red cattle and Portland, Soay and Herdwick sheep. Grazing resulted in an increase on species-richness, a significant decline in Wild Privet (*Ligustrum vulgare*) and a reduced extent of Grey Willow. There was also an increase in the frequency of typical dune plants. It was concluded that a mixed grazing regime would help to achieve 'favourable condition' at Braunton but would be insufficient to control established stands of shrubs, which would require mechanical removal. Hoffmann *et al.* (2005) studied livestock grazing regimes following scrub removal in large dune nature reserves on the Flemish coast. The aim was to maintain species-rich calcareous dune grassland and prevent further scrub growth. Ponies, cattle and donkeys showed a strong preference for grassy habitats and forage, none showing much interest in woody plants. The authors concluded that introduced ungulates contributed substantially to management goals, reducing cover of litter-accumulating graminoids, such as Wood Small-reed, Yorkshire-fog (*Holcus lanatus*), False Oat-grass and Sand Sedge (*Carex arenaria*), enabling preferred dune grassland species to colonise gaps in the sward. It was also found that grazers are important dispersal vectors for many duneland plants. However, there was much less impact by livestock on scrub encroachment.

Ford *et al.*, (2022) proposed that cattle or mixed pony/cattle grazing could provide ecosystem services of plant genetic diversity, food provision, cultural environmental appreciation and potential for increased crop pollination.

Effect of grazing on dune invertebrates

Although invertebrates represent a high proportion of the specialist biota of coastal dunes (Litt *et al.*, 2021; Smith, 2023), there is limited information on the impacts of grazing on them. Wallis de Vries & Raemakers (2001) monitored butterfly abundance on calcareous dunes in The Netherlands that had different management regimes, including low-intensity grazing. Although overall species-richness was not affected by grazing, some species of open grassland benefited. They concluded that extensive grazing had the potential to enhance butterfly diversity in restoration projects. Spiders were sampled in botanically-rich, calcareous dune grassland in Belgium. Part of the area was intensively grazed by cattle, while patchy grazing by Rabbits occurred throughout. Species diversity, including some rare taxa, was highest in the transition zone between grazed and ungrazed sites (Bonte *et al*., 2000). Batsleer *et al.* (2022) investigated the impact of sheep grazing on a threatened

digger wasp *Bembix rostrata* at two coastal dune sites in Belgium. Grazing reduced the densities of digger wasp nests, probably due to trampling during the summer months. To reduce the impact, while retaining advantages of dune grazing for floristics and other Hymenoptera, the option of winter-grazing was suggested.

Following a detailed invertebrate survey of Ainsdale Sandhills LNR in 2000, Judd (2002) reported that light grazing and trampling by livestock and Rabbits maintained a varied vegetation structure and was advantageous to sand-dune invertebrates. Kirby (1992) added that disturbance and localised dung enrichment by Rabbits favoured plants such as Common Ragwort and thistles (*Cirsium* spp.) which support important invertebrate assemblages. Within a few years, winter cattle-grazing on Ainsdale LNR produced habitat suitable for a population of Mottled Grasshopper (*Myrmeleotettix maculata*) (personal observations) (Fig. 17), a species known to require open ground and short turf, especially on south-facing slopes (Benton, 2012). The importance of bare ground for invertebrates was reviewed by Key (2000). He points to the value of Rabbit activity, low-level poaching by livestock and even occasional overgrazing in providing the right conditions for a rich and diverse fauna. As well as managing vegetation, grazing mammals produce dung, this being an essential resource for specialist invertebrates (Judd, 2002; Kirby, 1992). One such is the Ainsdale Dung Beetle (*Ammoecius brevis*), a species that is known in Britain only from the Sefton dunes. Having been last recorded in 1996, the beetle was thought to be extinct but seven individuals were re-discovered in 2017, associated with Rabbit droppings on Ainsdale NNR (Watkins & Mann, 2018). A further search In June 2020 by G. Hedges (personal communication) located as many as 82 adult beetles on cow dung in the NNR. Watkins & Mann (2018) recommended low intensity grazing at all seasons so that dung is available throughout the year (Fig. 18).

Figure 17. Mottled Grasshopper female, Ainsdale LNR, August 2021

Figure 18. Cattle dung on well-grazed fixed-dunes, Ainsdale LNR, December 2021

Conclusions

The evidence reviewed here suggests that grazing can often be an important management tool to maintain open habitats for specialist sand-dune biota, thereby preventing or reducing the rate of succession to coarse grassland, scrub and secondary woodland, including invasive species. This is especially relevant under current conditions of increased

stability, overgrowth of bare sand and lower dynamism in the coastal dune systems of Britain and Western Europe, such as Sefton's. Many factors, including aerial deposition of nitrogen and climate change, have been implicated in these changes. As a particularly significant grazer, the Rabbit is considered to be a 'keystone species' in sand-dunes. However, this species has suffered severe population declines in most dunelands, due to disease. Restoring Rabbit populations seems problematic but merits further study. In the relative absence of wild grazing animals, their activities have been replaced or supplemented by domestic livestock. Sheep, cattle, ponies/horses, and less often, donkeys, goats, deer and bison have been used for this purpose, the mix of species, stocking rates and timing being determined according to site characteristics. A variety of livestock types, for example, 'traditional' or 'heritage' breeds of sheep, cattle, and/or ponies is often preferred, as is winter rather than year-round-grazing. A long-term commitment to such management is essential. However, grazing can be detrimental to reptile populations, special care being necessary to avoid adverse impacts. The expense and visual impact of fencing may be mitigated by novel 'virtual fencing' technology. Some studies found that livestock prefer to graze drier habitats, meaning that dune-slacks were often under-grazed, becoming invaded by scrub and trees. Removal of woody plants by machinery or by volunteers working with hand-tools may therefore be needed. Where access and topography allow, annual mowing may be an option to replace or supplement grazing, especially in slacks; this may also help to encourage the return of Rabbits by creating short swards.

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Belted Galloway cattle, improving the condition of fixed-dunes, Ainsdale LNR, February 2021.