Grazing and scrub clearance promote open dune habitat regeneration in pine plantation canopy gaps in Merseyside, UK.

Natalie Hunt[1]*, David Mercer[2] & Anne Oxbrough[1]
[1] *Edge Hill University, St Helens Road, Ormskirk, Lancashire, L39 4QP, UK*
[2] *Natural England, Ainsdale Sand Dunes NNR, Pinfold Lane, Ainsdale, Southport, PR8 3QW, UK*

SUMMARY

Coastal management practices have shifted in recent decades to recognise afforestation of sand dunes as a principle factor in mobile dune system degradation and ecological decline. However, removal of conifer plantations to re-establish dune dynamics may be restricted by the presence of protected species and public antagonism to clear-felling. Alternatives include creation and management of canopy gaps such as glades and firebreaks, but little is known about the ecological value of these features. We investigated the effects of scrub clearance and livestock grazing on habitats and plant communities in pine plantation firebreaks at Ainsdale Sand Dunes National Nature Reserve, Merseyside. The results were compared with nearby open dunes, both unplanted and formerly afforested. Although the open dunes had significantly higher species richness, larger numbers of positive indicator species and significantly lower numbers of negative indicator species, the firebreaks showed signs of dune habitat and plant community recovery 10-14 years after creation. Greater similarity in plant community composition between firebreaks and open dunes occurred in quadrats subject to livestock grazing and/or regular scrub clearance. We conclude that managed canopy gaps within existing pine plantations can increase valuable dune habitat and provide an alternative where large-scale clear-felling is not feasible.

BACKGROUND

In the last 100 years, about 40% of UK coastal dune systems have been lost (Doody 2001), whilst 85% are considered threatened in Europe (Everard *et al.* 2010). Dune systems support a wide range of complex habitats attracting many national and international conservation designations. Historically, sand-drift associated with dynamic dunes was viewed negatively and stabilisation techniques including tree planting were widely used. Since the 1980s, the emphasis in coastal management has changed from sea defence objectives to more sustainable, long-term promotion and restoration of natural dynamism. Afforestation is known to interfere with the natural progression of sand dune erosion and accretion, lower water tables, fragment habitats and reduce biodiversity (Everard *et al.* 2010). However, public attitudes to trees and the attachment of some land managers to stabilised landforms have often impeded dune restoration (Rooney & Houston 2009).

Owned and managed by Natural England (NE), Ainsdale Sand Dunes National Nature Reserve (NNR) protects part of one of the most species-rich calcareous dune systems in northwest Europe. Established in 1965, the 508 ha NNR (Figure 1) is located within the Sefton Coast Special Area of Conservation (SAC) and Site of Special Scientific Interest (SSSI).

The reserve includes around 157 ha of pine plantation, established on dunes mostly between 1920 and 1934. There are two main blocks known as the Rear Woodland and Frontal Woodlands, both of which are dominated by Corsican pine *Pinus nigra* ssp. *laricio*. The 117 ha Rear Woodland is a stronghold for the red squirrel *Sciurus vulgaris* and so has limited potential for open dune habitat restoration. The 40 ha Frontal Woodlands, however, flanks an eroding coastline and is in poor condition. Research comparing seed banks of dunes, pine plantations and clearings (e.g. Sturgess & Atkinson 1993 and Lemauviel *et al*. 2005) has shown it is feasible to restore original dune flora following clear-felling, or at least create a similar habitat of greater conservation value than a pine plantation. As such, the Frontal Woodlands were targeted for dune restoration, with around 20 ha of pine clear-felled between 1992 and 1996; this newly open habitat was then managed by winter sheep-grazing. Subsequent monitoring showed a rapid return of characteristic dune plant communities and rare species (Skelcher 2010; Smith & Lockwood 2011). However, adverse public reaction to tree-felling led to a moratorium on further felling works. A less contentious management approach could satisfy both NE's legal obligation to achieve "Favourable Condition" status and the need to maintain local coastal landscape character, which includes pine plantations on the dunes. This study sought to establish if, as an alternative to large-scale clear-felling, managed (e.g. grazing, scrub clearance, undisturbed) canopy gaps, such as glades and firebreaks, leads to recovery of typical open dune habitats and plant species.

* Corresponding author: natalie@gurumoore.co.uk

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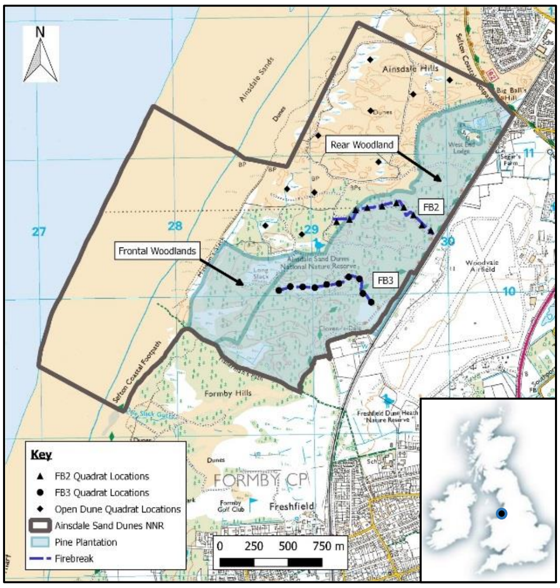

Figure 1. Ainsdale NNR boundary, pine plantation, firebreak and quadrat locations. Inset: NNR location within the UK (NE GIS database).

ACTION

Two firebreaks (FB2 and FB3) within the Rear Woodland were compared with two nearby areas of open fixed dunes and slacks (Reference habitats). Part of the open dune area was fenced for winter-grazing, mainly by sheep. Orientated approximately east-west and from around 25 to 80 m wide, the firebreaks were established between 2003 and 2007 with subsequent management being either grazed, grazed with regular scrub clearance, regular scrub clearance or unmanaged.

To determine the 'typical' plant communities of the open dunes, 10 sampling positions, comprising a 10 x 10 m quadrat with a centrally placed 2 x 2 m quadrat, were established in representative stands of vegetation (Rodwell 2000) across the Reference habitats (Figure 2). Quadrat locations (Figure 1), determined from site maps beforehand, were approximately evenly spaced across the open dunes (mean distance apart of 650 m) and included formerly afforested, unplanted, managed and unmanaged areas. Shrubs and other woody plants were identified in the 10 m quadrats, while herbaceous vascular taxa were recorded in the smaller units. Percentage cover of each species was estimated and converted to Domin values (Rodwell 2000). Presence and total percentage cover of bryophytes and macrolichens were estimated but not individually identified. In the firebreaks, interrupted belt transects (Yamamoto *et al*. 2011) were established along centre lines (Figure 1), comprising 10 stations with 10 x 10 m and 2 x 2 m quadrats arranged as above, evenly spaced along each transect (mean distance apart of 150 m). Species recording was the same as on the open dunes. Management treatments as above were recorded for each quadrat, together with any observations of rabbit *Oryctolagus cuniculus* activity (e.g. dunging, scraping and burrowing). All sampling took place in June 2017.

Using UK National Vegetation Classification (NVC) methodology, floristic tables were derived for each habitat (e.g. FB2, FB3 and open dunes) and plant communities identified with reference to the keys and descriptions in Rodwell (2000). Mean vascular plant species richness, together with positive and negative indicator species for each habitat, were obtained from the quadrat data. The indicator species are listed by Natural England (2017) as part of the criteria used to define "Unfavourable" and "Favourable" Condition status. Birch *Betula* spp., sycamore *Acer pseudoplatanus*, white poplar *Populus alba* and, to a lesser extent, pine *Pinus* spp., oak *Quercus* spp., gorse *Ulex europaeus*, rowan *Sorbus aucuparia* and hawthorn *Crataegus monogyna*, contributed to scrub cover in the firebreaks. Although not listed as negative indicator species by Natural England (2017), these woody species are controlled in the open dunes as part of NE's target of achieving no more than 5% scrub cover. It was therefore decided to include them as negative indicators.

Figure 2. Examples of: (**a**) a canopy gap quadrat (FB2) subject to cattle grazing and scrub clearance, **(b)** a canopy gap quadrat (FB2) not regularly managed, overgrown with birch, **(c)** a canopy gap quadrat (FB3) grazed by cattle, Shetland cows in the background with vegetation mosaic, (**d**) a canopy gap quadrat (FB3) not regularly managed and overgrown with scrub vegetation, (**e**) an open dune quadrat grazed by sheep, and (**f**) an open dune quadrat grazed by sheep and favoured by rabbits.

All statistical analyses were completed in the free R software (R Core Team 2016). Differences in vascular plant species richness and positive/negative indicator species between habitats were assessed using one-way analysis of variance or Kruskal-Wallis, depending on normality and homogeneity test outcomes, with Tukey's or Kruskal-Nemenyi *post-hoc* tests respectively. The effects of

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management on species richness and positive and negative indicators were investigated using generalised linear models (GLM), assuming a Poisson distribution (using quasi-Poisson when the model was overdispersed i.e. when the residual df was greater than the residual deviance). Using the glht function of the 'multcomp' package (Hothorn *et al*. 2008), post-hoc pairwise comparisons of significance were undertaken. Redundancy analysis (RDA) was used to investigate community composition of all plant species and positive indicator species only, with site and management treatment as fixed factors.

CONSEQUENCES

A total of 85 plant species was recorded for both the open dunes and firebreaks. Of the 67 taxa found in the open dunes, 45 were associated with fixed dunes and dune grassland while 48 were found in dune slacks. In the firebreaks, 34 plant species were found in FB2 and 47 in FB3. Positive indicator plants were recorded as follows: 38 in the open dunes (including three orchid taxa); 10 in FB2; and 13 in FB3. The firebreaks supported no orchids. Five negative indicator species were found in the open dunes and 15 in the firebreaks (10 in FB2 and 14 in FB3). Indicators of local distinctiveness, namely early marsh-orchid *Dactylorhiza incarnata*, marsh helleborine *Epipactis palustris* and dune fescue *Vulpia fasciculata,* were identified within the open dune quadrats, but none were found in the firebreaks.

Using NVC keys and descriptions in Rodwell (2000), the slack quadrats in the open dunes revealed the presence of SD14 *Salix repens-Campylium stellatum* and SD16 *Salix repens-Holcus lanatus* communities with SD15 *Salix repens-Calliergon cuspidatum* and SD17 *Potentilla anserina-Carex nigra* slack types more prevalent in the northern part of the reserve. Fixed dunes/dune grassland within the grazing enclosures had a mosaic of SD7 *Ammophila-Festuca rubra* and SD12 *Carex-Festuca-Agrostis* dune grassland, the latter being represented by two sub-communities: *Holcus lanatus* or, occasionally *Anthoxanthum odoratum*. Outside the grazing enclosures, SD9 *Ammophila arenaria–Arrhenatherum elatius* dune grassland was also identified. FB2 showed a transition from SD16 dry calcareous dune slack community to SD12 acidic dune grassland in areas subjected to grazing and/or regular scrub clearance. Where firebreak management intensity was considerably less, plant communities closely resembled OV27 *Epilobium-angustifolium* open habitats (sub-communities a-c), typical of secondary forest vegetation following clearance.

Mean species richness (ANOVA $F_{2,27} = 4.36$, $p = 0.023$), positive indicator species richness (GLM $X^2_{2,27} = 50.87$, $p < 0.001$) and negative indicator species richness (ANOVA $F_{2,27} = 10.21$, $p < 0.001$) differed significantly between habitats (Figure 3). Post-hoc testing showed no significant differences in species richness between the firebreaks themselves or between FB3 and the open dunes. FB2 however, was significantly different in species richness compared to the open dunes. Negative indicator species were lower in the open dunes compared to both firebreaks. Significant differences in species richness (GLM $X^2_{3,24} = 41.78$, $p < 0.001$) and positive indicators (GLM $X^2_{3,24} = 35.82$, $p <0.001$) were recorded between management treatments with species richness and numbers of positive indicators higher where grazing and/or scrub clearance had been undertaken.

Redundancy analysis distinguished between the plant communities of open dunes and firebreaks for both overall plant species and positive indicator species (Figure 4). Both models were significant ($p <0.001$). Overall, for grazed quadrats (with and without additional scrub clearance), plant community composition differed compared to 'not regularly managed' quadrats. Firebreak quadrats subject to grazing and/or scrub clearance, were more similar in species composition to managed open dune quadrats for both overall plant species and positive indicators.

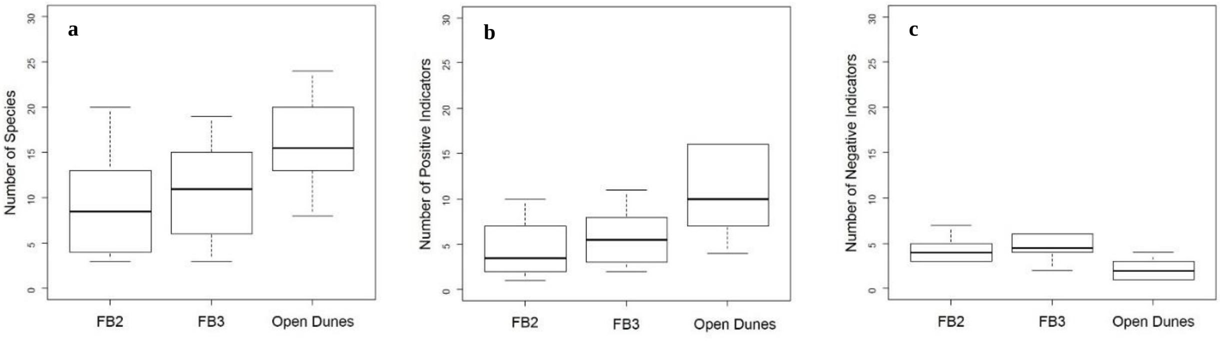

Figure 3. Comparison of plant species richness across two canopy gaps (firebreaks: FB2, FB3) and reference open dunes in June 2017 (n = 30). **(a)** total plant species richness, **(b)** positive indicator species, **(c)** negative indicator species. Boxplots show median (horizontal line), interquartile range (boxes) and 1.5 times interquartile range (whiskers).

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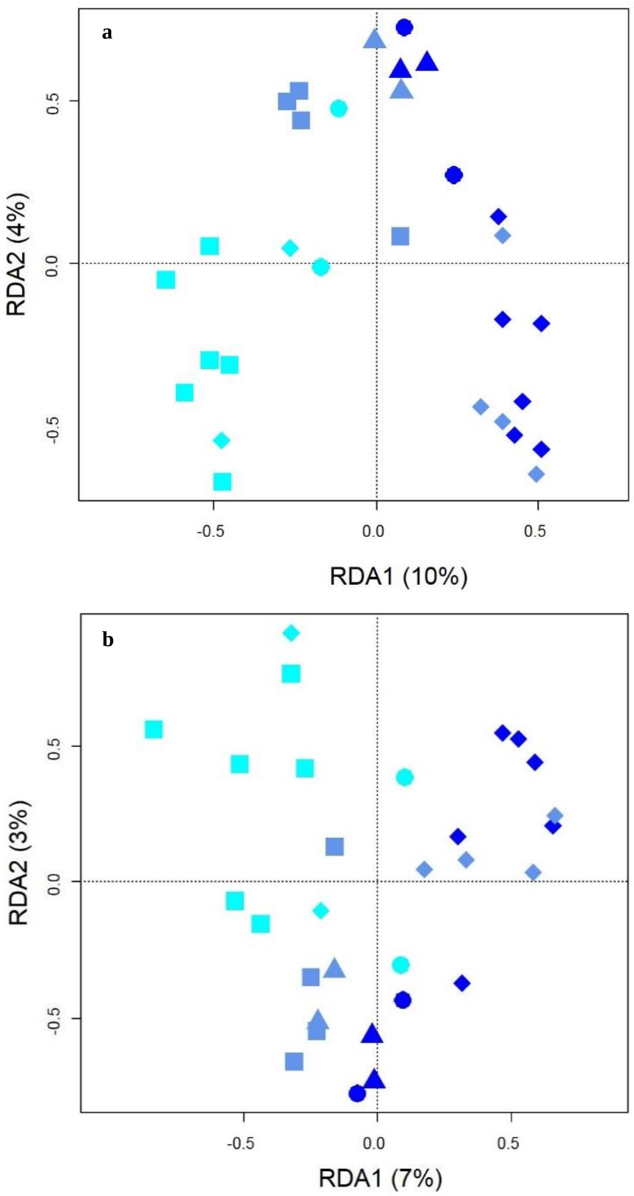

Figure 4. Redundancy analysis (RDA) of quadrats. **a)** total plant community composition, **b)** positive indicator plant composition. Points closer together on the figure indicate greater similarity in plant community composition.

Key:

FB2, FB3, open dunes

■ grazed, ● grazed and regular scrub clearance, ▲ regular scrub clearance, ♦ not regularly managed.

DISCUSSION

This study showed that although plant community composition was different between the firebreaks and open dunes, within 14 years of clear-felling, a level of dune habitat recovery is evident with the firebreaks developing mixed acidic grassland and dry calcareous slack species-rich sward, sharing up to 45% of plant species and up to 39% positive indicator species with the open dunes.

Given the age of the Ainsdale NNR pine plantations (typically > 70 years old), it is unlikely that most of the dune species present in the firebreaks have regenerated from the original seed bank (Sturgess & Atkinson 1993). This suggests that clear-felling alone is not enough to regenerate typical dune habitats. However, firebreak quadrats subjected to regular scrub clearance and cattle grazing (five Shetland cows) were closer in plant community composition to the open dunes, the latter having been winter/spring grazed by sheep since the early 1990s. In addition, observed rabbit activity became less widespread the more overgrown the quadrat, reflecting their preference for sparse, patchy vegetation provided by the livestock grazing, and avoidance of later successional stages (grasses and scrub) where food quality is lower.

Herbivores are important contributors to natural seed dispersal. The domestic livestock used at Ainsdale NNR likely contributes to seed inputs in the firebreaks from the wider reference areas (by seed both attached and passed through the animals), reflected particularly in FB3 which is surrounded by trees and has no direct access to nearby open dunes, effectively reducing the usual wind/seed rain dispersal mechanisms. This is consistent with studies that have found livestock successfully assisted with plant species colonisation and promoted biodiversity when either free-ranging or moved from target communities to restoration areas (e.g. Cosyns *et al*. 2005, Freund *et al*. 2014). Livestock grazing at low to medium stocking levels, preferably a combination of sheep and cattle (Burton 2001), reduces tall grass, increasing overall species composition and diversity, with a positive effect on indicator (Plassmann *et al*. 2010) and rare species (Smith & Lockwood 2011). In dune systems, effective grazing to augment existing rabbit populations, supplemented by regular scrub clearance, are essential to provide appropriate environmental conditions for seed germination, maintain species richness and vegetation mosaics. However, a careful balance between stock numbers and time spent in managed canopy gaps is needed to avoid the negative effects of overgrazing (Millett & Edmondson 2013).

Where restoration of coastal dynamics through clear-felling is restricted by the presence of protected species or other factors, this study demonstrates that creation and management of canopy gaps such as glades and firebreaks can produce valuable dune habitat in relatively short timescales.

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REFERENCES

Burton P. (2001) Grazing as a management tool and the constraints of the agricultural system: a case study of grazing on Sandscale Haws Nature Reserve, Cumbria, Northwest England. Pages 80-85 in: *Coastal Dune Management, Proceedings of the European Symposium Coastal Dunes of the Atlantic Biogeographical Region, Southport, September 1998,* Liverpool University Press, Liverpool.

Cosyns E., Claerbout S., Lamoot I. & Hoffman, M. (2005). Endozoochorous seed dispersal by cattle and horse in a spatially heterogeneous landscape. *Plant Ecology*, **178**, 149-162.

Doody J. P. (2001). *Coastal Conservation and Management: An Ecological Perspective, Conservation Biology Series, 13*. Springer, Netherlands.

Everard M., Jones L. & Watts B. (2010). Have we neglected the societal importance of sand dunes? An ecosystem services perspective. *Aquatic Conservation: Marine and Freshwater Ecosystems*, **20**, 476-487.

Freund L., Eichberg C., Retta I. & Schwabe A. (2014). Seed addition via epizoochorous dispersal in restoration: an experimental approach mimicking the colonization of bare soil patches. *Applied Vegetation Science*, **14**, 74-85.

Hothorn T., Bretz F. & Westfall P. (2008). Simultaneous Inference in General Parametric Models. *Biometrical Journal,* **50** (3), 346-363.

Lemauviel S., Roze F. & Clement B. (2005). A Study of the Dynamics of the Seed Banks in a Complex Dune System, with the Aim of Restoration. *Journal of Coastal Research*, **21** (5), 991-999.

Millett J. & Edmondson S. (2013). The impact of 36 years of grazing management on vegetation dynamics in dune slacks. *Journal of Applied Ecology*, **50**, 1367-1376.

Natural England (2017). Definitions of Favourable Condition for designated features of interest, Consultation Draft V.2.

Plassmann K., Laurence M., Jones M. & Edward-Jones G. (2010). Effects of long-term grazing management on sand dune vegetation of high conservation interest. *Applied Vegetation Science*, **13**, 100-112.

R Core Team (2016). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.r-project.org/.

Rodwell J. S., ed. (2000). *British Plant Communities, Volume 5, Maritime Communities and Vegetation of Open Habitats*. Cambridge University Press, Cambridge.

Rooney P. & Houston J. (2009). From wasteland to joy land – changing attitudes to coastal dunes. *ECOS*, **30** (2), 50-57.

Skelcher G. (2010). Ainsdale Sand Dunes NNR – NVC Monitoring of Dune Restoration Area, 2010. Unpublished report for English Nature.

Smith P. H. & Lockwood P. A. (2011). Grazing is the key to the conservation of *Gentianella campestris* (L.) Börner (Gentianaceae): evidence from the north Merseyside sand-dunes. *New Journal of Botany*, **1**, 127-136.

Sturgess P. & Atkinson D. (1993). The clear-felling of sand-dune plantations: soil and vegetational processes in habitat restoration. *Biological Conservation*, **66**, 171-183.

Yamamoto S., Nishimura N., Torimaru T., Manabe T., Itaya A. & Becek K. (2011). A comparison of different survey methods for assessing gap parameters in old-growth forests. *Forest Ecology and Management*, **262**, 886-893.

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