Dune Gardening? A critical view of the contemporary coastal dune management paradigm

Accepted for publication in *Area.* The information, practices and views in this article are those of the authors and do not necessarily reflect the opinion of the Royal Geographical Society (with IBG).

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Article type: Regular paper

Abstract: Modern coastal dune management is viewed largely through the prism of dune ecology. Achieving maximum biodiversity and preserving priority species are the primary objectives and management is based on interventions (grazing, mowing, burning, reseeding, and artificial destabilisation) to achieve that purpose. Under non-managed conditions, dune vegetation tends to evolve temporally following well-established succession patterns that lead to a low diversity scrub or woodland. Achieving high diversity involves resisting succession so as to preserve the more biodiverse, earlier stages. The net

effect of management is to create dunes with a network of vegetation types that conform to human wish lists. Rather than natural environments, such interventions reduce dunes to the status of parklands. The natural status of NW European dunes under the conditions of relatively stable sea-level and generally limited sand supply over the past few thousand years, and certainly since the Little Ice Age (1650-1800), is to be at a relatively well-vegetated and advanced stage of succession. Modern dune management effectively amounts to a form of 'dune gardening' to maintain a status that is not natural (i.e. attuned to the ambient environment) under contemporary conditions nor those of the past two centuries. Current practice is based on a human value-judgement that views natural succession as the enemy. This view and the resulting actions to resist natural change are at variance with the more pervasive environmental management goal of maintaining natural systems by resisting human intervention. Such an approach reduces dune resilience to global climate change. We advocate an approach that views dunes as combined geomorphological and ecological systems capable of change in response to changing environmental drivers.

Acknowledgments: This is a contribution to the UK Natural Environment Research Council grant NE/F019483/1

Funding information: UK Natural Environment Research Council (Grant number: NE/F019483/1)

Data availability statement: Data sharing is not applicable to this article as no new data were created or analyzed in this study.

Article type : Regular Paper

"All that in this delightful garden grows,

should happy be,and have immortal bliss".

(E. Spenser, The Fairy Queen, 1758.)

1 INTRODUCTION

Coastal dunes form as a result of accumulation of wind-blown sand adjacent to sediment sources (usually beaches). Outside arid areas, coastal dunes are at least partially vegetated whereupon a complex system develops that involves feedback between vegetation type, sediment dynamics and dune form (Hesp, 2008). The frontal sections of coastal dunes may be dynamically linked to the adjacent beach and provide sediment during periods of erosion, usually associated with storms. More landward sections beyond the influence of periodic wave-erosion may become stabilised by vegetation or continue to evolve under the influence of wind action and instability. Sustained vegetation growth and subsequent soil formation usually follows a succession as the dune evolves (Jones et al., 2008). The succession is strongly influenced by both local and more general climatic drivers but typically involves change from pioneer flora through grasses to more woody vegetation (Miller et al., 2010). At some stage in the succession, maximum diversity is reached (Isermann, 2011). Because succession leads to a decrease in habitat diversity, animals and plants associated with early stages of dune development tend to disappear. In Great Britain these include sand lizards

(*Lacerta agilis*), natterjack toads (*Bufo calamita*) and petalwort (*Petallophyllum ralfsii*), all of which are rare and protected species (Edmonson and Velmans, 2001).

As well as being specific habitats, coastal dunes, however, are part of the larger dynamic coastal sedimentary system. As such, they are controlled by the interplay of a range of variables and processes, including littoral sediment budgets, wave and wind climate, tidal regime, and sediment characteristics (Pye, 2001; Delgado-Fernandez et al., 2019). As a result, they contain a large range of physical dune forms that make up a myriad of habitats at various stages of maturity within individual dune fields and between dune field locations. Regional studies have shown that coastal dunes respond to climate variability at centennial to decadal timescales by changes in the amount of vegetation cover (e.g. Orford et al., 1999; Jackson and Cooper, 2011; Jackson et al., 2019a) and the degree to which they are mobile/transgressive (e.g. Jackson et al., 2019b; Gao et al., 2020).

Initially because of their shelter and foraging resources and latterly their arable and grazing potential, there is a long record of human interaction with coastal dunes globally (Martinez et al., 2013). Their proximity to coastal settlements has resulted in many dunes being destroyed (Feagin et al., 2005) through construction and/or mining. Van der Muelen and Salmann (1996) report that 75% of Mediterranean coastal dunes were damaged or destroyed in the previous 30 years. 25% of Europe's coastal dunes have been destroyed since1900 (Heslenfeld et al., 2004) and 55% of the remaining coastal dune area has lost its natural character (Delbaere, 1998). In NW Europe, and additional to a range of land uses such as agriculture (Provoost et al., 2001) many remaining dunes are currently occupied by golf courses (e.g., Stubbs, 2001) or military training grounds (Packham and Willis, 2001). Consequently, much attention has been devoted to the need for conservation of remaining coastal dunes, not least because of the ecosystem services they deliver (Everard et al., 2010).

As noted by Bonte and Hoffmann (2005, p 6.) "Within the coastal dune system a dynamic, stressed and unconstrained landscape phase is distinguished…The dynamic landscape is characterized by highest diversity of system specific species, which are often threatened at a regional and international scale". Dune management's ultimate aim is to maximise biodiversity and preserve key species (Westhoff, 1987). To do so, it actively intervenes to resist successional changes taking place within coastal dune systems. This highly interventionist approach which we here label as largescale 'dune gardening', may involve one or more of the following: removal of woody vegetation, mowing, burning, planting, controlled grazing, addition of nutrients, physical manipulation of the dune surface (excavation, destabilisation, construction), removal of exotic vegetation, regulation of human activity, all of which are utilised in gardening. ("Gardening: the laying out and care of a plot of ground devoted partially or wholly to the growing of plants such as flowers, herbs, or vegetables": www.britannica.com/science/gardening).

In this paper, we challenge this interventionist management of dunes and, instead, in an era of rapid climate change, advocate managing coastal dune systems as dynamic geomorphic *and* ecological systems. Drawing largely on European examples 'dune gardening' seems especially prevalent, the paper describes current biodiversity-dominated dune management approaches. This is then assessed in terms of the natural evolution and development of dunes in response to changing environmental conditions.

2 COASTAL DUNE MANAGEMENT

Coastal dunes are present worldwide in association with sandy beaches (Martinez et al., 2008). It has long been recognised that human interactions with coastal dunes require management in order to prevent degradation and destabilization (Carter et al., 1992). Nature conservation and, latterly (since the 1993 adoption of the Convention on Biological Biodiversity), preservation of biodiversity have been key drivers of coastal dune management policy and practice globally. In Europe for example, a key driver of dune management has been the EU Council Directive 92/43/EEC on the Conservation of Natural Habitats and of Wild Fauna and Flora, (the Habitats Directive). Its main aim is "to contribute towards ensuring biodiversity through the conservation of natural habitats and wild fauna and flora …" (Article 2). The Directive includes measures for conservation of features in the landscape which are important for wildlife, and the protection of listed species from damage, destruction, or over-exploitation. Member states select, designate, and protect Special Areas of Conservation (SACs) which are intended to form a coherent ecological network known as Natura 2000 (Hopkins and Radley, 2001). Against this background individual countries have developed responses to dune management that are geared to compliance with the Habitats Directive.

For example, UK guidance for managing sand dune habitats (JNCC, 2004) specifies the following specific targets for "fixed dune grassland":

- 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.

These guidelines are predominantly driven by ecological and biological targets. There is some recognition that vegetation structure might change due to natural dynamism, for example, but overall biodiversity ´should not diminish´ (JNCC, 2004, page 17). Other policies such as the UK Habitat Action Plan for sand dunes (which derives from the UK Biodiversity Action Plan (UKBAP) in 1994) also select key species and habitats in need of action plans based on whether these species have seen a decline in previous years, are endemic, or are covered by relevant Directories (Duncan, 2001) and guidelines for rare dune species have been prepared as part of a national "Species Recovery Programme" (Beebee and Denton 1996, Moulton and Corbett 1999).

This view of the landscape as a semi-fixed mosaic of particular habitats and species is opposite to what we know of coastal dune behaviour at time scales applicable to management (years to decades). Natural disturbances such as storms or changes to littoral sediment budgets can "reset to bare sand" portions of or even entire dune fields (Delgado-Fernandez et al, 2019b; Jackson et al. 2019b) and internal drivers (vegetation succession) in temperate environments naturally lead to changes in the vegetation cover and ultimately to dune systems with low biodiversity (Boorman and Boorman, 2001).

Additional to their strong ecological bias, dune management guidelines are often focused on managing the landscape, not human stressors. This is markedly different to environmental management based on identifying stressors to coastal dunes caused by human pressure (Lithgow et al., 2015) or recent calls for re-focusing dune management on preventing human impacts and landscape interventions (Delgado-Fernandez et al., 2019a).

3 DUNE MANAGEMENT TECHNIQUES

The overarching goal in contemporary coastal dune management is preserve and maximise biodiversity (Heslenfeld et al., 2004). A voluminous body of research has been generated into the utility and effectiveness of various techniques to enhance biodiversity. The key approaches and their justifications are outlined below.

3.1 Grazing

Grazing has long been used as a management technique to increase biodiversity levels (Oates et al., 1998; Simpson et al., 2001) because grazing animals can limit the growth of "rank vegetation" (Boorman and Boorman, 2011; p. 161). It is also seen as a sustainable habitat management tool (Rooney, 2001) and as a solution to issues derived from *undergrazing* (Davies, 2001). Sometimes it is preferred to mowing because of the "better quality of vegetation" it produces (Packham and Willis, 2001; p. 65). The biodiversity end-product varies spatially and temporally for any given grazing regime, as it depends on the original plant community (Boorman and Boorman, 2001).

The desired outcome may influence choice of grazing animal. "Cattle control some coarse vegetation well, as do ponies; sheep and ponies are more effective in the creation of a short sward" (Packham and Willis, 2001, p. 65). Donkeys prefer grasses and favour leaves rather than "dead and shrivelled plant material" and avoid "browsing of woody species" (Hoffmann et al, 2001, p. 96). According to Boorman and Boorman (2001; p. 166) the 'benefits' of grazing are maximised with mixed grazing regimes that are sustained over time, and "the intensities needed to maintain a well-managed system are very much lower than those needed to restore diversity to a neglected and overgrown system […] "The species diversity of a well-managed dune grassland can be maintained by the grazing of cattle at as low a density as 0.06-0.3 beasts per hectare and dune heath by sheep grazing at stocking rates of 0.2-1 individual per hectare […]. Although high grazing intensities can lead to soil eutrophication the use of grazing as a management tool should aim to limit "aerial biomass around an optimal biodiversity value" (Boorman and Boorman, 2001; p. 164).

3.2 Mowing & Burning

Mowing provides a practical tool for keeping "a short turf" (Doody, 2012). The mean number of vegetation species often increases with mowing, although the response can be species-specific, and vascular plant flora might not benefit from mowing in the long-term (Hewett, 1985). Mown sand dunes show considerably higher diversity levels compared to unmown dune plots, with plant richness increasing 2-3 years after mowing (Anderson and Romeril, 1992). Mowing can lead to issues of soil compaction and destruction of micro-topography, and can be labour-intensive, but has been 'successfully' applied to coastal dunes as a management tool, including the use of forage-harvesters, flail and rotary mowers. Forage-harvesters collect the vegetation following cutting, so this does not remain in the landscape. "Flails tend to produce a cleaner cut, though it is more difficult to rake and collect the chopped-up material. Rotary chains have been found to be more successful than blades, which tend to require more maintenance. Smaller tractors and mowers and low ground-pressure tyres cause less damage to slack topography and therefore microhabitat" (Simpson et al., 2001, p. 265).

Burning is often used to eradicate scrub or tall graminoids. The use of fire alone does not necessarily lead to species rich grasslands, and additional interventions are often recommended such as encouraging sand deposition and clearing away the burned vegetation (Ketner-Oostra et al., 2006). In the Sefton coast, for example, Sea buckthorn was cleared by machinery, burned, and then buried and covered with clean sand to avoid eutrophication (Rooney, 1998).

3.3 Planting

The planting of various vegetation types on coastal dunes has had several objectives, ranging from the cultivation of crops to deliberate stabilisation of mobile sand dunes.The extensive use of planting as a management technique for dune stabilization became widespread towards the nineteenth century(Proovost et al., 2011). These quickly became economic resources at some locations (Paskoff, 2001; Ovesen, 2001) or provided new habitats for endangered species such as red squirrels (Shuttleworth and Gurnell, 2001). Planting of marram grass (*Ammophila arenaria*) for dune stabilisation following heavy trampling or grazing is a widespread restoration technique (Martínez et al., 2013). Indigenous vegetation raised in nurseries has been transplanted to restore New Zealand dunes (Bergin and Kimberley, 1999).

3.4 Landscaping the dune surface

It is also possible to landscape the dune surface with the purpose of creating new habitats or deliberately destabilising fixed coastal dunes to 'rejuvenate' them (Arens et al, 2004; 2005; Darke et al., 2013; Walker et al., 2013; Ruessink et al. 2018, Bar, 2013). Dune rejuvenation measures include mechanical excavation of breaches in frontal dunes to establish sand transport corridors from the beach (Arens et al., 2013), removal of top surface layers and vegetation cover to create deflation basins and troughs, and deposition of the excavated sand.

The ‘requirement’ for large scale interventions reversing contemporary revegetation trends is regarded as urgent because small-scale interventions (e.g. scrapes for Natterjack toads) are not regarded as sustainable. Pye and Blott (2012) maintain that a “minimum of 30-40% [of bare sand is] considered necessary to maintain biodiversity in healthy, dynamic dune systems’ in the UK. The 4 year (2019-2023) ‘Dynamic Dunescapes’ project targets 34 individual dune sites, covering up to 7,000 hectares (35% of all coastal dunes in England and Wales).

4 DISCUSSION

Achieving maximum biodiversity in a coastal dune has become the default approach to management and has generated its own supporting literature on how best to achieve it using some or all of the interventions outlined above. The dune management literature views steps in this direction as positive (common descriptions include *favourable, benefits, better quality, improved, healthy, beautiful flowers*) while advanced succession states are viewed negatively (*rank*, *moribund*). Just like these terms, however, the chosen management goal is based on a human value judgement, i.e. dunes with high biodiversity are preferable. This focus on the essentially static preservation of key species and habitats has dominated dune management practice and effectively reduced it to ‘*dune gardening’* to fight natural succession. Yet, as others have noted in the context of dynamic ecosystems, “biodiversity and environmental quality are not simply proportional … what is a rare species in one state becomes a common one in another. Biodiversity richness *per se* is not necessarily something highly desirable and to be preserved at all costs” (Lovelock, 2007, p 141).

Although current dune management and policy is focused on species and habitats “these exist in an environment where natural and anthropogenic pressures cause change” (Berry et al. 2002, p.10). Dune slack communities, for example, are affected by a range of variables (water table, soils, organic matter content, etc.) all of which naturally change (Freitas et al., 2007; Curreli et al., 2013). Like the coastal systems of which they are a component, dunes are dynamic and highly responsive to climate change at decadal timescales. In the Little Ice Age, dunes were more mobile (Jackson et al. 2019a), and probably had high biodiversity, whereas the present climate favours stability (Jackson and Cooper, 2011; Jackson et al., 2019b), with concomitant advanced succession and lower diversity.

In the face of an understanding that dune geomorphology, habitats, communities and species are responsive to change it is therefore somewhat bizarre that management strives to achieve a static condition that is not even compatible with modern climate conditions.

This situation is in stark contrast to current trends in conservation management. Ecosystem-based management follows an Activity-Pressure-State-Response model (APSR) where an anthropic activity causes pressure in a system (e.g. Kelble et al., 2013). This causes a change in state of an indicator (biodiversity or species abundance) and triggers a management response. The perverse situation in dune management is that natural succession rather than human pressure is the opponent.

To a large extent this situation stems from the inadvertent conflation of the terms "biodiversity" and "conservation" in setting policy and management goals. Rather than conserving coastal dunes as active, dynamic landscape components in the coastal system, current management seeks to achieve maximum biodiversity. To do so it has to invoke the practices described above to fight natural succession and geomorphic change.

We call for a re-think on coastal dune management incorporating strong a geomorphological input and to view management of coastal dunes as self-sustaining systems based on physical landscapes as opposed to the current agenda driven by artificially set biodiversity targets. While much of the coastal dune resource has been lost to development, what is left has high conservation importance. If coastal dunes are to be properly viewed as natural landscape elements, they should be left untouched (aside from removal of invasive species), allowing succession to unfold at its own pace. Instead, we "…have become so concerned over the fate of the rare tree … about rare and beautiful animals … that we have lost sight of the forest itself" (Lovelock, 2007, p 141). Instead we should recognise that "dunes are important for ecology and biology, and hence as a place for 'retaining the whole range of successional stages within coastal systems' (Packham and Willis, 2001; page 66). Coastal dune management should not be a mono-disciplinary activity but needs to consider ecology *and* geomorphology (Lithgow et al., 2015) and incorporate an appreciation of the temporal and spatial scales of system behaviour.

Dunes can be managed for rare species, for biodiversity, for the toads, for the birds, but such goals lead to a landscape that conforms to a species wish-list, not a natural coastal dune. The same situation can also arise in other coastal environments including saltmarshes, lagoons, and sand or gravel beaches. Ongoing planetary-scale changes (e.g., in temperature, storminess, rising sea levels) affect coastal areas and prompt changes in the physical coastal system. Ongoing climate change is affecting species and biodiversity as well (Cheddadi et al., 2020) and caution points to the need to minimise, not increase interventions in coastal systems so they can adapt naturally to changing environmental conditions. If dunes are allowed to evolve naturally there is an opportunity to enhance ecological and geomorphological diversity and allow coastal dunes to achieve their inherent system resilience as changes occur. This approach is more consistent with achievement of "…ecologically representative and well connected systems of protected areas…" (Biodiversity Convention Target 11) than current practice of transforming dune surfaces into eco-gardens.

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