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Constructing notches in foredunes: Effect on sediment dynamics in the dune hinterland

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ABSTRACT

Measurements were carried out on the island of Ameland (The Netherlands) to determine whether notches cut into foredunes stimulated the supply of fresh calcareous beach and dune sand into the white and grey dune habitats behind the dunes, increasing these habitats' biological quality. Sediment characteristics and dynamics (deposition flux and grain size properties) as well as aspects of the vegetation (occurrence, composition and cover density) were studied along six transects, three behind an intact foredune and three behind a foredune with a notch cut into it. Compared to an intact foredune, the notched foredune exhibited higher deposition and accumulation behind the dune. The extra supply of sand was small, however, and for the notches studied, limited to the zone within approximately 50–60 m of the foredune's crest. Farther away from the dune, the effect of the notches became negligible. The presence of a notch did affect the grain size composition of sediment deposited behind the foredune. For intact foredunes, the grain size composition behind the dune was similar to that on the dune itself. When a notch had been cut, the sediment was finer behind the foredune, gradually coarsening away from the dune. Sand spray (deposition of sand eroded from the dune and transported in modified saltation during heavy winds) explains these granulometric results. The effect of the notches on the vegetation in the grey dune habitat behind the foredune was small and, for the notches studied, limited to the first approximately 35 m of the grey dune area, between 30 and 65 m from the foredune's crest. The notches had a greater effect on the white dune habitat but – in the opinion of the authors – this remained disproportionately small relative to the effort required for notch excavation and maintenance.

1. Introduction

Fixed coastal dunes with herbaceous vegetation ('grey dunes') commonly occur between the zone of active dunes near the shoreline and more inland dune shrub and woodland habitats. They are present in all major coastal dune areas in the Atlantic region. Across Europe, fixed dunes with herbaceous vegetation have been, and still are, the most threatened and exploited environments within these dune systems. A significant proportion of this unique coastal habitat has already been lost to tourism and residential development, and regrettably many sites have been dissected by infrastructural and coastal defence works (Houston, 2008).

From an ecological and geomorphological perspective, these habitats tend towards increasing stabilization of the topsoil, and succession from rank grasslands to heathlands, shrubs, and finally woodland (Houston, 2008). In Europe the past 50 years has seen a trend of increasing grey dune habitat, but mainly to old, stable, acidic stages, because dunes have become much more stable over this period (Houston, 2008). Newborough Warren in Wales, for example, was much more mobile in the 1950s, when mobile dunes occupied over 70% of the site, compared to just 6% today (Rhind et al., 2001). Similar trends are observed on the German Wadden Sea island of Spiekeroog, where semi-fixed grey dunes (at younger succession stages) have diminished, and heathlands, dominant grasslands, shrubs, and woodlands have expanded (Isermann and Cordes, 1992).

The main threat to the grey dune habitat comes from over-stabilization of the semi-active top layer (Houston, 2008). This stabilization may be caused by a variety of processes, such as dune management (application of techniques to prevent sand drift), diminished disturbance by animals, growth of native and non-native (introduced) shrubs, afforestation, and invasion by alien forbs. Atmospheric deposition of nutrients (such as nitrogen) is especially of concern, because of its effect on biomass production, which results in an increase of the succession rate and of soil formation. This problem is most acute on the less calcareous dune sites from The Netherlands eastward into Germany (Provoost et al., 2011).

Over-stabilization (dune management in which little or no room is allowed for sediment transport behind the foredune) has diminished the quality of several precious dune habitats. This has affected habitat

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type 2120 ('white dunes': shifting dunes along the shoreline with *Ammophila arenaria*), habitat type 2130 ('grey dunes': fixed coastal dunes with herbaceous vegetation), and habitat type 2190 (humid dune slacks) (European Commission, 2013). To counteract the deterioration of these unique habitats, a new method of coastal management, known as 'dynamic coastal management' (Arens and Wiersma, 1994; De Ruig and Hillen, 1997), was introduced in The Netherlands in the early 1990s. Dynamic coastal management aims to use natural processes (Löffler, 2010) to contribute to several goals:

- Sustainable coastal safety: giving room for wind- and water-driven sediment transport, to enable dunes and salt marshes to grow in height and follow sea level rise.
- Resilience of nature against overgrowth: regular burial with dune sand and flooding by saline water can slow or even set back natural succession, which is the process by which highly competitive plants replace the original plant species because of increasing soil fertility.
- The objectives of Natura 2000: most coastal dune areas in The Netherlands have been designated conservation areas under the European Habitats Directive, which is part of Natura 2000 (Commission of the European Communities, 2002; European Commission, 2013). This protected status requires these areas to be managed in such a way that the habitat increases (or at a minimum does not decrease) in size and quality. In dune systems, increased aeolian activity is considered an increase in quality (Arens et al., 2013).

An example of dynamic coastal management is to cut notches into foredunes along the coast, as shown by Fig. 1, at locations where this does not increase the risk of flooding. This has been done at several locations in The Netherlands. The idea is to create pathways through which wind can transport carbonate-rich beach sand towards the grey dunes behind the foredunes, thus supporting the presence of early succession stages of grey dunes.

Multiple studies have been performed to evaluate the effectiveness of this new approach for coastal management (e.g., De Ruig and Hillen, 1997; Arens et al., 2007, 2010; De Groot et al., 2012; De Jong et al., 2014). However, these studies have focused mainly on the effects of dynamic coastal management on geomorphological developments on a meso-scale, for example, at the level of a complete foredune ridge. Examples are Arens et al. (2010), which investigates the effects of nourishment on dune development, and De Jong et al. (2014), which examines the effect of dynamic dune management on dune size and position on the Dutch barrier island of Ameland. So far, little attention has been paid to the impact of dynamic coastal management on aeolian sedimentation patterns and the resulting consequences for vegetation development in the dune zone *behind* the foredunes. Nonetheless, as already noted, these zones are among the most threatened parts of the dune system, and they have suffered considerable disturbance from tourism and other human activities. It is, therefore, important to test dynamic dune management techniques that aim to conserve, or even strengthen these valuable habitats. The current study investigates whether cutting notches into a foredune stimulates the transport and deposition of fresh dune sand into the areas behind the foredunes, so that early succession stages can be restored. The aim is to determine both the amounts and patterns of sedimentation and their effects on vegetation.

2. Materials and methods

2.1. Background

Management measures were taken in 2011 on the barrier island of Ameland to stimulate sediment transport and deposition into the grey dunes. One of these measures was to cut notches through the foredune at regular intervals with the aim of creating blowouts that would remain active year-round. To evaluate the effectiveness of these artificially created blowouts in supplying fresh and calcareous sand to the grey dune area, we monitored sand deposition, soil properties, and vegetation development in transects starting at the inland foot of the foredune to approximately 100 m land inward. Our working hypothesis was that the notches would produce an extra influx of calcareous sand blown up from within the notch and/or from the beach upwind of the notch, which would nourish the acidified area behind the foredune and increase the amount of natural disturbance, thus enabling early succession stage species to successfully regenerate. Over time, the notches might develop into full-scale blowouts, and expansion of the white foredunes and the early stages of grey dunes could even be expected.

2.2. Study site

The study site is located on the barrier island of Ameland (Fig. 2), which is one of the barrier islands off the northern coast of The Netherlands and Germany. The orientation of Ameland's coastline is predominantly west–east. The longshore current direction is from west to east. The dominant wind direction is southwest, with the highest wind speeds observed in winter (Wieringa and Rijkoort, 1983).

The study site is located near the northeast fringe of the island, between 53° 27′49″ and 53° 27′58″ N and 5° 51′40″ and 5° 53′40″ E. The tidal range at the site is approximately 2 m (semi-diurnal). A single

Fig. 1. Notch cut in a foredune on the island of Ameland in 2012. The photo was taken 20 November 2012. The notch has evolved into a blowout-like structure since then.