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Initiation and evolution of blowouts within Padre Island National Seashore, Texas

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ABSTRACT

Blowouts once covered the entire northern section of North Padre Island as a result of overgrazing, but are now restricted to a 5.5 km length of beach where driving is permitted between the low water line and the toe of the foredune. A comparison between this driving section and a directly adjacent non-driving section of the beach reveals a significant difference in the ratio of storm run-up (R_{high}) to the elevation of the dune toe (D_{low}), suggesting that the foredunes within the driving section are more susceptible to scarping and blowout development. Where driving is permitted, blowouts are located in areas where R_{high}/D_{low} ratio is locally large, suggesting that the location of blowouts depends on the alongshore variation in storm surge. Results of a cluster analysis reveal two distinct blowout types, in which the relatively small blowouts of Cluster 1 are characterized by a small throat and limited expansion beyond the foredune. The large and more active blowouts of Cluster 2 tend to be found closer to the access road, where driving on the beach is more concentrated and the larger R_{high}/D_{low} suggests a greater potential for scarping during relatively small storms. The development of these blowouts feeds back on the height of the foredune, making it susceptible to scarping and washover during tropical storms and hurricanes. It is argued that historical overgrazing and recent beach driving have significantly altered this landscape and represents a long-term threat to island resilience and have the potential to hasten island transgression with sea level rise.

1. Introduction

Blowouts are saucer-, cup- or trough-shaped hollows that form in a dune after scarping and breaching of foredunes. This initial breach manifests as alongshore variation in vegetation density or total loss of vegetation, which occurs in response to a number of factors, including wave run-up during storms, topographic acceleration over the dune crest, or by way of climate change or direct human activities, such as beach driving (Hesp and Hyde, 1996; Hesp, 2002). Elongated, trough-shaped blowouts develop through the acceleration of airflow through gaps formed by scarping and overwash of the coastal foredune. The resulting blowouts are characterized by a deep deflation basin and long steep lateral erosional walls that terminate at a depositional lobe with a steep landward slip-face (Fig. 1; Carter et al., 1990; Hesp and Hyde, 1996; Hesp, 2002). Onshore winds accelerate through the relatively narrow gap in the dunes, thereby moving sediment from the blowout throat into a depositional lobe where the winds experience rapid flow deceleration, lateral expansion and in some cases flow separation (Lancaster, 1986; Hesp, 1996; Hesp and Hyde, 1996; Fraser et al., 1998). Even when winds are oblique to the dune or directed offshore, the low-pressure zone over the blowout causes the wind to deflect into the throat and transport sediment towards the depositional lobe (Hesp and Pringle, 2001).

Blowouts evolve from an initial gap in the foredune to incipient blowouts, then large blowouts that will either stabilize, if vegetation is able to re-establish, or decay (Gares and Nordstrom, 1995). Gares (1992) argues that some blowouts go through periods of growth and stabilization in response to a complex feedback between the availability of sediment and the rate and extent of vegetation growth. Specifically, blowout evolution depends, to varying degrees, on the width and depth of the initial dune gap and the type and extent of vegetation cover (Melton, 1940; Esler, 1970), the strength of the winds (Jennings, 1957; Cooper, 1958; Marta, 1958; Davies, 1980) and the directional variability of those winds (Jennings, 1957; Gares, 1992; Gares et al., 1979; Gares and Nordstrom, 1987; Shepherd et al., 1997; Byrne, 1997). If the blowout continues to develop and expand, it may evolve into a

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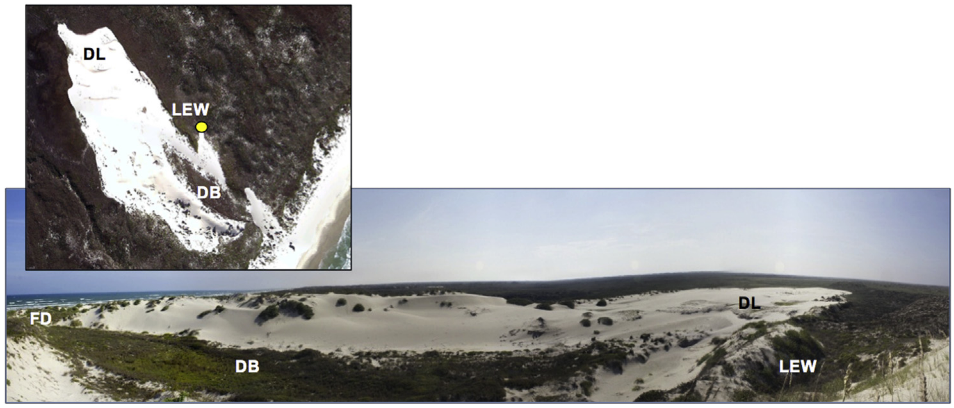

Fig. 1. Characteristic morphology of a trough blowout from Padre Island National Seashore, Texas, shown in both an aerial and an oblique photograph. Labels indicate the depositional lobe (DL), deflation basin (DB), lateral erosional walls (LEW) and foredune (FD). The oblique photograph was taken from the position of the circle in the aerial photograph.

parabolic dune that continues to migrate landward (Carter, 1990; Carter et al., 1990; Battiau-Queney et al., 1995), even if the foredune recovers, closing the throat, and the supply of sediment from the backshore and adjacent dune is limited (Mathewson and Cole, 1980; Gares, 1992; Hesp and Hyde, 1996; Hesp, 2002; Levin, 2011). Considering the slow rate of foredune recovery following storms (Houser and Hamilton, 2009), it is reasonable to assume that the incipient foredune in front of a blowout will have a relatively low elevation compared to adjacent dunes, and that there is a potential for the blowout to reactivate after relatively small disturbances to the foredune or vegetation cover (Anders and Leatherman, 1987). Storms can cause this disturbance, as can beach traffic or grazing (Nield and Baas, 2008).

Blowout development requires that scarping and washover of the foredune is not uniform alongshore, and that the wind accelerates within the gaps. An alongshore variation in erosion can develop in response to alongshore variations in run-up and/or dune morphology, leading to an irregular removal of vegetation and post-storm morphology (Hesp, 1982, 1996; Psuty, 1989; Ritchie, 1972; Carter, 1990; Saunders and Davidson-Arnott, 1990; Giles and McCann, 1997). Foredune lines are rarely uniform alongshore, and can exhibit considerable variation in height and width at a range of length scales that typically reflects a complex feedback with the alongshore variation in run-up (Houser and Mathew, 2011; Houser, 2013). Small variations in the height of an otherwise uniform foredune create instabilities in the duneline that can expand through washover and blowout initiation, leading to a more variable dune line that is more susceptible to change by subsequent storms. The run-up elevation (R_{high}) is dependent on the deepwater wave height (H_o) and length (L_o), and the local beach slope:

$$R_{high} = 1.1\left(0.35\beta_f(H_0L_0)^{\frac{1}{2}} + \frac{\left[H_0L_0\left(0.563\beta_f^2 + 0.004\right)\right]^{\frac{1}{2}}}{2}\right) \quad (1)$$

which suggests that run-up varies in response to the nearshore morphology and broader coastal geologic framework (Stockdon et al., 2006). Where the elevation of the run-up is high in comparison to the elevation of the dune base, blowouts may also develop from overwash hollows if vegetation is slow to recover (Leatherman, 1976; Godfrey et al., 1979; Ritchie and Penland, 1990; Saunders and Davidson-Arnott, 1990). As argued by Sallenger (2000), the potential for scarping and washover is dependent on the elevation of the storm surge (R_{high}) relative to the elevation of the dune base (D_{low}) and crest (D_{high}). Dune scarping is initiated when and where $D_{low} < R_{high} < D_{high}$, while overwash develops when and where $R_{high} > D_{high}$. Washover is, however, a self-reinforcing process and once an overwash lobe develops it can widen alongshore quite rapidly during a storm through lateral erosion (Mathewson and Cole, 1980; Houser, 2013); overwash lobes typically do not present a sufficient constriction for blowout development.

Mathewson and Cole (1980) describe the initial development of blowouts along North Padre Island, Texas as a consequence of extensive foredune erosion and breaching during an unnamed hurricane in 1933. This lead Mathewson (1987) to argue that is impossible to predict the location of blowout development since they only form as a result of "*hurricanes of significant intensity*" and not "*daily processes*;" we have found otherwise. The foredune recovered and steep lateral erosional walls developed as the blowout stabilized in 1948, although the depositional lobe continued to migrate landward as a low-profile parabolic dune. Since then the blowouts have gone through multiple cycles of activation and stabilization in response to storm events and the eventual recovery of the foredune (Mathewson and Cole, 1980). It is reasonable to expect that an increase in dune scarping and overwash with rising sea level will promote the reactivation of these blowouts in the future (Carter, 1990; Hesp, 2002; Davidson-Arnott, 2005). In other words, the unprecedented alteration of this barrier island landscape over the last century has made the island more susceptible to storm erosion and washover during tropical storms and hurricanes, which may hasten island transgression in response to sea level rise. The purpose of this study is to extend the initial descriptions of the blowouts by Mathewson and Cole (1980), and to identify the controls on blowout initiation and evolution at Padre Island. The results of these findings have implications for the management of Padre Island, and for any beach on which driving or other heavy human traffic is common.

2. Study site

At 182 km long, Padre Island is the longest barrier island in the United States, extending along the Texas gulf coast from Corpus Christi Bay in the north to the Rio Grande Delta in the South (Fig. 2). In 1962, Congress passed *Public Law 87-712* making the northern 105 km of the island a national seashore to "save and preserve, for