Raising the (subtidal) bar for embryonic dune growth and survival

Timothy Price[1], Marinka Van Puijenbroek[1], Elias De Korte[1], and Gerben Ruessink[1]

[1]Utrecht University

November 25, 2022

Abstract

Along sandy coasts, the seaward expansion of dunes starts with the development of embryonic dunes. Vegetation is crucial for their initiation and the subsequent increase in dune height and volume when sediment supply is sufficient. During severe storms, the plants' tolerance to and recovery from hydrodynamic disturbances, such as exposure to saline water during high water levels and their (partial) removal during storms, is vital to the long-term (months to years) resilience of the dune building process. Accordingly, areas with high embryo dune abundance have been correlated to wider beaches, attributed both to increased wind-driven sediment supply and increased wave attenuation during storms. Recent observations have shown that alongshore variations in subtidal sandbar morphology may also lead to variations in wave attenuation and foredune erosion, following a series of extreme storms. With our research we aim to determine whether subtidal bar characteristics play a role in long-term (months to years) embryo dune development. We first analysed a data set of 112 annual bathymetric profiles (spaced 250 m alongshore) and topographic (airborne Lidar) measurements in addition to observations of embryo dune presence derived from aerial photographs, spanning 50 km along the Dutch coast from 2010 to 2016. Embryo dune area extraction was done by supervised classification of vegetation pixels on the beach. Using a linear regression model, we found that profiles with a more seaward vegetation extent significantly correlated to shallower subtidal bars, in particular during stormy years. Second, to study the timing and alongshore variability of individual erosion events in more detail, we analysed 10 years (2005-2015) of half-hourly images of a 4-km stretch of the same coast, near Egmond aan Zee, in addition to the annual data. These images provide unique observations of the entire bar-beach-dune system, allowing for the concurrent analysis of bar morphology, embryo dune areas and, crucially, embryo dune exposure to saline water and wave action during storm events. At the conference, we will further explain the observed spatial and temporal (storm-driven) variability in embryo dune development.

Utrecht University

Netherlands Organisation for Scientific Research

Faculty of Geosciences
Department of Physical Geography

EP23C-2344
AGU FALL MEETING

Raising the (Subtidal) Bar for Embryonic Dune Growth and Survival

Timothy Price[1],
Marinka van Puijenbroek[1,2], Elias de Korte[1], Gerben Ruessink[1]
[1] Department of Physical Geography, Faculty of Geosciences, Utrecht University, Utrecht, the Netherlands
[2] Wageningen Marine Research, Den Helder, the Netherlands

(t.d.price@uu.nl)
@timothydprice

Introduction

Along sandy coasts, the seaward expansion of dunes starts with the development of embryonic dunes. During severe storms, embryonic dunes may be partially or even completely eroded. The tolerance to and recovery from their (partial) removal during storms is vital to the long-term (months to years) resilience of the dune building process. Areas with high embryo dune abundance have been correlated to wider beaches[1], and recent observations have shown that alongshore variations in subtidal sandbar morphology may also lead to variations in wave attenuation and foredune erosion, following a series of extreme storms[2, 3] (Figure 1).

Here, we aim to answer the following research question:
Do subtidal bar characteristics play a role in long-term (months to years) embryo dune development?

Two approaches:
➔ **Hourly video observations**
➔ **Yearly aerial photographs and bed levels**

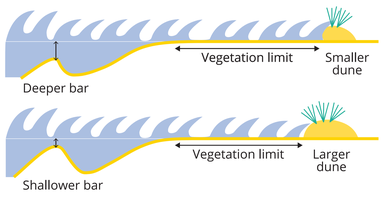


Figure 1 Hypothesis
Shallower bars dissipate more wave energy than deeper bars during storms. Over time, this allows embryonic dunes to grow in volume and further seaward.

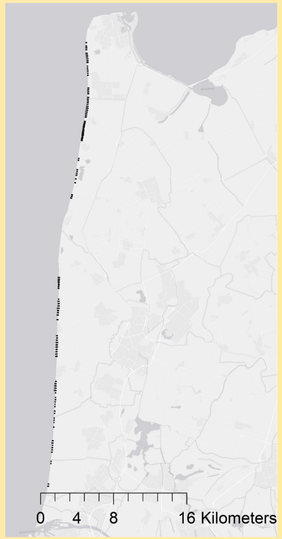


Figure 2 Study sites
Egmond aan Zee (triangle): Video observations
112 sites along the North-Holland coast (dots):
Yearly photos & bed levels. Meteorological measurements (*)

➔ Hourly video observations

Dune erosion events were visible in the video images, allowing us to observe **when** and **how much** embryonic dunes eroded.
Not all storms resulted in erosion and the degree of erosion varied alongshore.

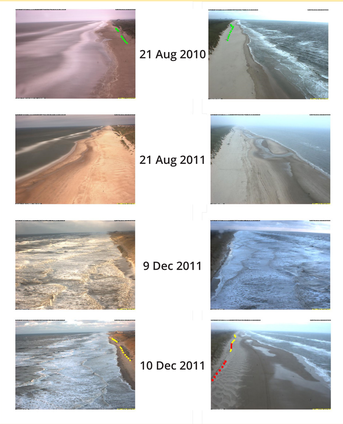
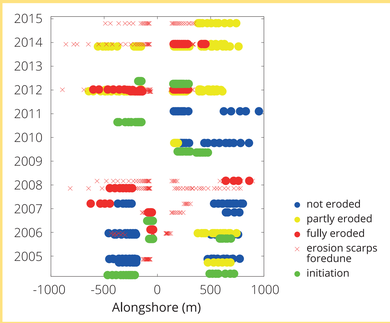


Figure 3 Example of observations of embryonic dune initiation and erosion from August 2010 – December 2011.



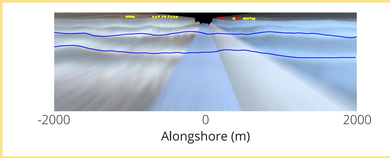


Figure 4 Video observations of embryonic dune erosion events and embryonic dune initiation. The planview below from 8 December 2011 gives an example of the alongshore variation in bar morphology and dune erosion extent.

Conclusions and outlook

➔ Embryonic dune development varies alongshore
? Alongshore variable dune **erosion** ⟷ Alongshore variable dune **growth**

➔ Subtidal bar depth correlates to embryonic dune development
? Alongshore variable **bar** morphology ⟷ Alongshore variable **dune** morphology

➔ Storms result in different erosion extents
? Pre-storm **dune** morphology ⟷ **Storm** properties ⟷ **Bar-beach** morphology

➔ Yearly aerial photos and bed levels

Aerial photographs ➔ **supervised classification** of vegetation pixels (2-6 m MSL).

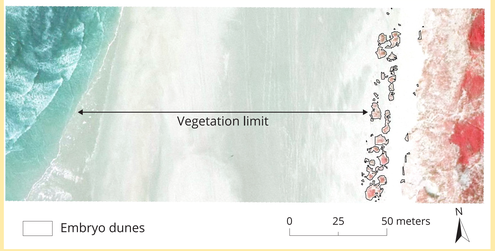


Figure 5 Example of embryo dune extraction from aerial photographs using supervised classification, for one location. The vegetation limit represents the distance between the 0m-contourline and the most seaward extent of the embryo dune vegetation.

Linear regression model, including:
- Storminess: Maximum water level, wave height, wave run-up, duration
- Weather during growing season: Precipitation and temperature
- Morphology: Beach width, beach slope, shoreface volume, **bar crest depth**

Experimental design	
112 sites 100 m alongshore	2010-2016
Response variables	
Area of embryo dunes	Aerial photograph
Vegetation limit	
Explanatory variable	
• Beach width • sandbar morphology	Cross-shore elevation profiles
• Storm intensity • Wave dissipation • Weather conditions	Meteorological measurements

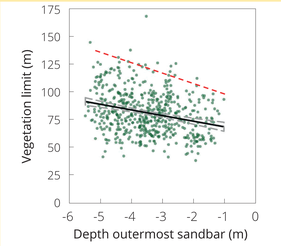


Figure 6 The linear regression model showed that cross-shore profiles with a more seaward vegetation extent significantly correlated to shallower subtidal sandbars, in particular during stormy years.

Acknowledgements
This work is part of the research programme Spawning sand from sea to land with project number 016.Veni.171.101, funded by the Netherlands Organisation for Scientific Research (NWO). MvP was funded by seed money from the Future Deltas research focus area of Utrecht University.

References
[1] Van Puijenbroek, M.E., Limpens, J., de Groot, A.V., Riksen, M.J., Gleichman, M., Slim, P.A., van Dobben, H.F. and Berendse, F., 2017. Embryo dune development drivers: beach morphology, growing season precipitation, and storms. *Earth Surface Processes and Landforms*, *42*(11), pp.1733-1744.
[2] De Winter, R.C., Gongriep, F. and Ruessink, B.G., 2015. Observations and modeling of alongshore variability in dune erosion at Egmond aan Zee, the Netherlands. Coastal Engineering, 99, pp.167-175.
[3] Castelle, B., Marieu, V., Bujan, S., Splinter, K.D., Robinet, A., Sénéchal, N. and Ferreira, S., 2015. Impact of the winter 2013-2014 series of severe Western Europe storms on a double-barred sandy coast: Beach and dune erosion and megacusp embayments. *Geomorphology*, *238*, pp.135-148.