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Coastal dunes - A nature based coastal protection element exposed to exacerbated anthropogenic stress

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Natural coastal dunes covered by vegetation are an essential component on many sandy coastlines worldwide and often provide the only physical protection against flooding by dissipating wave energy and enhancing erosion resilience. However, sea level rise, changing and widely intensifying coastal wave climates and storm surges constitute severe exacerbated stresses, calling into question the perseverance of such unique coastal ecosystems as dunes and their protective functions taken for granted.

Here we investigate the extensive coastal dune system of St. Peter-Ording, a major tourist draw of the German North Sea within a marine high energy zone. Lining the coast along 15 km, extending up to 1.5 km in cross-shore direction it covers an area of 18 sqkm characterized by overgrown dunes separating the tidal foreshore from the topographically flat hinterland. Featuring a dedicated, Germany wide unique, coastal protection function sets it apart from other national coastal dune systems - potentially creating a role model for mitigating coastal squeeze related driving factors, further adding to its awe-inspiring landscape character.

Consequently, the joint-research project ''Sandküste St. Peter Ording'' examines whether the local flood protection dune “Maleens Knoll”, a 16.6 m high natural coastal dune stretching a roughly 1.2 km long gap in the sea-dike defense, will continue to offer adequate protection in the future. Current hypothesis is, that due to the overgrowth with non-endemic and invasive vegetation species, the natural dynamic and self-adaptation of the system is impaired and will not withstand projected changes in coastal drivers. Therefore, the long-term goal is to develop a variety of nature-friendly flood protection measures to reinforce the dune and reduce its probability of failure during an extreme storm surge.

Possible options comprise the installation of hybrid systems, combining the existing dune core with one of the following structures: 1) a vertical wall to gain more stability during erosion of the sand cover, 2) rock filling to increase wave dissipation and reduce wave reflection and erosion and 3) geotextiles to provide a temporary and more environmentally protection against runup. The built-in materials will be covered with sand, to mimic the original landform and yield its previous degree of freedom regarding topographic adaptation. Another approach is to strengthen the resistance of the sand surface against aeolian and fluvial erosion. Through a microbiological process based on calcium carbonate precipitation (MICP), the strength can be increased in a

particularly environmentally friendly way that saves raw materials. Furthermore, adapted or additional planting with a site-typical vegetation can promote sand accumulation at the surface and thereby stabilize the dune.

Large-scale physical model experiments will be performed in a wave flume to investigate the protection potential of the dune. First, the natural dune condition will be recreated and tested under a combination of water levels and wave conditions to investigate current and future load cases. Based on the findings, a second series of experiments will be conducted to determine which engineering methods are most appropriate to reinforce the dune and ensure its coastal protection character and retain its naturalness at the same time.