Journal of
Marine Science and Engineering

MDPI

Editorial

Beach-Dune System Morphodynamics

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Coastal dunes are known for their functions in ecological systems in addition to their aesthetic qualities, providing a highly valuable and unique habitat of due to their biodiversity of flora and fauna. They also represent the boundary between land and sea, acting as a protective natural barrier against flooding due to storm surges and wave action. Beach–dune systems are highly dynamic phenomena whose evolution is primarily determined by the mutual and complex exchange of sand through hydrodynamic and eolian processes. The sustainable and resilient conservation of beach–dune (eco)systems in a changing climate requires important insights from multidisciplinary studies and approaches. Toward this vision, this Special Issue is dedicated to collecting original scientific contributions based on field observations, laboratory experiments, and/or numerical models.

The following is an overview of the contributions to this Special Issue.

The first published paper is entitled "Application of the Saffir-Simpson Hurricane Wind Scale to Assess Sand Dune Response to Tropical Storms" by Ellis et al. [1]. This study investigated the volumetric changes of two dune systems on the Isle of Palms, South Carolina, USA, before and after Hurricane Irma (2017) and Hurricane Florence (2018), which struck the island as tropical storms with different characteristics. Irma had relatively high wave heights and rainfall, resulting in an average volumetric dune loss of 39%. During Florence, a storm with low rainfall and moderate winds, the net volumetric dune loss averaged 3%. The primary driving force for dune change during Irma was water (rainfall and storm surge), while during Florence it was wind (aeolian transport). The authors suggest reconsidering the use of the Saffir–Simpson hurricane wind scale because different geomorphological responses were measured, even though Irma and Florence were both classified as tropical storms. Site-specific studies of dune morphology before and after the storm, as well as site-specific meteorological measurements of the storm (wind characteristics, storm surge, rainfall), are urgently needed.

The second published paper is entitled "Sensitivity of Storm Response to Antecedent Topography in the XBeach Model" by Mickey et al. [2]. In this study, a methodology was developed to investigate the uncertainty of the profile response within the XBeach storm impact model associated with different antecedent topography. A parameterized island Gaussian fit model (PIGF) generated an idealized base profile and a set of idealized profiles with different characteristics based on collected LiDAR data from Dauphin Island, AL, USA. Six synthetic storm scenarios were simulated and analyzed on each of the idealized profiles using XBeach in both one- and two-dimensional configurations to determine the morphological response and uncertainties associated with the different antecedent topography. The morphological response of the profile tends to scale with the strength of the storm, but for different profiles, the uncertainty of the profile response to the medium-strength storm scenarios is greater than for the low- and high-strength storm scenarios. XBeach can be very sensitive to morphological thresholds, both antecedent and time-varying, especially with respect to beach slopes.

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Citation: D'Alessandro, F.; Tomasicchio, G.R.; Frega, F. Beach-Dune System Morphodynamics. *J. Mar. Sci. Eng.* **2022**, *10*, 802. https://doi.org/10.3390/jmse10060802

Received: 1 June 2022
Accepted: 8 June 2022
Published: 10 June 2022

The third published paper is entitled "Predicting Morphodynamics for Beach Intertidal Systems in the North Sea: A Space-Time Stochastic Approach" by Bogaert et al. [3]. The authors developed a stochastic model of a macrotidal sandy-barred beach based on cross-shore elevation profiles. Intensive survey campaigns using Real Time Kinematics-GPS (RTK-GPS) and LiDAR approaches were conducted. The results of this study demonstrate how the temporal evolution of an integrated property, such as total displaced sand volume, can be estimated over time. This suggests that a similar stochastic approach could be useful for estimating other properties, as long as one is able to capture the stochastic space–time variability of the underlying processes.

The fourth published paper is entitled "Development and Application of an Empirical Dune Growth Model for Evaluating Barrier Island Recovery from Storms" by Dalyander et al. [4]. In this study, an empirical dune growth model (EDGR) was developed to predict the evolution of the primary foredune of a barrier island. EDGR was assessed against observed dune evolution along the western end of Dauphin Island, Alabama, over the 10 years following Hurricane Katrina (2005). The computational efficiency of EDGR allows for the rapid prediction of dune evolution and enables ensemble predictions to limit the uncertainties that can arise when terminal dune characteristics are unknown. In addition, EDGR can be coupled with an external model to estimate dune erosion and/or the long-term evolution of other subaerial features to enable the prediction of barrier island evolution on a decadal scale.

The fifth published paper is entitled "Investigating Changes in Aeolian Sediment Transport at Coastal Dunes and Sand Trapping Fences: A Field Study on the German Coast" by Eichmanns and Schüttrumpf [5]. In this paper, the authors present the results of field experiments conducted at the beach, on coastal dunes, and at a sand trapping fence on the East Frisian island Langeoog. The vertical sediment flux profile was measured by vertical mesh sand traps, and saltiphones measured instantaneous sediment transport. A meteorological station was set up to obtain wind data. On the beach, dune toe, and dune crest, the stationary wind profile can be effectively described by the law of the wall. Saturated aeolian sediment transport rates on the beach and dune toe were predicted by widely used empirical models. At the sand trapping fence, these empirical transport models could not be applied, as no logarithmic wind profile existed. The upwind sediment supply reduced after each brushwood line of the sand trapping fence, thereby, leading to increased deviation from the saturated conditions.

The sixth published paper is entitled "Use of Nanosilica for Increasing Dune Erosion Resistance during a Sea Storm" by Leone et al. [6]. In this study, the reliability of an innovative non-toxic colloidal silica-based solution for coastal sand dunes was verified for the first time using laboratory experiments. An extensive experimental campaign was carried out in the 2D wave flume of the EUMER laboratory at the University of Salento (Italy) to investigate the effectiveness of the use of nanosilica. The study was initially based on a horizontal seabed, and then a cross-shore beach–dune profile similar to those generally observed in nature was drawn. Detailed measurements of wave characteristics and observed cross-shore beach–dune profiles were analyzed for a wide range of wave conditions. In both cases, two sets of experiments were conducted. After performing the first set of experiments, which resembled the native conditions of the models composed with natural sand, the effects of injecting silica-based mineral colloidal grout were investigated. The observations show that mineral colloidal silica increases the mechanical strength of non-cohesive sediments, thus reducing the volume of dune erosion and improving the resistance and longevity of the beach–dune system.

The seventh published paper is entitled "Role of Storm Erosion Potential and Beach Morphology in Controlling Dune Erosion" by Lemke and Miller [7]. This study investigated the role of storm intensity and the vulnerability of location in controlling dune erosion based on data compiled for eighteen historical events in New Jersey. Storm intensity was characterized by the Storm Erosion Index (SEI) and Peak Erosion Intensity (PEI), factors used to describe a storm's cumulative erosion potential and maximum erosive power, respectively. In this study, a direct relationship between these parameters, beach morphology characteristics, and expected dune response was established through a classification tree ensemble. Of the seven input parameters, PEI was the most important, indicating that peak storm conditions with time scales on the order of hours were the most critical in predicting dune impacts. Results suggested that PEI alone was successful in distinguishing between storms most likely to result in no impacts (PEI < 69) and those likely to result in some impacts (PEI > 102), regardless of beach conditions. For intensities in between, where no consistent behavior was observed, beach conditions must be considered. Because of the propensity for beach conditions to change over short spatial scales, it is important to predict impacts on a local scale. This study established a model with the computational effectiveness to provide such predictions.

The eighth published paper is entitled "Effects of Anthropogenic Pressures on Dune Systems-Case Study: Calabria (Italy)" by Foti et al. [8]. This study aimed to evaluate the effects of anthropogenic pressures on the Calabrian dune systems, especially with regard to the triggering of coastal erosion processes. For this purpose, historical and current cartographic data, such as shapefiles, cartography, and satellite imagery, were analyzed using QGIS. This evaluation was carried out through the comparison between the current extension of the dune systems and their extensions after the Second World War, i.e., before increased anthropogenic pressures. This evaluation was also carried out through the analysis of shoreline changes in coastal areas where dune systems are currently present, and in coastal areas where dune systems have been partially or totally destroyed by anthropogenic causes. These changes were compared to the status of these same coastal areas in the 1950s, thus excluding coastal areas without dune systems in the 1950s and analyzing what was built in place of the destroyed dune systems. Two criteria were defined to identify the levels of destruction of the dune systems and to identify coastal erosion processes. The analysis showed a strong correlation between the destruction of dune systems by anthropogenic causes and the triggering of coastal erosion processes.

The ninth published paper is entitled "A Numerical Study on the Impact of Building Dimensions on Airflow Patterns and Bed Morphology around Buildings at the Beach" by Pourteimouri et al. [9]. In this study, a numerical model was developed using the open-source computational fluid dynamics solver OpenFOAM. First, the model was used to predict the airflow patterns around a single rectangular building. The model predictions were validated with wind-tunnel data, which had a good agreement. Second, a reference beach building was introduced, and then the building dimensions were increased in length, width, and height, each up to three times the size of the reference building dimensions. The impact of each dimensional extent on the near-surface airflow patterns was investigated. The results show that the near-surface airflow patterns are least dependent on the length of the building in the wind direction, and they depend most on the width of the building perpendicular to the wind direction. Third, the convergence of a third-order horizontal near-surface velocity field was calculated to interpret the impact of changes in airflow patterns on potential erosion and deposition patterns around the building. The numerical predictions were compared with the observed erosion and sedimentation patterns around scale models in the field. The comparisons showed satisfactory agreements between numerical results and field measurements.

The tenth published paper is entitled "Beach and Dune Erosion: Causes and Interventions, Case Study: Kaulon Archaeological Site" by Barbaro et al. [10]. The paper, through a case study, analyzed erosive processes of the beaches and dunes, their causes, and the possible interventions. The case study concerns the archaeological site of Kaulon, located on a dune on the Ionian coast of Calabria (Italy). The beach near the site was affected by erosive processes, and during the winter of 2013–2014, the site was damaged by two sea storms. To identify the causes of these processes, three erosive factors were analyzed. These factors are anthropogenic pressure, wave climate and sea storms, and river transport. The effects produced by these factors were assessed in terms of shoreline changes and damage to the beach–dune system, also evaluating the effectiveness of the defense interventions.

The main causes of the erosive processes were identified through a cross analysis of erosive factors and their effects. This analysis highlighted that, in the second half of the 20th century, the erosive processes mainly correlated with anthropogenic pressure, while recently, natural factors have prevailed, especially sea storms. Regarding the interventions, the effects produced by two interventions carried out during the winter of 2013–2014, one built in urgency between the first and second sea storm and the other built a few years after the second sea storm, were analyzed. This analysis highlighted that the latter intervention was more effective in defending the site.

The eleventh published paper is entitled “The Dune Engineering Demand Parameter and Applications to Forecasting Dune Impacts” by Janssen and Miller [11]. The breaching or overtopping of coastal dunes is associated with greater upland damages. Reliable tools are needed to efficiently assess the likelihood of dune erosion during storm events. Existing methods rely on numerical modeling (extensive investment) or insufficiently parameterize the system. To fill this gap, in this paper, a fragility curve model using a newly developed dune Engineering Demand Parameter (EDP) was introduced. Conceptually, the EDP is similar to the Shield’s parameter in that it represents the ratio of mobilizing terms to stabilizing terms. Physically, the EDP is a measure of storm intensity over the dune’s resilience. To highlight potential applications, the proposed EDP fragility curve models were fit to a spatially and temporally robust dataset and used to predict dune response subjected to varying storm intensities, including both extratropical and tropical storms. This approach allows for the probabilistic prediction of dune impacts through an innovative, computationally efficient model. Several different forms of the EDP were tested to determine the best schematization of the dune resilience. The final recommended EDP is the Peak Erosion Intensity (PEI) raised to the fourth power over the product of the dune volume and berm-width squared. Including both storm intensity and resilience terms in the EDP enables a comparison of different beach configurations in different storm events, directly fulfilling a need that existing vulnerability assessors cannot currently account for.

The twelfth published paper is entitled “Beach–Dune System Morphodynamics” by D’Alessandro et al. [12]. This study reviews traditional issues and design advances, building bridges between potential risks and adaptation measures. The benefits of nature-based and hybrid solutions, as well as the need for multidisciplinary studies and approaches to promote sustainable and resilient conservation of the coastal environment, are emphasized. Considering the importance and complexity of the subject, this research remains incomplete. It is limited in providing a general overview and outlining some important future directions. Instead, it intends to serve as a springboard for further research in the field of beach–dune system morphodynamics.

Author Contributions: Conceptualization, F.D., G.R.T., and F.F.; writing—original draft preparation, F.D., G.R.T., and F.F.; writing—review and editing, F.D., G.R.T., and F.F. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

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