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Coastal Dynamics 2025

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Editors

Coastal Dynamics 2025

Volume 1

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Foreword

The international *Coastal Dynamics* conference series is one of the most important meetings for scientists in the fields of nearshore dynamics and coastal evolution. The 1st edition was held in 1994 in Barcelona and envisioned to complement the *Coastal Sediments* conference series (since 1977) and the *International Conferences on Coastal Engineering* (since 1950). It emphasized the use of large-scale field experiments and laboratory facilities for understanding the underlying physics of the coastal processes and improving numerical modelling capabilities. Since then, embracing and expanding the initial aim and themes, following conferences were held in Gdansk, Poland (1995); Plymouth, UK (1997); Lund, Sweden (2001); Barcelona (2005); Tokyo, Japan (2009); Arcachon, France (2013); Helsingor, Denmark (2017); and Delft, Netherlands (2021).

The 2025 Coastal Dynamics conference, hosted by the University of Aveiro, Portugal, in April 7–11, 2025, was developed under the theme “Living with a Dynamic Coast”. 379 abstracts were submitted and critically reviewed by the Scientific Committee. Scientists and experts from all over the world conducting research on the dynamics and changes of the coastal systems contributed with their insights and research results. Approaches included field (remote and *in situ*) observations, laboratory experiments, theoretical formulations, numerical simulations, and data-based learning methods. Recent research and applications concerning hydrodynamics of coastal waves and currents, interactions between wind, water, sediments and eco-systems, and morphology changes in different environments (with and without structures) such as sandy, rocky, and muddy coasts, inlets, and estuaries were presented. Emerging contributions of nature-based solutions and sediment-biota/plastics interactions were also presented.

The theme of the conference was highlighted by two Keynotes, delivered by Bregje van Wesenbeeck, a scientific director of Deltares (the Netherlands) and a senior expert in nature-based solutions, and Alec Torres-Freyermuth, a researcher in the Engineering Institute at the National Autonomous University of Mexico. Van Wesenbeeck presentation “Including nature and natural dynamics into management of coastal zones” addressed science and valorisation of working with nature and natural processes. Torres-Freyermuth presented “Linking beach morphodynamics and coastal resilience”, highlighting that coastal resilience has become a key element for coastal management and for climate change adaptation plans. The two Keynotes were complemented by nearly 280 professional presentations in four concurrent oral sessions and poster sessions for three days. These sessions followed an initial day where three short courses were provided, on the topics of “Coastal Resilience Assessment – Transferring the principles of ecological resilience to coastal geomorphic system”, “Incorporating Data Science and Climate in Coastal Engineering” and “Coastal Restoration Under Sea Level Rise”. The last day of the Conference included three technical visits, to allow participants to contact with the dynamics of the coastal region of central Portugal, which is characterized by sandy beaches with extensive erosion problems, a Natura 2000 protected area (“Dunas

de S. Jacinto Nature Reserve), important coastal protection structures and recent beach nourishment projects.

During the conference, the Coastal Award 2025 was attributed to Andrew Short, a coastal scientist specializing in beach morphodynamics and coastal processes and evolution. He has degrees from the University of Sydney, University of Hawaii and Louisiana State University and has worked on the coasts of North and South America, including north Alaska and Hawaii, Europe, Korea, New Zealand and the entire Australian coast. He is presently Honorary Professor at the University of Sydney and University of Wollongong, Visiting Scientist in the Coastal Oceanography Lab at the Universidade Santa Catarina, Brazil, Senior Coastal Scientist (part-time) with CoastalCOMS.com, and Chair of National Surfing Reserves (Australia) and serves on the NSW Coastal Panel. He has written 12 books and over 200 scientific publications, many dealing with rip currents and beach hazards. In collaboration with Surf Lifesaving Australia, he used his knowledge of surf zone processes to develop the Australian Beach Safety Program. The Organizing Committee of Coastal Dynamics 2025 joins conference participants and the extended research community in celebrating Andrew Short contributions towards advancing science and engineering for resilient coastal systems.

The Proceedings of *Coastal Dynamics 2025* contain the findings of the world's leading scientists and engineers in the area of coastal dynamics. The contents are a valuable source of up-to-date information on coastal processes and morphodynamics, ranging from basic research to case studies and lessons learned.

We would like to acknowledge all the sponsors and partners who have turned this conference possible: Rohde Nielsen; Port of Aveiro; Dravo S.A.; Teixeira Duarte—Engenharia e Construções, S.A.; Inersel; Dragus—Engenharia Hidráulica; Atlantic Land Consulting; Consulmar Projectistas e Consultores, Lda.; CPTS Underwater Services; R5 marine solutions; Geosurveys—geophysical consultants; APRH—Associação Portuguesa dos Recursos Hídricos; PIANC—The World Association for Waterborne Transport Infrastructure; OE—Ordem dos Engenheiros; EurOcean—The European Centre for Information in Marine Science and Technology; Applied Sciences—an Open Access by MDPI; Journal of Marine Science and Engineering—an open Access by MDPI.

Finally, we would like to thank the Local Organizing Committee, the International Steering Board of the Coastal Dynamics Conference series and the Technical Abstract Review Committee for supporting us in organizing the CD2025 conference session.

Carlos Coelho
Caroline Hallin
Francisco Sancho
Paulo Silva

About This Book

This open-access proceedings of Coastal Dynamics 2025 compile 231 manuscripts of the communications presented at the University of Aveiro, Portugal, between 7 and 11 April 2025. The works are divided in 15 chapters (2 volumes), in accordance with the topic of the sessions where they were presented. The conference theme was “Living with a Dynamic Coast”. Most updated research on the dynamics and changes of the coastal systems include field (remote and in situ) observations, laboratory experiments, theoretical formulations, and numerical simulations. Recent research and applications concerning coastal waves and currents, interactions between wind, water, sediments and eco-systems, and morphology changes in different morphological environments (with and without structures) such as sandy, rocky, and muddy coasts, inlets, and estuaries are described in this compilation.

The extended list of highlights coming out of the conference included the following keywords: *machine learning algorithms; automatic techniques; neural networks, clustering, random forests, multivariate analysis; extensive time/space datasets; stochastic modelling/simulators; model-data hybrid approaches; climate versus seasonal drivers; dune evolution modelling; long-term trending/forecasting; high-resolution; young researchers; satellite/UAV/LIDAR imagery/data; sediment-vegetation-flow interaction under/above water; multi-disciplinary, across-scales processes; nature-based interventions; new field experiments; digital twins; adaptation pathways; climate change impacts; role of infragravity waves; process-based models; small/remote coastal environments; sea-level rise.*

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Barrier Islands Facing Sea Level Rise in the Northern Adriatic Sea

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Abstract. Because of the presence of a unique freely-developing sandy barrier system, the Marano and Grado Lagoon provides as a useful case study in the debate on barrier island responses to relative sea level rise. To analyze the multi-decadal evolution of these 10-km-long landforms, the coastline configuration in 16 different years was examined using historical cartography, aerial photos and topographic surveys. After subdividing the coast into 50 cells, the differences in the subaerial barrier area (AREA) and shoreline position (SHO) were computed for each temporal step and examined as morphodynamic indicators. The results show that barrier islands have been preserved throughout time as the AREA has increased, along with a general pattern of coastal retreat, indicating a dominant rollover process as a response to sea level rise. This process becomes significantly more complex when the behavior of indicators is examined at various time scales. On a four-year time scale, there are both typical rotational trends and periods of significant variability due to the coexistence of transgressive process and intense longshore constructive dynamics. The multidecadal history of Grado barrier islands demonstrates the complexity of barrier island response to sea level rise, often resulting in contemporary small-scale opposite dynamics due to either erosive or depositional phenomena.

Keywords: Barrier Island · sea-level rise · adaptive response · washover · rollover

1 Introduction

Barrier islands have unique environmental, socioeconomic, and cultural values that make challenging the understanding and predicting of their coastal response to relative sea level rise [1, 2]. The ability to adapt of barrier islands is not uniform and assumes significant local variability in response to the coastal forcing, sediment supply and human constraints [3–5]. Thanks to the equilibrium between tidal forcing and waves, the coasts of the northern Adriatic (Italy) feature notable lagoon and barrier island systems. Although the majority of these barriers are fully fixed due to engineering works, the easternmost sandy barrier islands of the Marano and Grado Lagoon evolve rather freely. A quantitative

multidecadal analysis of the sandbanks evolution makes this study case useful in the debate of barrier island responses to relative sea level rise.

2 Study Area

The Marano and Grado Lagoon (NE Italy), part of the Natura 2000 network (IT3320037) is protected in its easternmost sector by about 10 km of very dynamic, narrow (160 m), and low emerged barrier islands (Grado sandbanks, Fig. 1), only in some tracts fixed by littoral vegetation [6]. The back barrier area is represented by a small para-lagoonal basin limited landward by an ancient system of barrier islands, which was stabilized by engineering works in the early 1900s. The local wind climate is affected by the strong wind from the ENE (Bora), and the subordinate Sirocco wind from the SE, which, however, generates the highest waves, both because of the 10 times longer fetch and because of the geographical arrangement of the sandbanks. Tides are semi-diurnal with a mean range of 76 cm and mean spring-neap tide ranges of 105 and 22 cm. Because of their high degree of naturalness, the sandbanks provide breeding habitats for endangered coastal bird species.

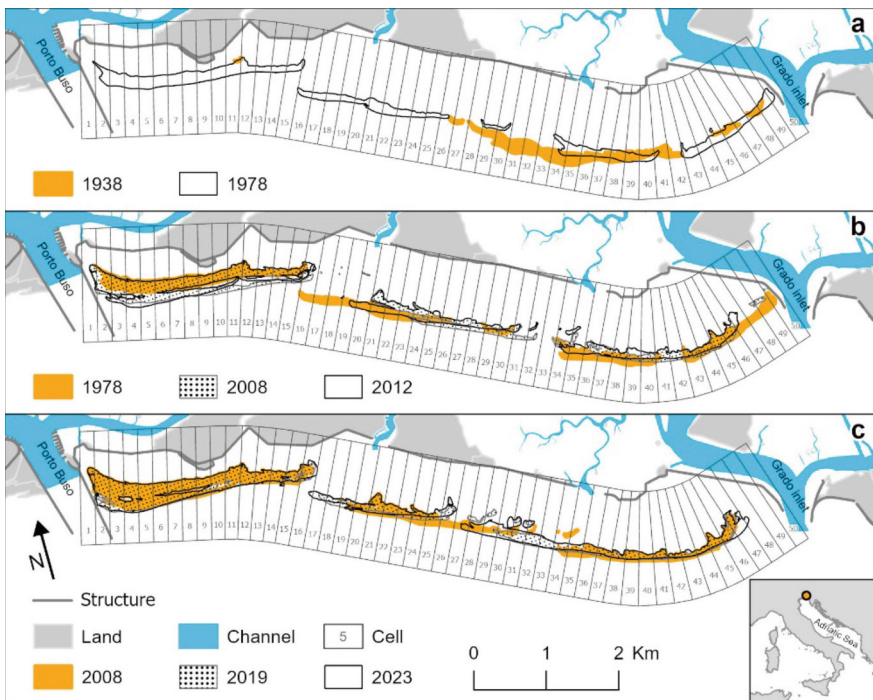


Fig. 1. The barrier islands located between the tidal inlets of Porto Buso and Grado: the maps report the evolution of the sandbanks during different time spans.

3 Methods

Starting from the work of [7], we revised and updated the shoreline multidecadal evolution of the Grado sandbanks. We derived the shoreline from historical cartography (1891/1938), aerial photos (from 1954 to 2014), and five “ad hoc” topographic surveys (from 2015 to 2023). After subdividing the coast into 50 cells, the variations of subaerial barrier area (AREA) and the shoreline position (SHO) were computed for each temporal step and then analysed as morphodynamic indicators. In addition, two surveys (1968 and 2015) along 11 bathymetric sections allowed for the analysis of shoreface volumetric changes down to a depth of 6 m.

4 Results and Discussion

A multidecadal qualitative and quantitative analysis of the landforms’ changes described by AREA and SHO has allowed to reconstruct the evolution of the Grado sandbanks starting from old, imprecise geographic maps (IGM from 1891 and 1936) to the most recent GNSS survey in 2023 (Fig. 1).

The first phase of barrier island formation, from 1891/1938 to 1978, was strongly influenced by coastal defense works: a 1200-m-long seawall along the western side of the Grado inlet (1928–1934) and two jetties to fix the entrance of Porto Buso (1960–1964). In response to the interruption of the longshore sand drift, sandbanks emerged in a previously shallow water area, first in the eastern sector and later in the western one. In 1978, the barrier island system appeared to have fully formed over the entire coastal sector between the two tidal inlets, marking the end of this initial phase (Fig. 1a). In the second phase (from 1978 to 2023), the increased availability of data allows us to observe the banks’ evolution at various time scales. Considering a medium-term interval (45 years, Fig. 1b, c and Fig. 2) a rise in AREA is the most prevalent pattern along the 50 bank cells, while SHO exhibits a relevant variability. The trap effect of the Porto Buso jetty with respect to the dominant longshore drift is attested to by the western sector (cells 1–15), which shows the highest progradation values close to the jetty and gradually decreasing towards the east.

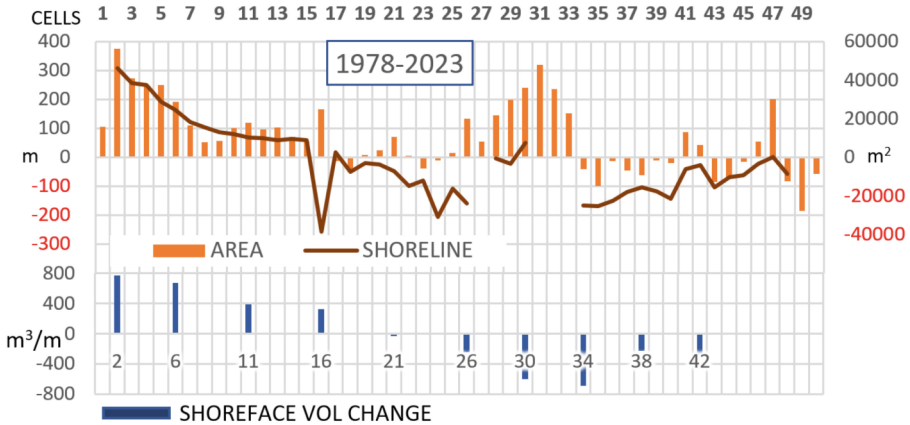


Fig. 2. Spatial distribution of the AREA and SHO indicators along the 50 cells in a medium-term interval (1978–2023).

The middle and western sectors (cell 16–50) exhibit a large degree of variability, significant shoreline retreat, and little concordance between the two morphodynamic indicators. The shoreface budget, which displays a typical rotational effect on the entire barrier island system, validates the spatial differentiation (Fig. 2). As examples on a shorter time scale, we provide two datasets with the same temporal span (4 years, Fig. 3). The cell data distribution in the 2008–2012 period clearly shows longshore variability resulting from a typical cannibalisation. The three distinct barrier islands exhibit a rotational pattern, as evidenced by the strong correlation between the two morphodynamic indicators (AREA and SHO), which show coastline progression and area gain in the downdrift sectors, as well as shoreline retreat and area loss in the updrift ones.

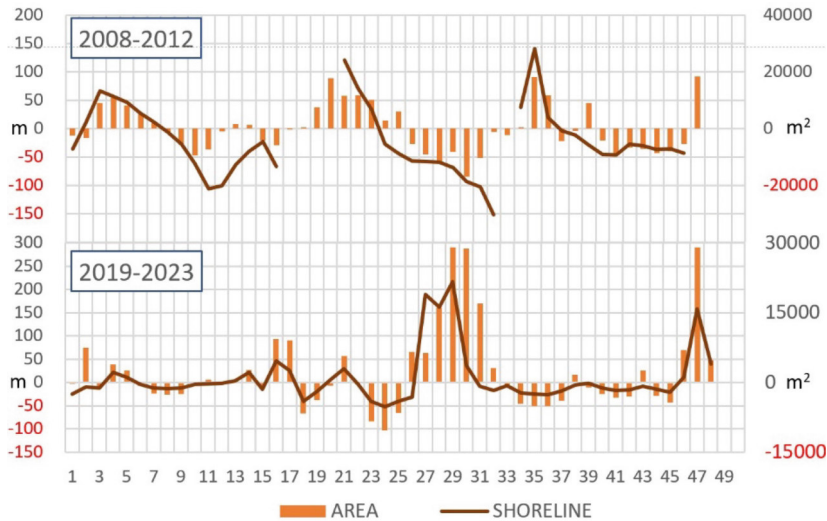


Fig. 3. Spatial distribution of the AREA and SHO indicators along the 50 cells in two short-term intervals (2008–2012 and 2019–2023).

A high spatial variability prevails in many of the time periods we have examined, and the 2019–2023 period is no exception. Different combinations of the two indicators are feasible within this variability, and they are associated with distinct geomorphic behaviours. Among the transgressive processes, the simplest is identifiable thanks to negative values of both indicators, i.e., the erosional response induces a shoreline retreat resulting in barrier thinning with surface loss (Fig. 4a). AREA and SHO are both negative also when overwash events lead to island breaching and landward spreading of sediments to form a subaqueous fan (Fig. 4b). When the washover deposit emerges, the indicators become opposite (SHO negative and AREA positive, Fig. 4c).

Progradational patterns coexist in other cells nowadays. Spit gemination and/or lengthening (Fig. 4d, e), as well as nearshore bar welding (Fig. 4f), are typical long-shore constructive processes that give positive values for both indicators. Depressions between newly formed emerged bars evolve into parallel swales or cat’s-eye ponds (Fig. 4g). An unusual combination of the indicators or extremely high anomalous values for both can arise from more complicated circumstances brought on by distinct evolutionary processes taking place at a scale smaller than the one taken into consideration for the analysis.



Fig. 4. Various morphodynamic scenarios in the sandbank evolution (see the text for details).

Finally, we can observe the overall signal (mean data of SHO and AREA) of the barrier island evolution and investigate if there is a relationship with the rate of sea level rise. The general trend, albeit through alternating phases, is towards an increase in the barrier area over time (Fig. 5a). This is explained by the fact that a washover tends to reduce the accommodation space through the rollover process. Despite the limitation of this type of analysis, the movement of the shoreline (Fig. 5b) appears to be related to the sea level fluctuation by alternating periods of stasis with times of severe retreat, according to a similar stepped variation of sea level, which significantly increased after 1989. The morphological adaptation seems to occur with a delay of around 4 years.

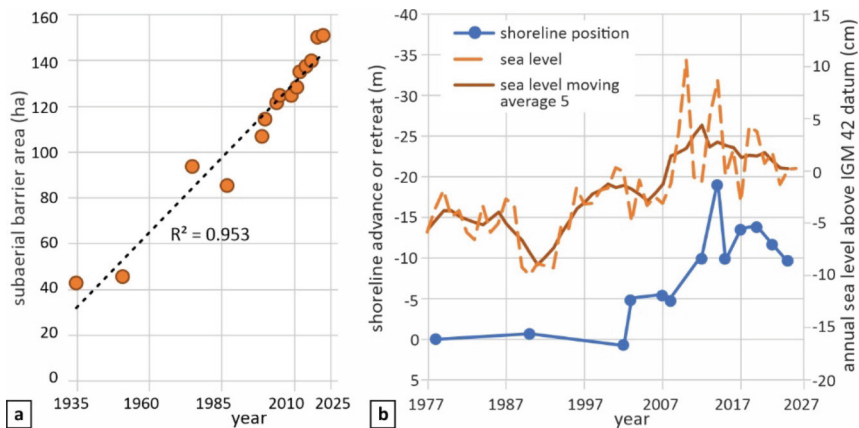


Fig. 5. Overall evolutive signal (mean value) for the entire sandbank system with regards to subaerial barrier area (a) and shoreline position (b) in relation to sea level rise. Sea level annual data from Trieste, Molo Sartorio tide gauge, available through SEANOE <https://doi.org/10.17882/62758>).

5 Conclusions

The multidecadal development of the Grado sandbanks demonstrates the potential of barrier islands to adapt to sea level rise, which may result in a dynamic coexistence of erosive and depositional processes. With a sea level rise rate of 1.4 mm/y (century-long) to 3.5 mm/y (after 1989), the barrier island system is self-sustaining via a rollover process and a compensatory longshore mechanism that benefits from sediment supplies deriving from the eastern riverine coastal tract. The degree of freedom and maintenance of sedimentary sources is inextricably linked to the preservation of these landforms and their role as ecosystem services. Given that the bulk of landforms, both submerged and subaerial, are destined to change swiftly and even suddenly, conservation programs must take on a unique meaning and application in this context. It should ideally be founded on the fundamentals of adaptive management and centered on the preservation of morphodynamic systems.

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