Understanding the resilience of barrier islands and coastal dunes after storms

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When a coastline undergoes massive erosion, like a hurricane flattening a beach and its nearby environments, it has to rebuild itself—relying on the resilience of its natural coastal structures to begin piecing itself back together in a way that will allow it to survive the next large phenomena that comes its way.

Drs. Orencio Duran Vinent, assistant professor, and Ignacio Rodriguez-Iturbe, Distinguished University Professor and Wofford Cain Chair I Professor, in the Department of Ocean Engineering at Texas A&M University, are investigating the resilience of barrier islands and coastal dunes after high-water events and storms. In doing so, they are helping engineers and researchers assess the vulnerability of coastal landscapes.

Their full findings were published as related articles in the *Proceedings of the National Academy of Sciences* titled "Probabilistic structure of events controlling the after-storm recovery of coastal dunes" and "Stochastic dynamics of barrier island elevation."

"If you understand how dunes grow, then you can take action, for example, in terms of vegetation or artificial barriers, to protect the coastline," Rodriguez-Iturbe said. "But you cannot protect or manage, in this case, dunes and barrier islands if you don't first understand the dynamics taking place."

In general, there are two types of high-water events along the coast: natural disasters like hurricanes and tsunamis, which cause waves that devastate the shoreline, and lesser storm surges, which do not cause widescale damage but still affect the coastal environment. As Duran Vinent explained, it is these smaller, routine events that control the post-storm resiliency of dunes and barrier islands that play a key role in protecting coastal communities by absorbing some of the impact from surges.

"Those events are not really strong enough to erode a mature dune completely, but they are strong enough to prevent one from growing in the first place after a storm that erodes the dunes and the vegetation ecosystem," he said.

With that in mind, the research team first studied the structure and properties of such smaller high-water events from around the world, utilizing buoy and other data to calculate characteristics like beach elevation, wave runup and water level to analyze them.

Their findings were twofold: first, they confirmed that the high-water events happen randomly and unrelatedly to one another. Then the team discovered that high-water events around the world shared the same general characteristics and had the same typical frequency per year with a given intensity when measured at beach level.

"This means that we can actually say something about the typical size of these nuisance flooding events or the typical size and frequency of events affecting the recovery of the coastal environment," Duran Vinent said. "Regardless of location, we have a unified description. And this simplifies the work for policymakers or managers a lot because then they don't need complex calculations."

The team took their newly discovered information and applied it to developing a model that would determine the elevation of a barrier island and, ultimately, whether or not a dune would be able to succeed. Additionally, this model provides a valuable tool in rebuilding coastlines that have been broken down and deteriorated over time, as it gives engineers a way to see how tall a dune or barrier island needs to be in order to prevent frequent overwashes and, thus, ensure ecosystem survival.

"The dynamic between high-water events and the geomorphology of barrier islands is complicated because the impact of any high-water event depends on how big the dunes are," Rodriguez-Iturbe said.

"And then while the dune is growing, you have these high-water events randomly interrupting its growth," Duran Vinent said. "This means that there is a competition between the frequency of the high-water erosional event and how fast the dune is growing."

This competition became the base of their analytical equation developed to determine whether or not a dune would be able to succeed, mathematically mapping in which conditions a barrier island would be resilient or vulnerable.

Dunes on barrier islands are vitally important, Duran Vinent explained, because they prevent water events from breaching the island and protect the vegetation on the back of the island from flooding, allowing a diverse set of vegetation to grow that is otherwise intolerant to seawater.

More information: Tobia Rinaldo et al, Probabilistic structure of events controlling the after-storm recovery of coastal dunes, *Proceedings of the National Academy of Sciences* (2020). DOI: 10.1073/pnas.2013254118

Orencio Durán Vinent et al. Stochastic dynamics of barrier island elevation, *Proceedings of the National Academy of Sciences* (2020). DOI: 10.1073/pnas.2013349118

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