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EARTH SCIENCES
Published: 01 May 2024
doi: 10.3389/frym.2024.1347213

WHAT ARE BARRIER ISLANDS AND HOW ARE THEY AFFECTED BY CLIMATE CHANGE?

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LYRA MONTESSORI LICHTENTAL
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Barrier islands are complex ecosystems that exist off the coast of every continent except Antarctica. They protect the coastline from direct impacts of storms and sea-level rise. These islands are home to people and animals, some of which are endangered. Barrier islands naturally move and change shape, but climate change and human development can prevent this movement, disrupting natural processes. Conservation of barrier islands is important for providing habitats for plants and animals as well as for protecting the coast of the mainland.

WHAT IS A BARRIER ISLAND?

Barrier islands (Figure 1) are made of sand and are created and changed by wind, waves, and tides. Barrier islands are found on about 15% of the world's coastlines, on all continents except Antarctica [1]. Along the east coast of the United States, barrier islands occur along 78% of the shoreline from Maine to Florida. Some islands are close to the mainland (a few 100 m), but others can be found several

kilometers away. Barrier islands are surrounded by water—on one side is the ocean and on the other is the **lagoon**, a body of saltwater separated from the ocean by the island. No matter where they occur, barrier islands protect the mainland (a large, non-island land mass) by reducing damage from storms.

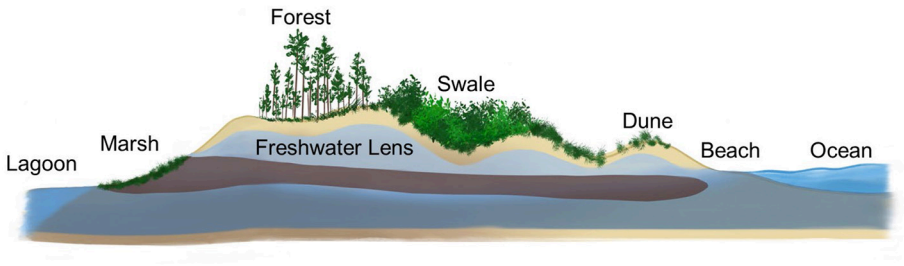

Figure 1

Depending on the location, climate, and amount of disturbance from storms, wind, and waves, barrier islands have different kinds of plant communities that provide habitats for animals. On the ocean side of the island, the high tide determines where plants can grow, because the high salt content of ocean water limits plant growth. In the beach environment there is a lot of salt and sunlight, and summer temperatures can be very hot. Only a few plant species grow in these harsh conditions. Plants that can survive here may begin to trap wind-blown sand, forming small dunes. Many of these plants are grasses, but some trees and shrubs also build dunes. As dunes grow, they protect the interior of the island from salty seawater and windblown sand, allowing different types of plants to grow in these protected areas (Figure 2).

Because they are surrounded by seawater, barrier islands have limited freshwater. The only source of freshwater comes in the form of rainfall, but it travels quickly through the sand and floats on top of salty seawater in the sand underneath the island. This is called the **freshwater lens**, and it provides an important source of freshwater for island plant communities (Figure 1). Water in the freshwater lens usually does not mix with seawater unless it is disturbed by a storm. Storms that contaminate the freshwater lens with seawater are expected to happen more often as the climate changes and sea levels rise.

Inland areas behind dunes are called **swales**. Swales are often lower in elevation than dunes and they support plants that may not be as tolerant of the beach environment. Over time, grasses and other plants in swales may be replaced by shrubs and small trees that provide perches for birds and cover for mammals. If the inland areas of the barrier island are left undisturbed by storms and sea-level rise, forests can develop. On the lagoon side of the island, opposite the ocean,

LAGOON

A shallow body of water separated from the ocean by a barrier island or barrier reef.

Figure 1

A cross-section of a barrier island. The beach is found between the dune and the tideline of the ocean. Dunes are mounds of sand formed by the interaction of plants and windblown sand. The swale is a low-elevation inland area that is protected by the dune. Forests can grow in the interior of the island when disturbance is low. Marshes are found in low-lying areas flooded by tides. The lagoon contains saltwater and is separated from the ocean by the barrier island. Below the island but above the saltwater sits the freshwater lens, where rainwater collects (image credit: Julia Yee).

FRESHWATER LENS

Groundwater (from rain) under a barrier island that is less dense than seawater, sits on top of seawater under a barrier island, and is accessible to plant roots.

SWALE

The low-elevation area of land behind a dune or between dune ridges. These areas are usually sheltered from wind and waves, and can be flooded by groundwater.

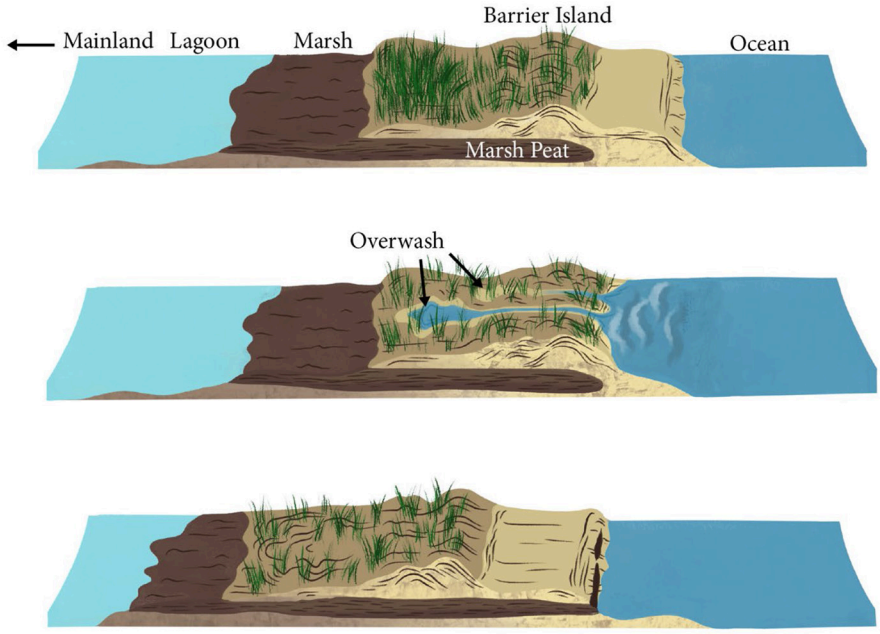

Figure 2

Overwash occurs when sand washes over the dunes and into the island interior. High waves can push water over dunes, carrying sand from the beach to the middle of the island and sometimes into the marsh behind the island. Over time, overwash can help barrier islands move toward the mainland and stay above rising sea-levels (image credit: Julia Yee).

SALTWATER MARSH

Low-elevation habitat that is built on mud, regularly flooded by high tides, and covered by flood-tolerant vegetation.

OVERWASH

The flow of seawater and sand (usually storm driven) over a dune, which is then deposited inland.

saltwater marshes often form in shallow water and are flooded by daily tides (Figure 1). Marshes are covered by plants that grow in thick mud and are tolerant of flooding and saltwater carried by the tides.

Storms and sea-level rise create changes on barrier islands. Strong storms (like hurricanes) affect the coast every year, causing damage from flooding, large waves, and strong winds. During storms, high waves can erode or knock down dunes and can change the landscape of the whole island by moving sand from the beach and dunes toward the interior and back of the island (Figure 2). This is called **overwash** because sand is washed over the dunes into the island interior or the lagoon-side marsh [2]. When overwash occurs, dunes may be flattened by waves, but eventually new plants can grow in the bare sand and build dunes again. These new dunes may form further inland, away from the ocean. When the marsh is buried in sand by an overwash event, different plants can grow in the new sand and create a new swale habitat over an old marsh. Marshes may also form on the lagoon side of the island after large overwash events. When all these habitats change together, the entire island can move away from the ocean, toward the mainland (Figure 2). This movement keeps some of the barrier island above sea level [3]. When sea levels rise, waves and storms increase and overwash occurs more often, causing barrier islands to move faster. However, if a barrier island cannot move and keep up with sea-level rise, it may shrink or sink beneath the ocean.

BARRIER ISLANDS, CLIMATE CHANGE, AND HUMANS

Barrier islands are important for plants, animals, and humans on the coast. Migrating shorebirds and sea turtles nest on barrier islands. The isolation from the mainland helps these animals to protect their young. Fish use the shallow lagoons behind barrier islands as nurseries where their young can grow and hunt, protected from larger predators that live in the open ocean.

JETTY

Hard structure built out from the beach and into the ocean, meant to capture and stabilize sediment that moves along the shoreline.

For humans, there are many benefits to living near the ocean, and large populations of people live along coastlines all over the world. The ocean provides delicious seafood, waterways and harbors for shipping and transportation, and opportunities for recreation on the water and at the beach. Because of this, many barrier islands have been developed with beach houses, boardwalks, and fishing piers.

SHORELINE HARDENING

Building hard structures (such as seawalls and jetties) along shorelines to prevent or decrease erosion. Hard structures are often built from concrete or rock.

A well-known example of barrier island development can be seen in the Outer Banks of North Carolina in the United States. People have constructed entire towns, neighborhoods, highways, and marinas on these islands. On other developed barrier islands, humans frequently build structures such as seawalls and **jetties** (solid walls that extend perpendicular to the beach) that create a shoreline that is harder than sand. This process is called **shoreline hardening**. Unfortunately, these structures can cause problems for the natural barrier island movement that we described. Sand moving down the beach in ocean currents becomes trapped on one side of a jetty, leaving the other side without a source of new sand (Figure 3).

EROSION

The movement of sand, dirt, or rocks from one location to another by water or wind.

When houses, roads, and other hard structures are built on barrier islands, sand cannot move freely, and the island becomes fixed in place. This leads to **erosion** and coastal flooding. To prevent erosion, people build dunes made of sand that they get from the sea floor. This sand is pumped onto the beach and used to build new dunes that are planted with common dune plants. Unfortunately, without natural island migration, dunes frequently erode and need to be rebuilt every few years. This process is incredibly expensive and affects animal communities along the sea floor by disturbing and destroying their habitats.

Climate change affects all life on barrier islands. Changing temperatures impact where and how well barrier island plants can grow. Plants, like animals, need a certain habitat and environment. As Earth's climate changes and winter temperatures do not get as cold, plants that live in warmer climates can spread into new, previously colder, places [4]. Warmer temperatures also make it harder for plants that are used to cooler environments to thrive. Changing where plants naturally grow affects how islands can move and alters available habitat for animal communities. In many coastal areas (and in other environments around the world), higher winter temperatures are increasing the growth of shrubs. As shrubs grow, they push out other plant species,

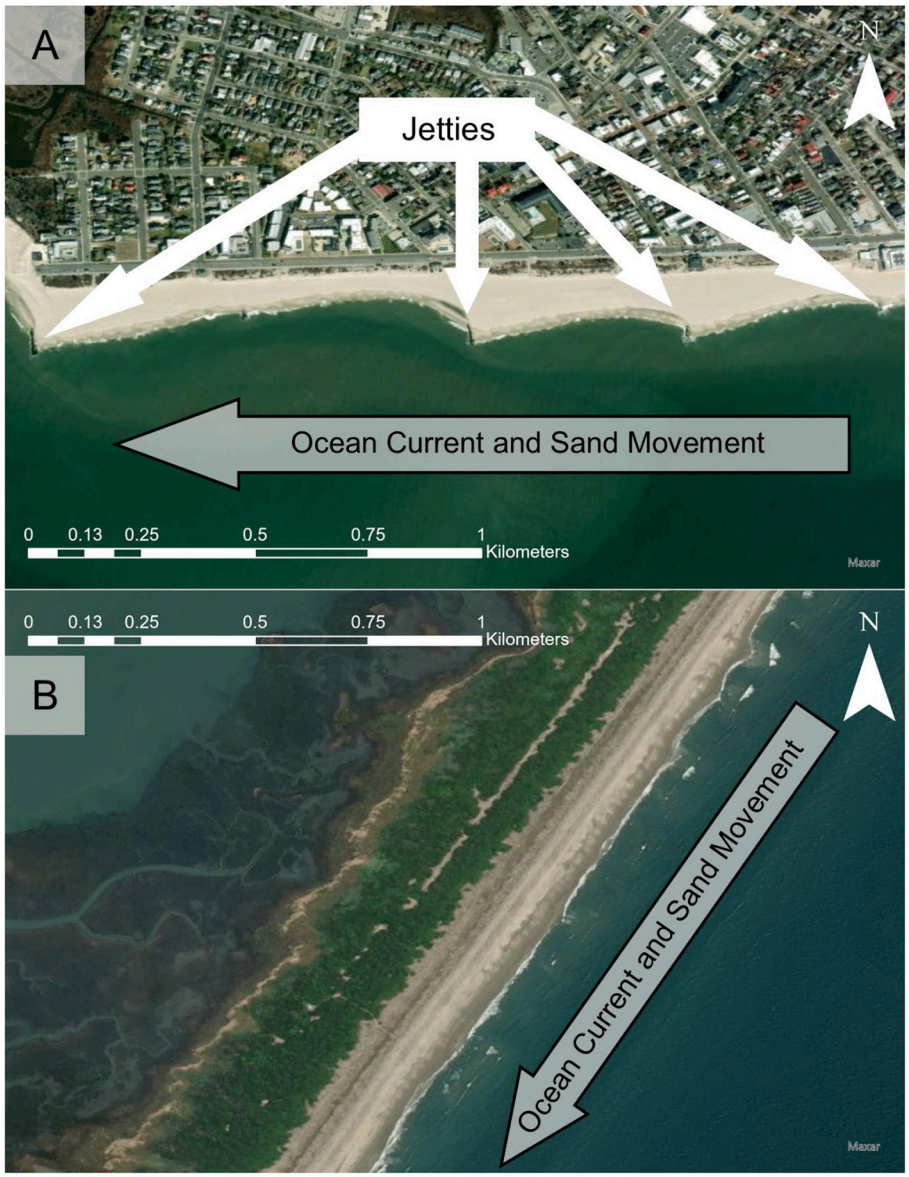

Figure 3

(A) Jetties constructed on the beachfront in Cape May, NJ. Sand movement is interrupted by these structures, causing sand to build up along one side of the jetties. **(B)** An undeveloped beach on Hog Island, VA. Sediment movement can occur naturally (satellite images from the Esri World Imagery Basemap provided by: Esri, Maxar, Earthstar Geographics, and the GIS User Community).

like dune grasses. Shrubs also reduce the amount of sand that can move across the island when overwash occurs. A lot of shrubs growing in a coastal area can behave similarly to a row of houses on an island, stabilizing the island and making it unable to adapt and move [5].

THE FUTURE OF BARRIER ISLANDS

Predicting how barrier islands will respond to the effects of climate change, including warming temperatures, stronger storms, and faster sea-level rise, is a priority for scientists. High rates of sea-level rise make it hard for barrier islands to increase in elevation, putting them at risk of ending up under water. This affects the unique animal and plant communities on these islands, as well as the people that live on and around the islands.

Around the world, scientists and members of coastal communities are working together to understand and adapt to these changes, to protect cities, people, and threatened and endangered species living on barrier islands. Scientists monitor changes on the ground or from satellite images, and they use computer models to predict how storms affect the way barrier islands move and respond to rising sea level. Communities are beginning to understand the importance and protection provided by the movement of barrier islands, and in some places communities are even allowing barrier islands to move naturally, rather than keeping them fixed in place. This natural movement allows the islands to stay above sea-level, collect sand, provide habitat for plants and animals, and protect the mainland from storms. Understanding why and how these islands adapt to a changing climate is important for preserving them for as long as possible. As we learn more about barrier islands, we can protect them from climate change and use them to protect ourselves.

ACKNOWLEDGMENTS

The authors thank the members of the Coastal Plant Ecology Lab for providing feedback on earlier drafts. This study was supported by the National Science Foundation Long-Term Ecological Research Grant: DEB-1832221.

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SUBMITTED: 30 November 2023; **ACCEPTED:** 18 April 2024;
PUBLISHED ONLINE: 01 May 2024.

EDITOR: Melissa Hamner Mageroy, Norwegian Institute of Bioeconomy Research (NIBIO), Norway

SCIENCE MENTORS: Oscar Fernandez and Valerie Kern

CITATION: Riffe EC, Canfield M, Sabo AB, White AE and Zinnert JC (2024) What Are Barrier Islands and How Are They Affected by Climate Change? Front. Young Minds 12:1347213. doi: 10.3389/frym.2024.1347213

CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWERS

LYRA MONTESSORI LICHTENTAL, AGES: 8–11

We are a group of children from the school Lyra Montessori Lichtental, a German-English bilingual Montessori school with a mixed-age class for learners aged 6–12: Anton (8), Aeon (8), Olivia (8), Mateo (10), Maël (10), and Armin (11). Together, we speak five languages: German, English, Spanish, Hungarian, and Macedonian. We love sports (but could not agree on our favorites, that is why a comprehensive list of all we like): basketball, football, chess, dance, table tennis, tennis, archery, and swimming. And of course, we want to reach high in our goals, who would not?

SEA CREST SCHOOL, AGES: 11–12

We are a curious group of 6th grade science students who live in coastal California. While we all have individual interests, we are united by a shared passion for environmental stewardship and, in all things, we are determined to "leave it better than we found it": our school's mantra. Our group members include: Oliver, Duncan, Aiden, Kayden, Greyson, Nathan, Marijn, Skyler, Malina, Crystal, and Daphne.

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Emily is a Ph.D. candidate at Virginia Commonwealth University in the Integrative Life Sciences Program. She received her master's in ecology and evolutionary biology from Appalachian State University in 2018 and her bachelor's in plant biology from North Carolina State University in 2016. She has studied

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Andrew White received a master's degree in biology from Virginia Commonwealth University (VCU) in 2022. His main research interests revolve around the interaction between water, wind, sediments, and plants and how each of these factors shape the landscapes around us. In addition to his work in the Coastal Plant Ecology lab at VCU, Andrew also holds a fisheries technician position with the Virginia Department of Wildlife Resources.

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Julie has worked in coastal systems since 2001, with a focus on the barrier islands. Her research at Virginia Commonwealth University centers on plant interactions with living and non-living factors in the context of global change in coastal systems. Trained as a plant ecologist, she is interested in why individual species move and respond to climate change. She is a creative person and spends much of her non-working time cooking, knitting, sewing, designing, gardening, dyeing yarn with native plants, and traveling, while raising two wonderful children.