Exploring Earth Surface Changes Along North Carolina's Coast

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Lesson Abstract: Students will learn about the geology of the North Carolina coast and the major processes that shape beaches and barrier islands. The lesson will incorporate photographs and sediment samples of the environments composing barrier islands (e.g. marsh, dune, etc.), as well as a core sample through the subsurface of a barrier island. The lesson will culminate in a class discussion where students will utilize the information they learned in the lesson to make predictions on the future of the North Carolina coast.

Approximate time of Lesson: Estimated 2 periods - 45 minutes each, or 1 long period - 1.5 hours

Target Grade Level: Middle (but we are willing to adapt for other grade levels)

Essential Standards Considered:	**Middle School: 6.E.2, 8.E.2.1, 8.L.3.1** Elementary: 3.E.2.2, 4.E.2.3 (with modification) High School: EEn.2.1.3, EEn.2.6.4, EEn.2.7.1 (with modification)
Setting & Resources Needed:	Indoors. **Required**: Powerpoint, paper, pencils, and colored pencils. **Recommended**: if the lab has a dissecting scope, students will be able to inspect sediment much closer – it looks cool close up!
Type of Activity (Groups or Class)	Class/group/individual activity – OR if we (Ethan and Justin) come to the classroom, we will bring physical sediment samples and have the class break into groups of 2-4 students for the sediment examination and interpretation
Website for Materials:	https://vimeo.com/102137304

Learning Objectives

Section 1

1. List the components of a barrier island system and state where barrier islands exist along the North Carolina coast.
2. Recognize the problems faced on the Outer Banks of NC using a New York Times article.
3. Describe the major cause of change on barrier islands and the impacts to the human inhabitants and landscape using a video entitled "Windy People, Dynamic Landscapes".
4. Identify the different environments on a barrier island using an aerial photograph.
5. Sketch the profile of the barrier island and apply knowledge on the different environments to label them on the profile.
6. Compare these environments in terms of their characteristic vegetation, topography, and physical processes.

Section 2

7. List the 2 major processes that move and shape barrier islands (refer back to "Windy People video".
8. Describe how sea-level has varied in the past, identify whether sea-level is rising or falling presently, and discuss how sea-level impacts barrier islands.
9. Explain how storms impact barrier islands. Compare these impacts to those of sea-level rise.
10. Apply knowledge about impacts of sea-level rise and storms on barrier islands to illustrate barrier island transgression.

11. Illustrate how a geologist studies barrier island response to storms and sea-level rise through core studies.
12. Examine properties of the sediments from each barrier island environment and assess the environment of unknown sediments.
13. Interpret the environments of sediment layers within a core with justification based on sediment properties.
14. Debate human's impact on the natural evolution of barrier islands.

Background

Barrier islands are elongated bodies of sand that front the ocean coastline and are separated from the mainland by an estuary, bay, or lagoon. These islands buffer the mainland from the high waves and energy from storm events, such as hurricanes. They also provide habitat for many plants and animals, including shrubs and grasses, shorebirds, and sea turtles. These islands are punctuated by inlets, which connect the ocean to the bays and lagoons behind the island and through which tidal waters are exchanged. Several different environments makeup the barrier island system, including the beach, dune, maritime forest, backbarrier marsh, and lagoon. Each of these environments has a unique set of sediment and vegetation characteristics as well as different processes that shape them.

Sea-level rise is an important driver of change on barrier islands. Sea-level controls, along with sediment availability, whether a barrier island will move landward, seaward, or remain in place. If sediment supply is held constant, a rising sea-level will result in landward movement of a barrier island. In a similar manner, if sea-level falls, but sediment supply is constant, the island will move seaward. Barriers that are moving landward are called transgressive barrier islands, while those that are moving seaward are entitled regressive barrier islands. Transgressive and regressive barriers also have varying characteristics in terms of topography. Transgressive barriers have low elevation, discontinuous dunes and the distance between the beach and the backbarrier marsh is generally short. North Carolina examples of these types of barriers include most of the Outer Banks and the southern end of Onslow Beach, where materials and examples in this lesson were collected. Regressive barriers have higher elevation dunes, are generally much wider, and may contain extensive maritime forest behind the dunes. An example of a regressive barrier island is the section of Bogue Banks near Pine Knoll Shores, NC.

Storms are the agents of change along barrier islands. The movement of sand across the barrier island, which is necessary to keep pace with sea-level rise occurs during storms in a process called overwash. This occurs when water levels on the oceanside exceed the elevation of the beach and dune, thus allowing water and sand to flow across the island. Increases in water levels during large storms, such as hurricanes and nor'easters, are called storm surges. During this process, eroded beach and dune sand is deposited on top of the backbarrier flat and/or the backbarrier marsh in a landform entitled a washover fan. These washover fans eventually become colonized by grasses and shrubs and are transformed into either backbarrier flats or marshes, thus maintaining the islands width and continuing the process of barrier island transgression.

Natural processes, such as overwash, are altered when humans develop barrier islands. Infrastructure, such as condominiums and roads, block the across-island transport of sediment necessary to maintain island width with a rising sea. However, the beach will still erode in response to storms, thus narrowing the island width and making it more vulnerable to catastrophic overwash and inlet breaching during large hurricanes. Engineering attempts to stop barrier island erosion, such as beach nourishment, jetties, and groins alter the transport of sediment along and across barrier islands and can have negative consequences, such as increasing erosion along parts of the beach that are not engineered. North Carolina's barrier islands range from highly developed, such as those along the Outer Banks north of Cape Hatteras, to completely undeveloped, such as the barriers along Shackelford and Core Banks.

Lesson Outline

Section 1- Barrier Islands of North Carolina

1. What is a barrier island?
    a. Show overhead view of a barrier island (slide 2) and point out the various components of a barrier island system (e.g. ocean, island, lagoon, etc.)
2. Where are the Outer Banks?
    a. Ask students if they can point out the Outer Banks on a photograph of North Carolina (slide 3). Slide 4 has the Outer Banks highlighted.
3. Introduction to Hatteras Island
    a. Point out where Hatteras Island is on slide 5 (orange highlighted area). Introduce that they will be reading (or have read) a newspaper article about the impacts of Hurricane Isabel on Hatteras Island. Use before and after Isabel photos on slide to introduce that hurricanes can dramatically impact islands.
    b. Have students read the NY Times article, ask them to pay particular attention to the what the problems are for the Outer Banks
    c. After reading article, ask students to summarize the problems for the Outer Banks, use slide 6 to make sure they get the major take home points.
4. "Windy People, Dynamic Landscapes" (6 minutes)
    a. Introduce that the students will now watch a video about the Outer Banks and the processes that influence the landscape and life on the islands.
    b. After the video, ask the students the discussion questions on slide 8.
        i. Answers: (1) storms, (2) human development
5. Environments of a barrier island
    a. Ask students to identify in an aerial photograph the major environments on a barrier island (beach, dune, maritime forest, backbarrier marsh) – Slide 9
    b. Show students a profile of a barrier island and then ask them to identify the 4 environments on the profile – Slide 10
    c. Go through each environment and have students discuss the vegetation, topography, and processes acting to shape the environment
    d. Beach (Slide 11)
        i. No vegetation generally, just sand or gravel/pebbles on some beaches
        ii. Generally flat topography
        iii. Waves and winds are the processes that move sand around on beaches- erode during storms, accrete during fair weather
    e. Dunes (Slide 12)
        i. Grasses and shrubs may grow on the dunes, help to stabilize and accrete the dune sand
        ii. Dunes are built by wind and can be eroded away by waves.
        iii. Dunes can be quite steep; can be high or low elevation depending on how well established they are (e.g. Jockey's Ridge in NC)
    f. Maritime Forest (Slide 13)
        i. Trees, shrubs, and grasses colonize the forest- can be quite dense
        ii. A sandy organic soil forms as plant matter dies and decays
        iii. Wind is the main physical process acting on this environment, in extreme storms, waves might reach the forest because of storm surge
    g. Backbarrier marsh (Slide 14)

i. Marsh grass (namely, spartina alterniflora and spartina patens) is the dominant vegetation
ii. Growth of the marsh is controlled by the availability of sediments for the grasses to grow on and accumulation of dead plant material
iii. Tides and waves in the lagoon influence the marsh. Tides can bring in sediments to help the marsh grow. Waves can erode the marsh.

6. Section Quiz (Slide 15)
   a. Have students draw an island cross-section and label each of the major environments.
   b. For each environment, describe the physical processes at work and distinguishing features that we discussed.

<u>Section 2- Moving Islands</u>

1. Question to students: What are the 2 major processes that move barrier islands?
   (1) Sea-level rise and (2) storms
2. Discuss the trends in sea-level over the past 200,000 years
   (1) Sea-level influences barrier islands on many different time scales- months to centuries
   (2) Sea-level has risen and fallen many times over the past 200,000 years- reference figure in slide – has been higher and lower than present
      i. Point out that around 20,000 years ago sea-level was about 140 m below where it is currently- would have been near where the modern continental shelf break is
      ii. Point out that around 120,000 years ago, sea-level was 8 m above where it is presently- point out where this shoreline is on the satellite image of NC
   (3) Current rate of global sea-level rise (called eustatic) is 3 mm/yr
   (4) "Relative sea-level" which is the sea-level at a given location can be higher or lower than the global sea-level because of vertical land movement
      i. Land movement up and down can be from glaciers melting (less weight)
      ii. Land surface sinking (subsidence) because of sediment deposition (e.g. Louisiana and the Mississippi River delta)
      iii. Ask the students if they recall from the "Windy People" video how barrier islands respond to sea-level rise? Answer is they move landward (for the Outer Banks)
3. Storms
   (1) While barrier islands respond to sea-level rise by moving landward, the agents of this response are STORMS
      i. Hurricanes and nor'easters erode material from the oceanside and deposit on the backside of the barrier (behind dunes and on top of marsh)
         1. This process is called overwash and the resulting landform is called a washover fan.
         2. Students may ask if a tsunami could impact a barrier island. The answer is that this is highly unlikely because tsunamis are triggered by events, such as earthquakes or an underwater landslide that occur on active margins (where plates collide). Barrier islands form on passive margins where seismic activity of this magnitude does not occur.
4. Island transgression- series of slides that explain how as sea level rises, the barrier moves landward
5. How do we study island change?
   (1) Major way that geologists understand how barrier island environments have changed from past to present is to take core samples
   (2) Show students the video that explains how cores are collected

i. Use a vibrating mechanism to pound the core into the ground to the desired depth
ii. Use a tripod and a wench to pull the core out of the ground
iii. Core is transported back to the lab where it is split open, described, photographed, and sampled for various analyses
1. Show photographs of a core and explain that we can interpret the past based on the stacking of the various layers (e.g. beach on top of marsh means barrier island moving landward)

6. Sediments from barrier island environments
(1) In order to interpret what the sediments in cores are, we must understand what the sediments of the different environments look like in the present.
(2) Beach sediments
i. Mostly quartz sand grains, may be fine or coarse or mixed, may have shell fragments or heavy minerals mixed in; could be both well or poorly sorted (refers to whether grains are all about the same size)
(3) Dune sediments
i. Fine-grained, well sorted quartz sand grains
ii. Well-sorted because the process that transports them is the wind, which moves only a certain size of sand grains around.
iii. May be some dune grass material in it, but generally very little organic material
(4) Maritime Forest
i. Sandy soil forms as plant material dies and accumulates
ii. Soil is generally brown, organic rich, and sandy- looks a lot like coffee
(5) Backbarrier Marsh
i. Muddy and organic rich- lots of old plant material
ii. May have a substantial fraction of sand in it
(6) Lagoon
i. Mud or muddy sand, not much organic material
ii. May have shell fragments or whole shells, oysters, clams, mussels
iii. Now show the students 3 unknown samples of sediments and ask them to identify what environments they come from. Answers: (1) Marsh, (2) Beach, (3) Dune
(7) Now show the students a core sample and ask them to identify what environment each layer is from
i. Ask them to explain what they think the core tells us about how the barrier island has moved with time? Answer is moved landward with rising sea.

7. **Break out group discussion**- How are humans impacting the natural evolution of barrier islands? What should we do to mitigate this?
(1) Key points: how are humans impacting?
i. Development inhibits landward movement of barrier sand through overwash
ii. Nourishment and hard structures, such as groins and jetties, tend to exacerbate erosion in the long-term
(2) What should we do to mitigate this?
i. Limit development on barrier islands- allow sand to naturally move across the island
ii. Specific development issues
1. Build less bridges – use ferries
2. Use mobile structures
3. High cost