2016 Teachers on the Estuary Teacher's Sentinel Site Lesson Plan Booklet

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Activity 1

Habitat Mapping: A River Mouth of Change

Estuary Principle

Principle 2: Estuaries are dynamic ecosystems with tremendous variability within and between them in physical, chemical, and biological components.

Research Questions

How can we detect landscape changes over time using aerial maps?
What impact can landscape changes have on habitats and those plants and animals living in them?

Disciplinary Core Ideas (from Next Generation Science Standards)

- MS-LS2-4: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
- HS-LS2-6: Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.

Crosscutting Concept (from Next Generation Science Standards)

- **Patterns:** Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.
- **Cause and Effect:** Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.

Introduction

Landscapes are dynamic, changing over time due to a variety of driving forces. Weather, water, human impacts, and climate are several common causes of landscape change. In the same way, estuaries can change quickly, within hours or days. They are constantly shaped by water flowing from uplands as well as tidal cycles moving and mixing fresh and salt water within the estuary. They can also be dramatically changed by single, severe events such as a hurricane or the building of a levee.

It is important to record and study these changes that happen within such unique ecosystems to understand why change is happening, as well as its positive or negative effect. Once the effect of change is studied, steps can be taken to mitigate negative change or encourage positive change.

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TEACHER GUIDE

Habitat Mapping

Research Questions
How can we detect landscape changes over time using aerial maps?
What impact can landscape changes have on habitats and those plants and animals living in them?

Content Objectives
Students will understand that:

- Landscapes change over time
- Maps are useful tools for detecting change over time
- Exact causes of change and the implications of those changes are the focus of research projects

Exercise 1: Detecting Changes over Time

In this exercise, students will examine several aerial habitat maps from different years to detect change in a coastal landscape. They will mark the changes on the maps to do a visual comparison. Students will discuss the causes and implications of these changes, for both humans and wildlife. They will delve into a case study regarding landscape change and nesting success of the threatened (MA) and endangered (ME) Piping Plover, a small shorebird found along the New England coast.

Students will compare a series of aerial maps to detect changes in the landscape over time. Using Piping Plover nesting data, students will draw conclusions regarding what effect the landscape change might be having on nesting success rates of these shorebirds.

Vocabulary

Aerial – of the air

Dynamic – characterized by continuous action or change

Fledgling – a young bird that has left the nest, able to fly

Habitat – the place where a plant or animal lives

Habitat map – a map that shows relationships between different habitats

Landscape – visible features on an area of land, often a large expanse

Piping Plover – a small shorebird that nests on beaches, and is threatened or endangered throughout its habitat range

Taking it Further

Google Earth:

- Google Earth tutorial so students can make their own maps: https://www.american.edu/ctrl/upload/Intro-to-Google-Earth.pdf
- Google Earth time slider feature: https://support.google.com/earth/answer/183758?hl=en

Habitat Mapping Lessons:

- NOAA's "Do You Have Change?" activity: http://oceanservice.noaa.gov/education/lessons/do_have_change.html

- Green Schools Ireland habitat mapping activity: http://www.greenschoolsireland.org/_fileupload/biodiversity%20resources/Habitat_mapping.pdf

Piping Plover Case Study:

- Background video: http://maineaudubon.org/blog/2012/07/help-protect-maines-piping-plovers/

- Effects of storms on Piping Plover nests: http://maineaudubon.org/blog/2012/06/heavy-rain-and-a-heavy-burden-on-piping-plovers/

Exercise 1

Detecting Changes over Time

Estuary Concept
Estuaries can change quickly, within hours or days. They are constantly shaped by water flowing from uplands as well as tidal cycles moving and mixing fresh and salt water within the estuary. They can also be dramatically changed by single, severe events such as a hurricane or the building of a levee.

Focus Questions
What causes landscapes to change over time?
What effects do changing landscapes have on people?
What effects do changing landscapes have on plants and animals?

Performance Tasks
Students will:

- Analyze a series of aerial maps to detect landscape changes over time
- Reflect upon the detected changes and articulate possible reasons for the changes
- Use scientific data to develop an argument that explains whether changes in beach size and shape affect nesting success of an endangered/threatened shorebird

Overview
In this exercise, students will analyze a series of aerial maps of the Wells, ME Reserve to determine changes over time. They will also be able to use evidence and data to determine what effect these changes have on shorebirds.

Time Required
One 45-minute class period

Teacher Background
Landscapes are dynamic, changing over time due to a variety of driving forces. Weather, water, human impacts, and climate are several common causes of landscape change. One method of studying landscape change is through the creation and analysis of habitat maps. For example, some habitat maps show similar habitats marked or coded similarly, with all forest habitats outlined and colored green (see Teacher Master 1). Comparing images of the same habitats in subsequent years over time can demonstrate changes that occur. The foundation imagery of a habitat map is often created by merging aerial photos with aerial maps (e.g. Google Earth). It helps the user visualize all the different habitats found in a given area. By comparing maps from different time periods, we can tell whether those habitats have changed in size, species distribution, etc.

Classification systems help mapmakers group similar elements together. Habitats can be grouped together generally, such as all forests being classified as “forest,” or the habitats can be grouped together specifically such as “evergreen forest” and “deciduous forest.” It all depends on how the mapmaker wants to display the data.

When comparing habitat maps across extended time frames, changes in the size, shape and distribution of habitats help us understand the effects of human activities in that area, in addition to changes occurring through natural processes. Maps have a wide range of applications in

management, planning, policy, and research, forming an important and integral part of habitat management activities (e.g. forest harvest projects, managing farmland, water pollution remedies, protecting land for endangered species).

Habitat maps are used in many ways. Following are several applications for habitat maps:

- Provide information used in strategic planning by towns and municipalities
- Offer a holistic ecosystem approach to managing human activities that affect habitats and the plant and animal species inhabiting them
- Help focus research monitoring efforts
- Visualize the placement of rare or threatened habitat types in an area of interest
- Increase our understanding of ecosystem functioning
- Support scientific research

Teacher Preparation:

1) Do a search for images online of visible long-term change to share with your students (puppy/dog, planktonic crab/adult crab, acorn/oak tree, Monarch butterfly egg/adult).

Print Wells National Estuarine Research Reserve Google Earth maps (Teacher Master 3). Each student will be comparing all four years, so will need copies of each map year. Included in Teacher Master 3 are two sets, one with close-up views of the river mouth for all four years and the other zoomed out for a more expansive aerial view of each of the four years. The four years of habitat mapping occurred in 1998, 2002, 2007, and 2014.

2) Gather one sheet protector and four different colored dry erase markers per student.

3) Print a Piping Plover fact sheet and data sheet (Teacher Masters 4 and 5) for each student.

Procedure:

1) To introduce the concept of change over an extended period of time, show your students pictures of a puppy and a dog, a planktonic crab and adult crab, a Monarch butterfly egg and adult, and/or an oak tree acorn and adult oak tree. Explain that just as plants and animals evolve over time, landscapes change over time. Sometimes the changes happen quickly, as with a tornado ripping across a landscape. Other times, change happens over a longer time scale, as with climate change.

2) Ask your students to brainstorm types of changes affecting landscapes over short periods of time (hours or days) versus long periods of time (years). Large storms and building/development can change landscapes quickly; whereas erosion from water and wind, gradual temperature increases, and long-term pollution can affect landscapes over the longer term.

Materials:

- Aerial maps (one set of four different years per student)
- Sheet protectors (one per student)
- Dry erase markers (one set of four different colors per student)
- Piping Plover fact sheets (one per student)
- Piping Plover data sheets (one per student)

3) Ask your students why it is important to know if a landscape is changing. Why might this information be important for human communities? How about for plant and animal communities?

4) Explain to your students that one way researchers study changes in landscapes over time is by using aerial maps. By comparing aerial images of land and water, changes can be detected and documented on a large scale.

5) Share the aerial maps (Teacher Master 3) from the Wells National Estuarine Research Reserve with your students. Note that they were taken in four different years: 1998, 2002, 2007, and 2014. Ask your students to look for changes in the landscape from one year to the next.

6) The most visible changes can be seen at the Little River mouth, where the river meets the sea. Instruct the students to insert one map at a time into their sheet protector and outline the beach profile and the path of the river at its mouth (see Teacher Master 2 for example). The students should use a different color marker for each map/year, and create a key of the colors on the sheet protector.

7) Distribute the Piping Plover fact sheets (Teacher Master 5) and nesting success rate data sheets (Teacher Master 4) to your students. Ask them to first read the fact sheet. Next, compare the Little River mouth habitat maps with the nesting success rate data for each of the same years.

8) Ask your students if they see any correlation between how small/large the sandy beach is each year and the number of plover nests. Challenge them to write a short "argument" that explains why they think the size of the beach does or does not affect the number of plovers nesting on Laudholm Beach and/or RHC Easement-Kennebunk Beach. Once each student has completed this task, have a group discussion.

Questions & Possible Answers

1. **What types of changes affect landscapes over short periods of time?**

   Storms can create changes in a landscape quickly, yet have long-term consequences. For example, hurricanes along the coast can cause surging seas that flood homes, sometimes wiping neighborhoods out completely. Winds within a forest habitat often bring down large trees, changing the amount of sunlight reaching the forest floor and thereby affecting what types of plants grow.

2. **What types of changes affect landscapes over long periods of time?**

   As air and water temperatures increase with global warming, some species less tolerant to warming temperatures will move towards colder temperatures to adapt. This means that a species living in Maine may migrate north to Canada and go "extinct" in Maine. With

rising sea levels, salt marsh plants will need to migrate upland to avoid being inundated by the sea.

3. **Why is it important to know if landscapes are changing?**

   Changing landscapes can have implications for the people, plants, animals, and infrastructure experiencing the change. Knowing about a change allows us to plan ahead so adaptation strategies can be put into place. If changes are detected early enough, sometimes prevention or mitigation strategies can be employed. For example, knowing about rising sea levels enables us to build infrastructure with flooding in mind (houses on stilts, relocating buildings further from the ocean, etc.) or to preserve land behind salt marshes to give them room to migrate inland. In regards to plants and animals, rising sea levels will change management strategies for species experiencing the change.

4. **Why does the shape of the beach and path of the river change at its mouth over time?**

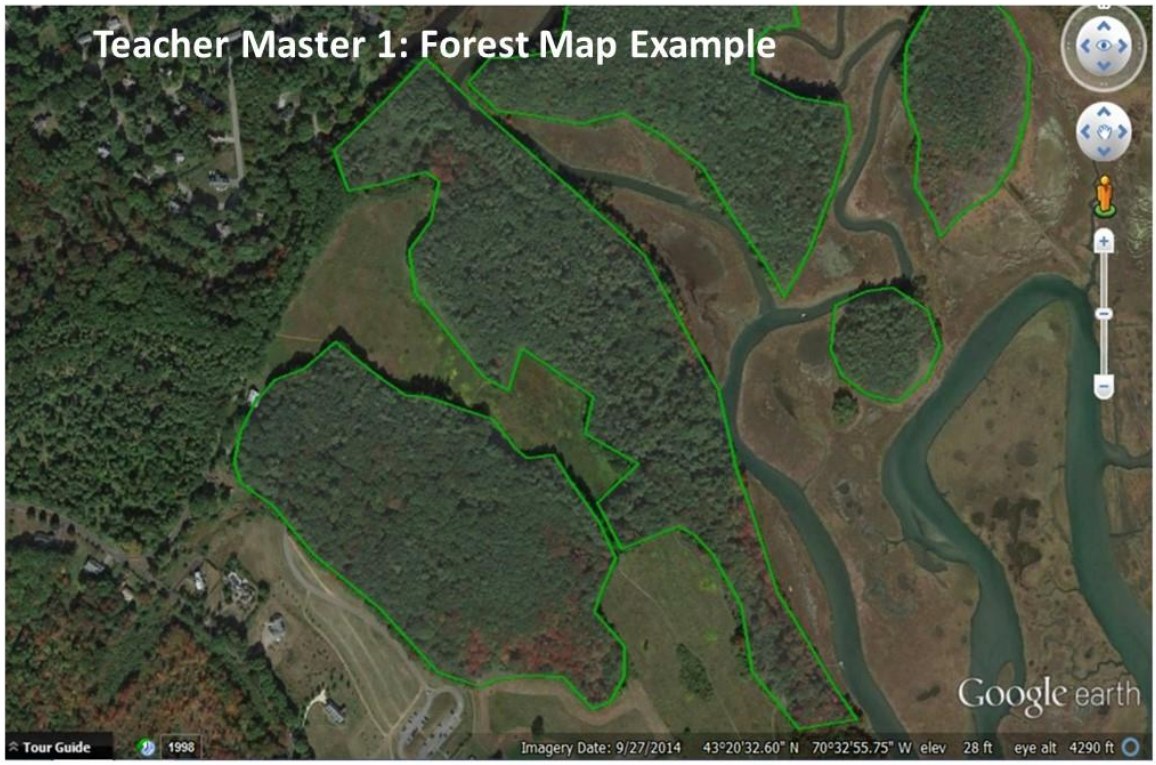
   The interaction between water currents and shifting sands is complex. Beaches are dynamic systems actively changing over time. Sometimes human activity can cause change, too. For example, building a jetty in a harbor can shift the pattern of water currents along a beach and thus affect how sand is distributed along a beach, creating more in some areas and reducing sand in other areas. Rising sea levels due to human-caused climate change can increase erosion on beaches and cause a beach to change in shape and size.

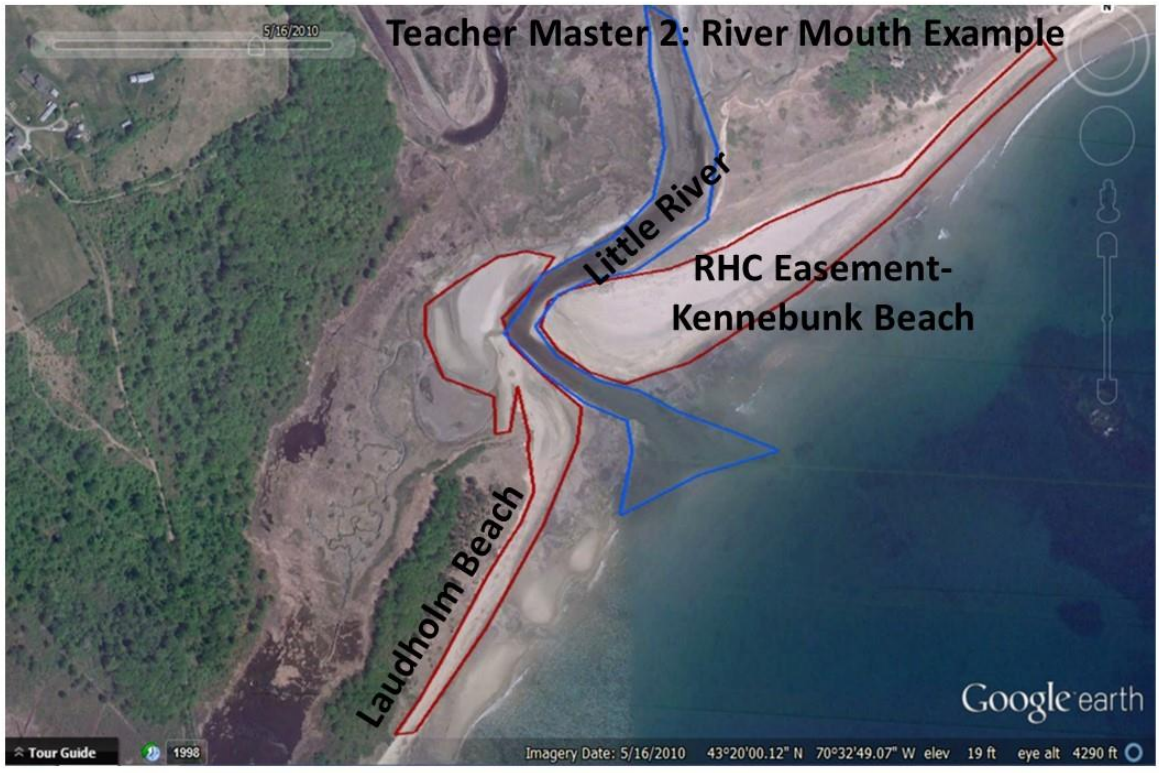
5. **How do shifting sands and water affect buildings built on beaches?**

   Properties can incur expensive damages, if not complete loss, from shifting sands and water. Large storms often make these effects even more dramatic, with entire stretches of beachfront property destroyed

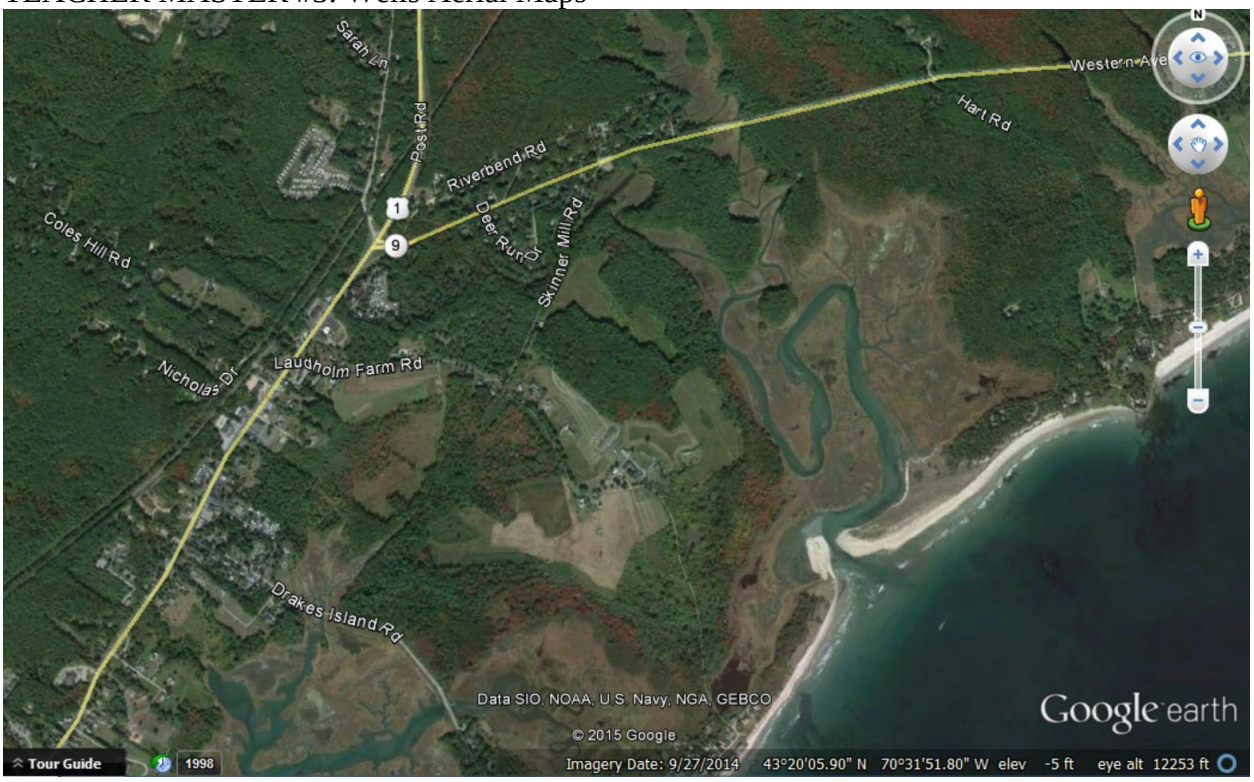
6. **How do shifting sands and water affect nesting birds on beaches?**

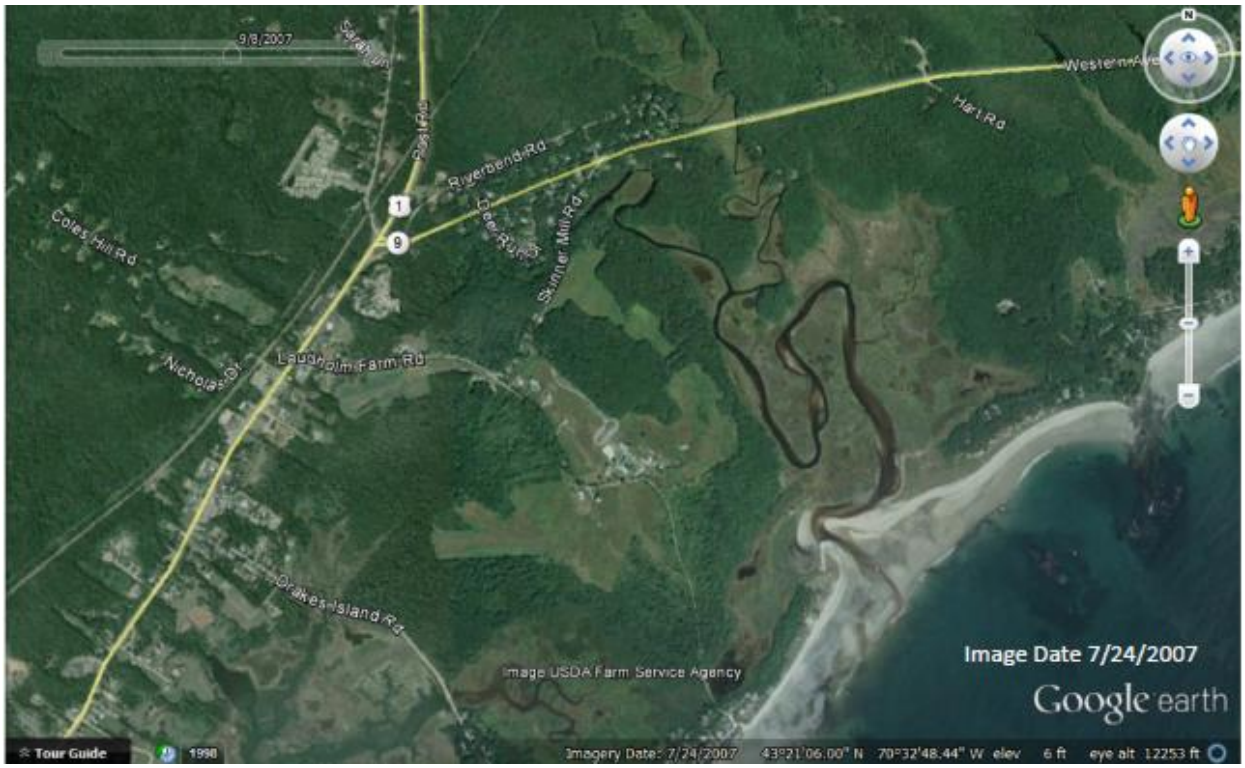
   Shifting river mouths and strong storms can flood bird nests on beaches. Piping plovers require beaches where there is plenty of sand in order to nest successfully; if the meandering of the river at the mouth changes such that there is a smaller beach one year, the plovers will likely choose not to nest on that beach that year which could result in lower reproductive success.

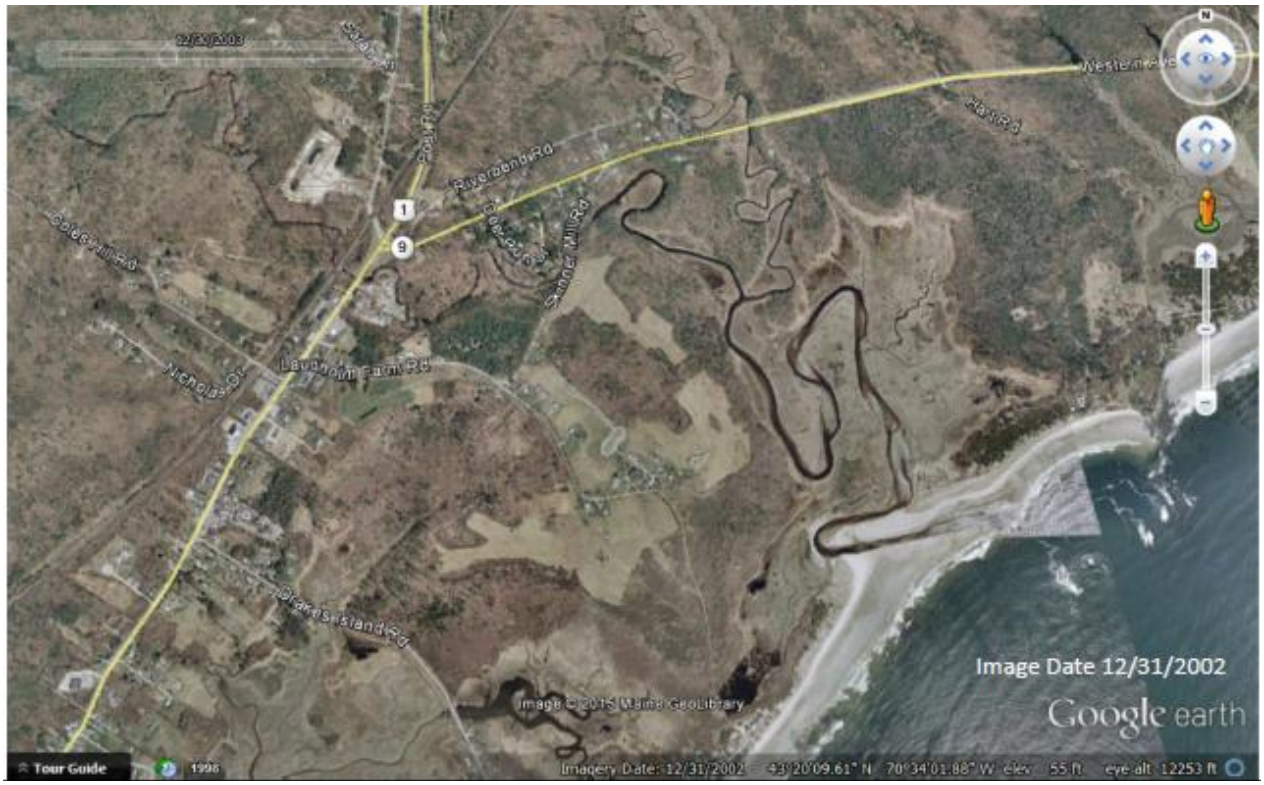

Teacher Master 1: Forest Map Example
Google earth
Tour Guide
1998
Imagery Date: 9/27/2014 43°20'32.60" N 70°32'55.75" W elev 28 ft eye alt 4290 ft
Trees


Teacher Master 2: River Mouth Example
5/16/2010
Little River
RHC Easement-
Kennebunk Beach
Laudholm Beach
Google earth
Tour Guide
1998
Imagery Date: 5/16/2010 43°20'00.12" N 70°32'49.07" W elev 19 ft eye alt 4290 ft
River
Beach

TEACHER MASTER #3: Wells Aerial Maps






Riverbend Rd
Cole's Hill Rd
Nichols Ct
Laudholm Farm Rd
Skillins Rd
Image Date 12/31/2002
Google earth
Tour Guide

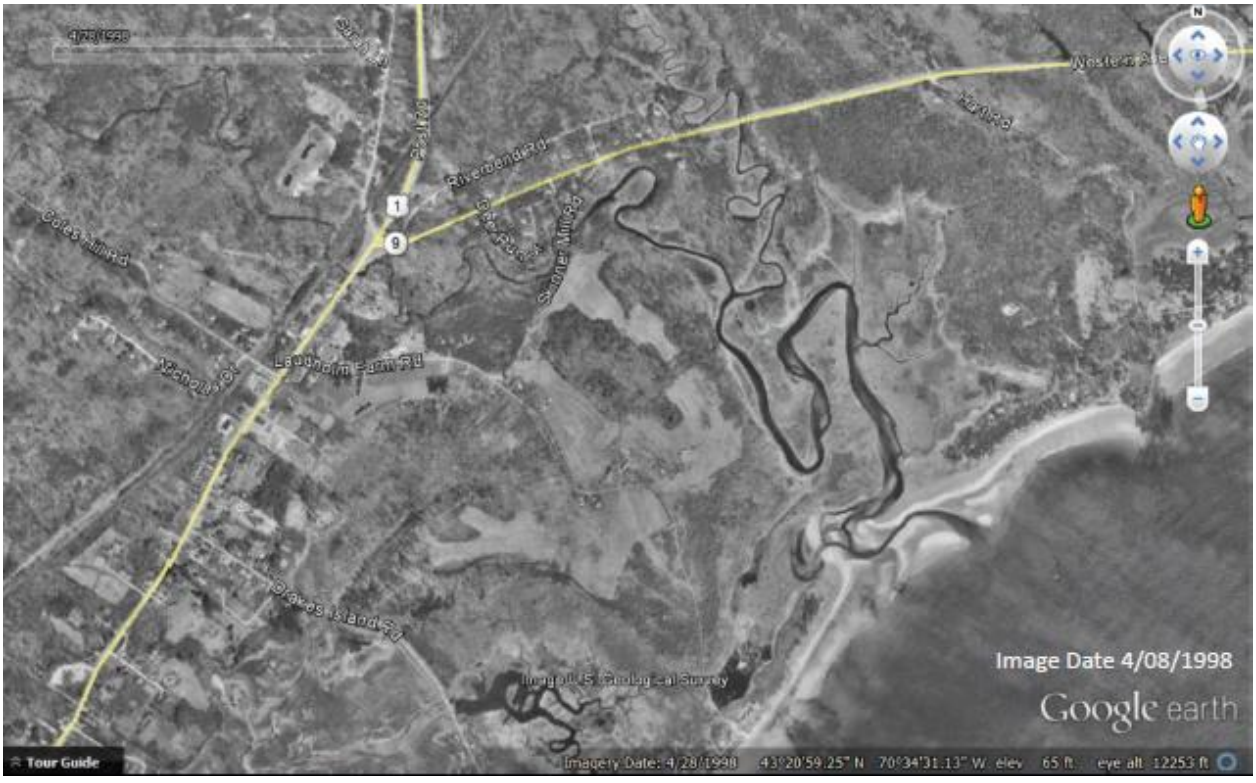

Riverbend Rd
Cole's Hill Rd
Laudholm Farm Rd
Image Date 4/08/1998
Google earth
Tour Guide


Image Date 4/08/1998
Google earth
Tour Guide
1998
Imagery Date: 4/28/1998 43°19'59.87" N 70°32'09.66" W elev -6 ft eye alt 2806 ft


Image Date 12/31/2002
Google earth
Tour Guide
1998
Imagery Date: 12/31/2002 43°20'01.31" N 70°32'09.61" W elev -5 ft eye alt 2806 ft


Image Date 7/24/2007
Google earth
Tour Guide
1998
Imagery Date: 7/24/2007 43°20'06.33" N 70°32'23.14" W elev 1 ft eye alt 2806 ft

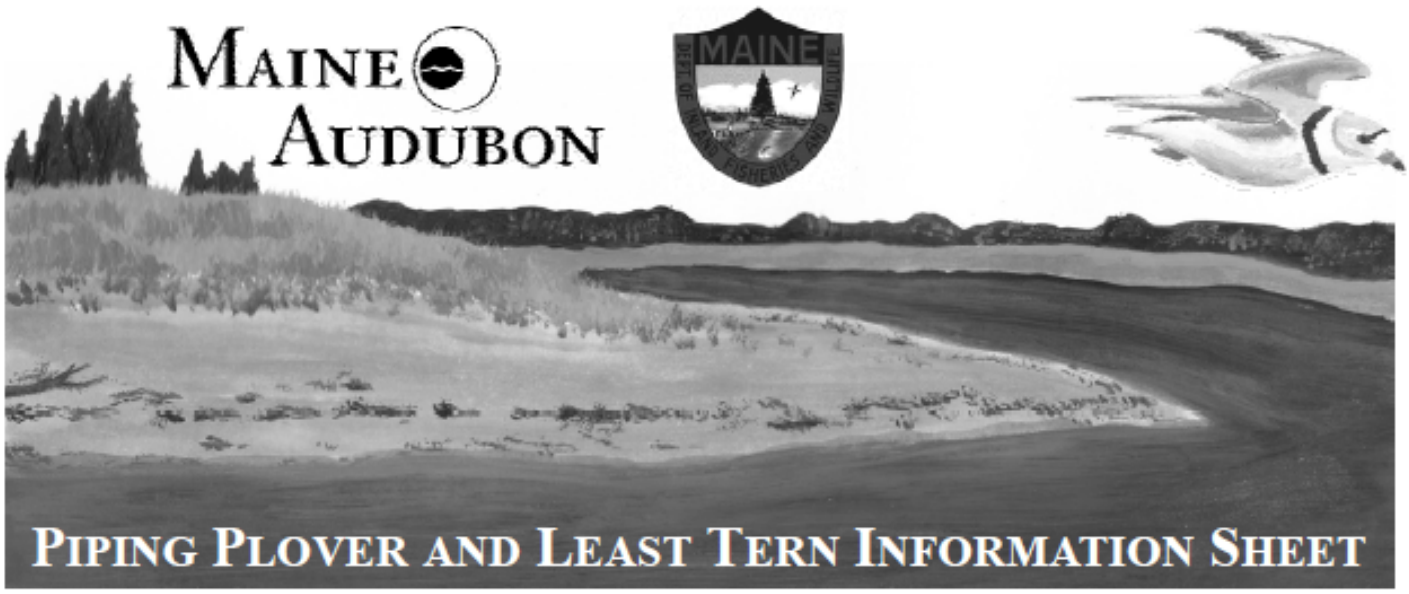

Image Date 9/18/2014
Google earth
Tour Guide
1998
Imagery Date: 9/18/2013 43°20'06.33" N 70°32'23.14" W elev 1 ft eye alt 2806 ft

TEACHER MASTER #4

Data Sheet: Number of Nesting Piping Plover Pairs and Fledglings ( ) at Little River Mouth Beaches in Wells, Maine

	Laudholm Beach	**RHC Easement-Kennebunk Beach**
1998	**2 (3)**	**3 (6)**
2002	**5 (15)**	**5 (6)**
2007	**0**	**4 (4)**
2014	**1 (1)**	**6 (18)**

***When using this data sheet in tandem with the aerial maps, Laudholm Beach is on the left side of the river mouth and RHC Easement-Kennebunk Beach is on the right side of the river mouth.**



PIPING PLOVER AND LEAST TERN INFORMATION SHEET

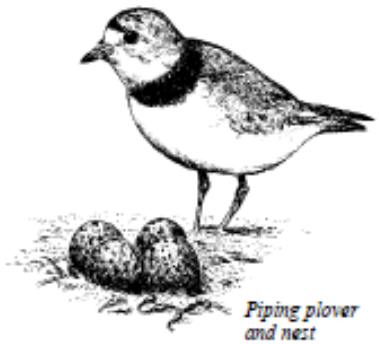
Each spring, Piping Plovers and Least Terns return to nest and raise their young on Maine's coastal beaches. They share the beach with other wildlife and with people - both of which affect their ability to survive.

Unfortunately, their survival is not guaranteed. Both are listed as Endangered Species in Maine, which means they are in imminent danger of disappearing. These birds are an important part of the natural beauty and heritage of Maine's coast. By conserving them, we are also conserving the beach environment, which relies on a delicately balanced interplay of all its inhabitants.

Maine Audubon and the Maine Department of Inland Fisheries and Wildlife work in partnership with other groups to protect and conserve these rare birds. This is only possible with the assistance of people like you. By taking the time to learn more about these birds and their needs, you can greatly contribute to their recovery.

The Piping Plover

While its plaintive call is easily recognized, the six-inch-tall Piping Plover can be difficult to spot against a sandy backdrop. The small bird's back and head are soft gray, while its belly and chest are creamy white. Viewed from a distance, the strokes of black across its forehead, around its neck, and at the tip of its tail feathers look like seaweed washed up onto the beach. Adult Piping Plovers have yellow-orange legs which speed them along as they search the shoreline for marine worms, crustaceans, sand fleas, and various insects.



Piping plover and nest

After wintering on beaches from North Carolina to Florida, and occassionally south to the Bahamas and West Indies, Piping Plovers migrate north to breed, some as far as Canada. Arriving in Maine by early April, they remain until September, when they migrate south again for the winter. The Piping Plover's nest - or "scrape" - consists of a small indentation made in the sand above the high tide line and may be lined with seashell fragments or small stones. Sometimes the birds choose to shelter their nests under a tuft of vegetation.

Unlike other coastal birds in Maine, nesting Piping Plovers are not colonial. During courtship, a male bird makes numerous scrapes before his mate chooses one in which to lay her clutch of four eggs. Usually, she will lay one egg each day or two, incubating the clutch only after laying the fourth egg. Piping Plover chicks hatch after approximately four weeks and are already covered in downy feathers and able to probe the sand and wrack line for invertebrates. They fledge (begin to fly) in 28-35 days and, if they are lucky, may live as long as fourteen years.

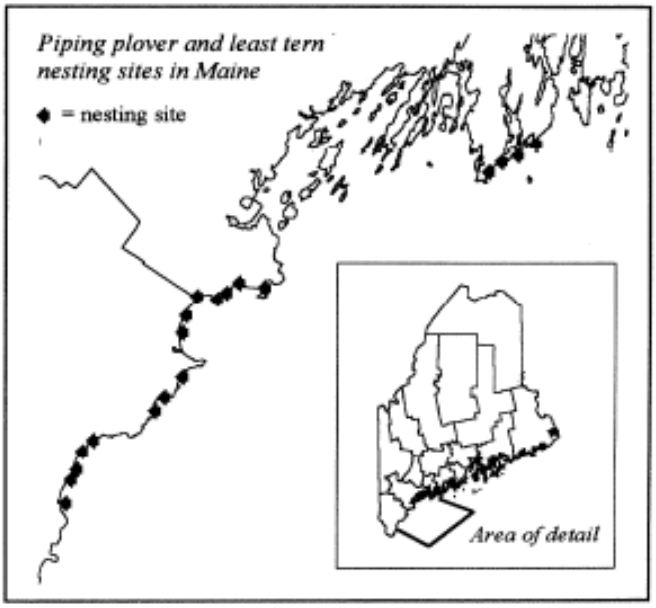
The Least Tern

At only nine inches in height, the Least Tern is the smallest North American tern (it was once known as the "sea swallow"). The Least Tern has a gray back, white chest and belly, orange legs, and the black head characteristic of the tern family. The most observable field mark for the identification is the white wedge on the Least Tern's forehead. Although Least Terns will eat crustaceans, they are more likely to hover above the water before diving to catch small fish.

Least Terns winter in Brazil, but migrate annually to their breeding habitat on the sandy beaches along North America's Atlantic coast. They reach Maine, their northernmost destination, by mid-May and begin their courtship ritual.

Least tern and chick

Least Tern nests consist of small scrapes in the sand above the high tide line. A female Least Tern will lay two to three eggs in a nest. After approximately twenty-one days of incubation, the chicks hatch, but are completely dependent on their parents for small fish brought to them by their parents. The Least Tern's colonial nesting behavior means that the chicks stay within the colony and often in the nest so the adults can easily locate the chicks. The birds in the colony also provide protection from predators by "dive bombing" intruders and pelting them with droppings. Least Tern chicks fledge three weeks after hatching and are known to live twenty years or more.



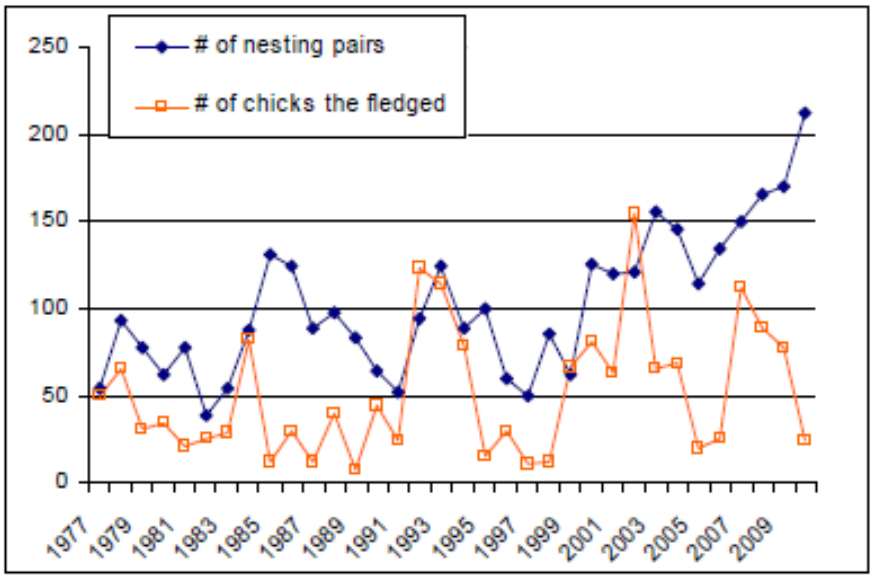
Threats

By the end of the nineteenth century, both Piping Plover and Least Tern populations were only a fraction of what they once had been. Their decline was caused by feather and egg collectors and market gunners who sometimes took as many as 1200 Least Terns in a day (at that time terns and plovers were hunted for food). The birds' demise helped ignite a public outcry for their protection. In 1918, federal lawmakers passed the Migratory Bird Treaty Act providing protection for all migratory birds, their nests and eggs.

Under protection from this law, Least Tern populations began rebounding by the late 1930s in the central part of their breeding range, although records show that the birds didn't return to Maine to breed until 1961. Maine's Least Tern population increased until the 1970s when it began to decline once again. Piping Plovers are believed to have had a significant recovery in Maine by the 1940s. Unfortunately, interest in development of shorefront property and recreational use of beaches was increasing at that time, bringing with it a new threat to the plovers and terns.

Historically, Maine had more than thirty miles of suitable nesting beaches which may have supported more than 200 pairs of Piping Plovers and 1200 pairs of Least Terns. Since World War II, construction of seawalls, jetties, piers, homes, parking lots and other structures along the shoreline has reduced the available habitat for these two species by more than 75%, overtaking approximately twenty-one miles of shoreline.

LEAST TERN NESTING PARIS/CHICKS FLEDGED 1977—2009



PIPING PLOVER NESTING PAIRS (2005 → 2010)		
Town	**Beach**	**# of pairs**
Ogunquit	Ogunquit	4 → 2
Wells	Wells	6 → 3
	Drakes Island	1 → 0
	Laudholm	1 → 0
Kennebunk	Crescent Surf	6 → 6
Kennebunkport	Goose Rocks	1 → 8
Biddeford	Hills Beach	2 → 0
	Fortunes Rocks	1 → 2
Saco	Goosefare Brook	1 → 1
Old Orchard Beach	Old Orchard Beach	1 → 0
Scarborough	Scarborough	2 → 0
	Higgins	6 → 1
	Western	2 → 1
Cape Elizabeth	Ram Island	4 → 2
Phippsburg	Seawall	5 → 0
	Popham Beach State Park	0 → 2
Georgetown	Reid	6 → 2

This increase in development has led to a more intense presence of humans and their pets on nesting beaches, which keeps adult plovers from tending to their eggs and chicks, which are then vulnerable to the elements and to predators. In addition, because the nests are hard to see, beachgoers can inadvertently step on them. Sometimes the birds will try to nest again, but a second nest is even less likely to survive later in the summer amid the increased presence of both humans and predators on the beach.

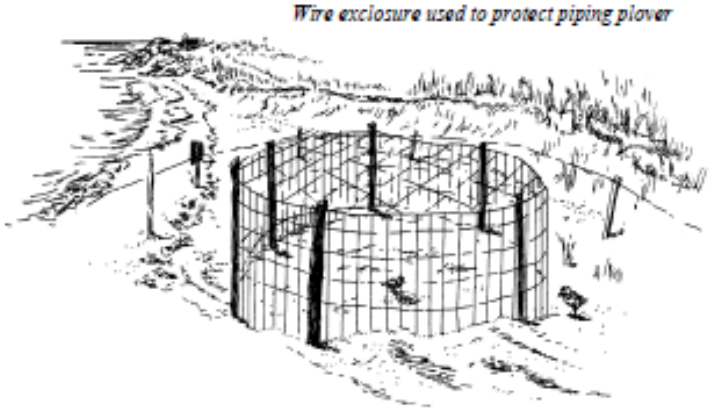
Encroaching development has also caused an increase in the numbers of predators such as foxes, raccoons, skunks, gulls, and crows, preying on eggs and chicks. Least Terns will aggressively attempt to chase a predator away, but are not always successful. When a Piping Plover perceives that a predator is threatening its nest, the bird will attempt to distract it by moving a few feet away from the nest, pretending to have a broken wing and sounding a distress call. Even if this ruse works, the adult bird's absence leaves the eggs or chicks vulnerable to the elements. Coastal beaches are dynamic systems, and Piping Plovers and Least Terns are well adapted to surviving losses natural to such systems, but only if the system is intact. The problem is that Maine's beach systems, like all others on the Atlantic coast, can be dramatically altered by winter storms or exceptionally high tides that erode nesting areas or wash eggs out to sea. Historically, birds could easily move to other sites; now those sites are unavailable due to development or other beach alterations. The remaining habitat's ability to support nesting plovers and terns is further reduced by intense recreational use and continued development. Although Least Terns still face declining populations, the Piping Plover has begun recovering due to some innovative conservation measures.

Conservation Measures

Recognizing the threat of inappropriate development within these rare habitats, the Maine Department of Inland Fisheries and Wildlife designated nesting, feeding and chick-rearing habitat as "essential" for Piping Plovers and Least Terns under Maine's Endangered Species Act in 1994. This designation allows the department to work with landowners to assure that any activity requiring a permit will not adversely affect habitat of Piping Plovers or Least Terns. Other state laws that protect natural dune systems in Maine have also benefited plovers and terns. These laws work to assure that the last remaining habitat will not be lost. Management, however, is still a key component of the recovery effort.

For over 25 years, a coalition of groups (starting with Maine Audubon, and now including the Maine Department of Inland Fisheries and Wildlife, The Nature Conservancy, the U.S. Fish and Wildlife Service, the Maine Bureau of Parks and Lands, and municipalities) has worked with local residents, landowners, and beachgoers to protect these endangered shorebirds with a goal to increase their populations.

Wire exclosure used to protect piping plover



Conservation Measures *(Continued from Page 3)*

Once piping plovers return to their Maine breeding grounds, Maine Audubon staff and volunteers begin visiting each site. When the pairs begin to nest, each nest is surrounded with a circle of wire-mesh fencing, called an exclosure.

The openings in the mesh are large enough to allow birds to easily walk through, but are small enough to prevent predators from getting in. Rows of twine or netting placed over the top of the exclosure keep avian predators from swooping down on the nest. Studies in Maine and elsewhere show that these exclosures greatly increase the likelihood that piping plover eggs will hatch.

Least terns nest in large colonies, making it difficult, costly, and ineffective to erect exclosures around their nests. Moreover, past attempts simply have not stopped predators. Instead, least tern nests are protected from human disturbance by erecting stakes, twine, and signs. They are protected from perisistent predators by occasionally removing problem animals.

Signs alert beachgoers of the presence of endangered birds.

Protective measures have led to a gradual increase in the piping plover population from a low of six nesting pairs in 1983 to a high of 66 pairs in 2002. Nest exclosures have enabled more chicks to survive, returning to Maine beaches to breed themselves in the following years. However, due to stormy weather and increased predation, this number has dropped steadily to just 24 pairs in 2008. As efforts to protect endangered birds continue in Maine, the state has exceeded *interim* goals for nesting piping plovers.

The least tern population has continued to remain well below desired levels. Efforts to protect least terns by restricting access to their nests and controlling predators have allowed variable success with a high of 156 pairs producing 66 fledglings in 2003 to a low of ninety pairs producing only eight fledglings in 1989. New methods of protection are being tested with the hope of increasing their nesting success.

For more information regarding the Piping Plover/Least Tern Project, please contact us at Maine Audubon, 20 Gilsland Farm Road, Falmouth, ME 04105, (207) 781-2330 or check out our website: www.maineaudubon.org.

Illustrations by Bob Hooper.

WHAT YOU CAN DO TO PROTECT ENDANGERED PIPING PLOVERS AND LEAST TERNS

- Keep dogs leashed and cats indoors. (April 1st to September 1st). Roaming dogs and cats have injured and destroyed the eggs and chicks of Piping Plovers and Least Terns.
- Stay out of fenced areas marked with "Restricted Area" signs to avoid forcing birds off their nests or crushing hard-to-see chicks or eggs. If you want to observe these birds, do so from a distance using binoculars.
- Leave no trace: ►fill in sand castle holes (so that chicks aren't trapped)
  ►take all trash with you (garbage attracts predators)
- Fly kites well away from nesting areas. Plovers mistake them for predators and leave their nests to ward off the "intruders".
- Notify Maine Audubon (207) 233-6811 of any disturbances to nesting areas.

MAINE AUDUBON

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Activity 2
Salt Marsh Vegetation & Sampling Techniques

Estuary Principle
Principle 3: Estuaries support an abundance of life, and a diversity of habitat types.
Principle 4: Ongoing research and monitoring is needed to increase our understanding of estuaries and to improve our ability to protect and sustain them.

Research Question
What is the plant species composition of a salt marsh and how does it change as you shift from low marsh to high marsh to upland edge?

Disciplinary Core Ideas (from NGSS)
- MS-LS2-4: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
- HS-LS2-6: Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem structure.

Crosscutting Concept (from Next Generation Science Standards)
- **Stability and Change:** For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of the system are critical elements of study.

Introduction
Salt marshes are important coastal habitats found throughout New England's estuaries, supporting an abundance of plant and animal life. Plants found in salt marshes have special adaptations that allow them to survive in brackish water – normally a very difficult environment for plants. The diversity of plant species and their distribution in a salt marsh is affected by abiotic factors like water level and salinity at the seaward edge and by inter-specific competition at the landward edge. Some plants are more salt-tolerant than others and would likely flourish in areas prone to tidal flooding. Scientists are concerned that rising sea levels may significantly alter the species composition of New England salt marshes as less salt-tolerant species are replaced by more salt-tolerant species, thus affecting the entire marsh ecosystem.

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TEACHER GUIDE

Salt Marsh Vegetation Sampling

Research Question

What is the plant species composition of a salt marsh and how does it change as you shift from low marsh to high marsh to upland edge?

Content Objectives

Students will understand that:

- Salt marshes are dominated by a variety of plant species and influenced by tides.
- Plants that live in salt marshes have different levels of salt tolerance and this tolerance level determines where the plant lives in the marsh.
- Vegetation can be sampled at just a few locations using the point-intercept method to estimate the species richness and composition of the marsh; repeated sampling over long periods of time can show changes to the plant communities of salt marshes.
- Rising sea levels may change the plant species distribution and composition in salt marshes, impacting the entire marsh ecosystem.

Exercises

Exercise 1: An Introduction to the Plants of New England Salt Marshes

In this exercise, students will learn about the different plants found in New England salt marshes and where each of these plants can be found in the marsh (low marsh, high marsh or upland edge). Students will learn about the unique adaptations that allow these plants to thrive in this brackish water environment and how some species are more salt-tolerant than others.

Exercise 2: Point-Intercept Sampling Method of Salt Marsh Vegetation

In this exercise, students will use the point-intercept method to determine plant species composition and percent cover of each species. Students will be divided into groups so that sampling is completed in the low, high and upper edge marsh for comparison purposes and to determine changes in species dominance as you move from low marsh to upland edge.

Vocabulary

Abiotic – all of the non-living things in an ecosystem such as temperature, soil and wind

Biotic – all of the living organisms within an ecosystem, including plants and animals

Brackish – a mixture of salt water and fresh water

Estuary – a semi-enclosed body of water that has a free connection to the open sea and within which seawater is measurably diluted by fresh water derived from land drainage

Ecosystem – the biotic community and its abiotic environment

Habitat – the specific environment where an animal or plant is able to survive

Herbaceous – those plants having little or no woody tissues

High Marsh – located between the low marsh and the upland edge; generally only flooded during higher than average tides. Low plant diversity with dominant species being saltmeadow hay (*Spartina patens*), spikegrass (*Distichlis spicata*) and black rush (*Juncus gerardii*)

Low Marsh – located along the seaward edge of the salt marsh; usually flooded at every tide and exposed during low tide. This area is typically dominated by salt marsh cordgrass, *Spartina alterniflora*

Point-Intercept Sampling – a method designed to sample within-plot variation and quantify changes in plant species cover and height, and/or ground cover over time

Quadrat – a small area, usually a square meter, selected to conduct point-intercept sampling

Salt Marsh – coastal wetlands that are flooded and drained by salt water brought in by the tides

Sea Level Rise – the rising level of the ocean due to thermal expansion caused by the warming of the oceans (since water expands as it warms) and the loss of land-based ice (such as glaciers) due to increased melting

Species Composition – the identity of all the different organisms that make up a community

Upland Edge – marks the transition area from salt marsh to upland; generally only flooded at extreme astronomical tides and under irregular conditions such as storm and wind-driven tides

Exercise 1

An Introduction to the Plants of New England Salt Marshes

Estuary Concept

Salt marshes are an important habitat found in estuaries. Salt marshes support a variety of plant species specially adapted to survive in the brackish environment.

Overview

In this exercise, students will learn about adaptations of salt marsh plants, where those plants grow in a marsh and what determines where they grow. They will also learn how to identify the different species.

Time Required

One 45-minute period

Focus Question

What are the dominant species of plants in a New England salt marsh and how are they adapted to the brackish environment?

Performance Tasks

Students will:

- Identify plant specimens, either living or preserved samples
- Describe the adaptations of each plant that allow it to survive in the brackish environment
- Hypothesize what determines where the plants will grow within the salt marsh

Teacher Background

Salt marshes in New England are vegetated by soft-stemmed grasses and herbaceous plants. Marshes are influenced by the action of tides, which bring in salt water from the ocean that mixes with fresh water from upland rivers and streams, resulting in a mix of fresh and salt water known as brackish water. The marsh can be divided into three different vegetation zones and the plants that grow at each one are largely determined by the water levels. These zones are known as the low marsh, high marsh and upland edge. The ability of a plant to withstand more or less salt water will determine in which zone it grows. In general, the more salt tolerant the plant is, the lower it will be in the marsh with the less tolerant plants inhabiting the high marsh and upland edge zones. This is because the high marsh and upper edge are less frequently flooded by the tides, typically only during new/full moon or storm-driven high tides.

Salt marsh plants have special traits (adaptations) that enable them to survive in the brackish water environment. Most of these plants have one of three adaptation techniques to deal with the salt: **excrete** the salt through specialized glands, **exclude** the salt at the roots, or **sequester** the salt in its leaves. Saltmarsh cordgrass (*Spartina alterniflora*) thrives in the lower elevations of the marsh and alongside tidal creeks because of its tolerance to a high level of salinity. It has a special adaptation that allows it to excrete excess salt onto the blades of grass – often times you can see the salt crystals with the naked eye! Spikegrass (*Distichlis spicata*) can also excrete the salt onto its blades and is usually found in higher marsh elevations. Saltmeadow hay (*Spartina patens*) is adapted to exclude salt, and Glasswort (*Salicornia spp*.) is a fleshy, succulent plant whose roots take up the salt water, sequestering the salt in its leaves. Plant diversity is low in salt marshes because of the harsh conditions (salt water, regular flooding by tides, temperature changes, and low oxygen in the soil) so those that are found here are especially well adapted to their environment.

An essential component of a salt marsh is peat – the 'ground' of a salt marsh, providing the foundation for plants and animals living there. Several feet thick, waterlogged, and composed of decomposing plant material, peat is low in oxygen leading to a condition known as hypoxia. Certain bacteria thrive in hypoxic conditions, emitting the characteristic rotten egg smell associated with salt marshes. Examining a handful of peat shows the abundance of organic matter as well as its capacity to hold water. This ability of peat to act like a sponge means that marshes play a vital role in soaking up excess water during storm events, resulting in diminished flooding along the coast.

Procedure

Materials:

- Laminated enlarged version of the Teacher Master: Salt Marsh Profile
- Preserved specimens or copies of the Teacher Master: Common Plants of New England Salt Marshes
- Laminated cutout images of each plant
- Tape or putty

1. Review the definition of a salt marsh and how tides affect marshes. Discuss the different vegetation zones of the marsh and have students brainstorm what might impact where plants can grow in a marsh (low marsh = plants have to withstand more or constant salt water; high marsh and upland edge = plants will be exposed to salt water less frequently or only on rare occasion).
2. Ask students what kind of adaptations they think plants living in a salt marsh might have. This can include things like the ability to excrete, exclude or sequester the salt.
3. Using identification cards (see Teacher Master: Common Plants of New England Salt Marshes) or preserved specimens, have students identify the common salt marsh plants.
4. Use small cutout images of each plant to locate where they would expect to find those plants along the salt marsh profile, from low marsh to upper edge and place them on the profile (see Teacher Master: Salt Marsh Profile) using tape. If access to cutout images is difficult, simply have the students write in the name of each plant at the correct zone.

Questions and Possible Answers

1. How does the tide influence salt marshes and the plants that grow there?

The incoming tide floods the marsh with brackish water, which is a mixture of salt and fresh water. Most plants cannot tolerate growing in salty water, so salt marsh plants must have special adaptations that allow them to grow there. The frequency and duration of tidal inundation will determine where certain species of plants can grow.

2. How might sea level rise impact the marsh zones and subsequently the plants that grow there?

As marshes become more frequently flooded or hold more standing water, plants that are less salt tolerant (like those that grow in the high marsh or upland edge) may die back and be replaced by the very few salt tolerant species that inhabit the low marsh.

Exercise 2

Point-Intercept Sampling Method of Salt Marsh Vegetation

Estuary Concept
Plant species distribution and cover in a salt marsh is directly related to the frequency and duration of flooding by tides.

Focus Question
How does the diversity and cover of plant species differ among vegetation zones as you survey from low marsh to the upland edge of the marsh?

Overview
In this exercise, students learn how to use the point-intercept method to survey the vegetation diversity and percent cover at different zones in a salt marsh.

Time Required
One 60-minute period

Performance Tasks
Students will:

- Hypothesize what species of plants will be found in the low marsh vs. high marsh vs. upland edge.
- Use the point-intercept sampling method to determine plant species diversity and cover at each location.
- Understand that the distribution of plant species across a salt marsh is directly related to the water level in the marsh as a result of tidal flooding.
- Recognize that plant species diversity and distribution are affected by abiotic factors like water level and salinity at the seaward edge, and by inter-specific competition at the landward edge.

Teacher Background
There are many ways that scientists are able to study salt marsh plants and their distribution across a marsh and how it changes over time. One way is through point-intercept sampling, a method used by researchers when they want to monitor changes in the plant species cover over time and space. Using a square meter quadrat at each sampling plot, researchers can detect species presence and abundance along a transect line. This is repeated in the same locations at different areas of the marsh over many years to detect change in species distribution and cover. One reason this kind of monitoring is so important is that as sea level rises and marshes experience more tidal flooding, changes in the plant distribution across a marsh can be expected, and these changes could have ecosystem-wide impacts. Another method for estimating the abundance of each plant species is to visually estimate the percent cover.

An addition to this activity could include having students first estimate the percent cover of each species in the quadrat by visual estimation, and then follow up by conducting the point-intercept method. Comparison of the two results is an interesting lesson in using various sampling methods and the pros and cons of each method. For example, visually estimating percent cover is subjective and may lead to greater error, especially if done by different people over time. Conducting point-intercept samples is time consuming and could result in undercounting a species that doesn't happen to fall along one of the 50 sample points. However, this can be somewhat avoided by visually identifying all species within the plot before starting your

sampling; if a species is identified that isn't hit at any of the 50 points, you can say it is 1% cover by default, ensuring you get all species and are able to quantify richness.

Procedure

This procedure* could be adapted for a habitat** in or around your school such as a meadow, pasture, grassland or forest floor. It is especially useful when monitoring shorter plants, like grasses, herbs and ground cover species. ***Be aware of any potential dangers in your selected habitat such as ticks or poison ivy and take necessary precautions.***

1. Share with students various sampling methods used by researchers and the pros and cons of each (estimating percent cover, point-intercept sampling) and discuss why these kinds of sampling methods are important.
2. Before going out to the field, have students practice estimating percent cover by using pre-determined examples of various percent covers. To create these, take a percentage of a colored sheet of paper (10, 25, 50, 75, 90, etc.), cut them up into random sized pieces and place them on a full size sheet of white paper. Make one each for each percent cover amount you want them to practice estimating. Laminate these for future use or place in sheet protectors. See example in the "Materials" section.
3. Head out to your site and lay a transect line along which you will place your sampling plots using the quadrats. The transect line should be placed randomly but somewhere that you can return to year after year, as the plot locations will not change from year to year (this ensures you can see change over time by looking at the same sites annually). The transect line should extend from one edge of the habitat to the other edge, if possible, in order to show species variability and cover across a distance.
4. Location of the first plot nearest the edge should be randomized to within a few meters of your edge; after this, plots are placed at regular intervals along the transect line, ideally no less than every 10 meters. However, depending on the distance of your transect line and class size, you may want to reduce this distance or space them out further; the important thing is to keep the distance consistent regardless of what you choose.
5. Break students into teams so only 4-5 students are at each plot, if possible. Each team should have a meter stick, 5 dowels with graduated markings, sampling rod, ID guide, clipboard, pencil and data sheet.
6. Have students identify each of the species present and write that on their data sheet. Now have them visually estimate the percent cover of each species in the plot and record the estimate for each species (this can be written down off to the side as an added exercise to compare visual estimates to point-intercept methods). Remember that total percent cover can exceed 100% because of different plant heights – taller plants may take up the same space as ground cover – thus giving you more than 100% when adding up all the estimates for the various species. *NOTE: It is important to note that plants may look different from the images in field guides depending on the month that you are sampling. For example, sea lavender does not bloom until mid to late summer, so the leaves will be the only identifiable feature on the plant in the late spring, early summer and fall months. Some plants may not be visible at all during the winter months or will look vastly different than how they appear during the growing season.*
7. Once this is done, have students begin the point-intercept sampling method. In order to sample vegetation that has not been trampled while laying out the transect line, offset the

quadrat 1 meter to the right from the transect line. Place the meter stick down on the surface, parallel to the transect line, in the direction of the transect (0cm should be closer to the creek or downward edge, 100cm should be moving up the transect, towards the uplands edge). Then, at 0cm, 25cm, 50cm, 75cm and 100cm, place a dowel perpendicular to the meter stick at each of these intervals. Each dowel should have a total of 10 marks, at 11.1cm apart. These marks will be the 50 points you are sampling. The first point should be taken at the 0cm/0cm mark. A thin rod (less than 3mm in diameter) is held vertical to the first sampling point and lowered through the vegetation canopy to the sample point on the ground. All species that touch the rod are recorded as a 'hit' on the data sheet for that point. *Note that if 3 plants of the same species 'hit' the rod, you only count this once, not three times.* Repeat the process for all 50 points. See a visual example of the quadrat in the "Materials" section.

8. On the data sheet, students will write the name of the plant encountered and check off in the corresponding boxes at which of the 50 points they 'hit' that plant.
9. After recording the species at all 50 sampling points, students will need to calculate the percent cover for each species. To do this, students will add up the number of points that a particular species was found and multiply that number by 2 (we only counted at 50 points but we want to know the results for a full 100%). This result is the percent cover for that species. Have students repeat this for each of the plant species they identified in their plot.
10. Ask students to compare their visual percent cover estimates with the results from the point-intercept method. Were they similar? What could have attributed to differences? Were there any species of plants that the point-intercept method missed? Which method do they think is more reliable over time? Why?

Here is an example to clarify the process:
Let's say Species #1 is *Spartina alterniflora*. At every point in your quadrat that you get a 'hit' by *S. alterniflora,* you put check mark in the corresponding box on the data sheet (1-50, as labeled). So let's say *S. alterniflora* 'hit' your rod at points 1, 4, 8, 10, 15, 24, 30, 42 and 48. Now add up the number of check marks for that species and place that number in the Total box - in this example that would be at 9 different points in our quadrat. But, you're not done! You want to find out the percent cover in 100% of the quadrat, but we only sampled at 50 points, not 100....so, simply multiply 9 by 2 in order to get your estimation for 100% of the quadrat. The percent cover of *S. alterniflora* would be 18%.

Questions and Possible Answers

1. **What factors explain the species composition and cover at each site in the marsh (low marsh, high marsh and upland edge?)**

Some species are more salt tolerant than others, and thus the amount of daily tidal flooding and elevation of the marsh will play a significant role in what plants grow where in the marsh. We would expect very salt-tolerant species to dominate the lower marsh while the less salt-tolerant species will inhabit the high marsh and upland edge.

2. **How would you expect sea level rise to affect the plant distribution and cover in a marsh?**

Sea level rise could cause more brackish water to cover areas of the marsh that once remained relatively dry. Plants that once were exposed to tidal flooding once per month may now be experiencing the flooding more regularly, leading to stress and die-off of that plant. We could expect to see a 'shift' in the distribution of the plants, as low marsh plants take over more of the marsh because it is wetter for longer periods of time, and the high marsh plants are pushed to the upland edge. Upland edge plants will need to migrate even further inland, which can often be impossible if barriers like roads are present. In this case, we would expect to see the upland edge plant species greatly reduced or even removed from the habitat.

3. Why is it important to collect this kind of data over a long period of time?
Monitoring changes in vegetation over time can help us understand other changes in the ecosystem. With salt marshes, we know that water levels play a major role in the species that grow there; by studying changes in the diversity and cover of salt marsh plants, we can better understand how changes in water levels are affecting the marsh. As the habitat changes, other species like birds and insects that once relied on certain marsh plants may also be impacted if those plants become less abundant. This kind of data can help natural resource managers better understand the challenges facing the ecosystem, which can then lead to consideration of possible solutions to mitigate the impacts of sea level rise. For example, coastal researchers are studying the benefits and impacts of adding sediment directly on top of marshes, in an attempt to build up the marsh so that it is able to keep pace with rising sea levels.

**Procedure was gathered in part from the 'Monitoring Salt Marsh Vegetation: A Protocol for the Long-term Coastal Ecosystem Monitoring Program at Cape Cod National Seashore' by Charles T. Roman et al, 2001.*

Percent Cover Estimate Activity

Example: (top: 5%, 50%; bottom: 25%)

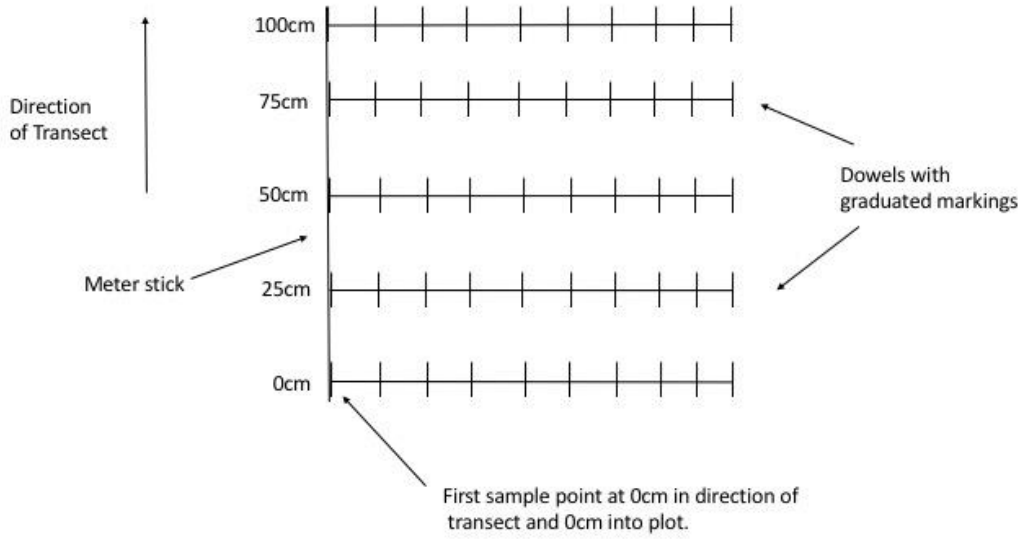
Materials:

Percent Cover Estimate Activity:

- Colored paper
- White paper
- Glue
- Laminator or sheet protectors for longevity

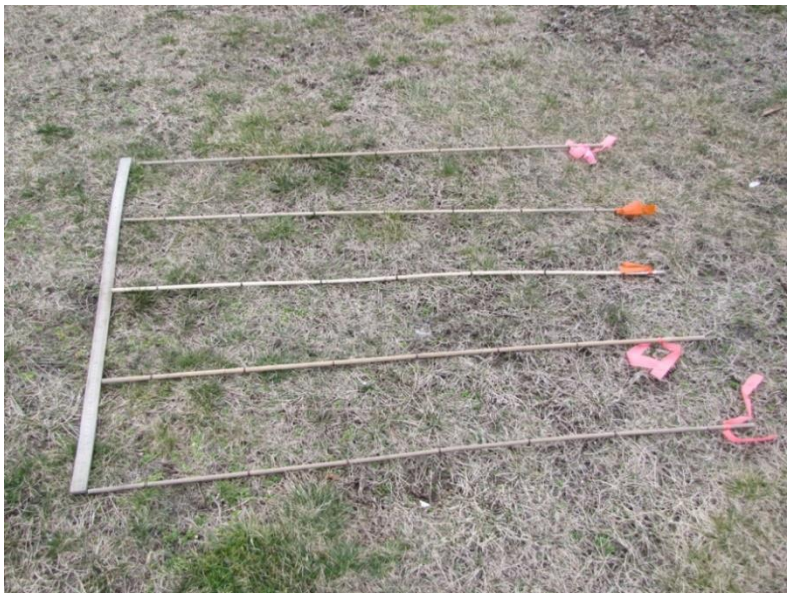
Point-Intercept Activity

Example: Point-Intercept Sampling Diagram



Materials:

- Meter stick
- 5 dowel rods (<3mm in diameter) with 10 marked intervals at 11.1cm
- Thin rod (<3mm in diameter)
- Clipboard
- Vegetation sampling data sheet
- 100-meter tape
- Pencil
- Vegetation identification guides or preserved specimens for reference during activity



TEACHER MASTER #1
Exercise 1

Common Plants of New England Salt Marshes

Please note that the common growing season of these plants is May-September; visiting salt marshes earlier or later in the year may result in plants that are not fully emerged, flowering or are brown in color.

Saltmarsh cordgrass (*Spartina alterniflora*)
Low Marsh


Saltmeadow hay (*Spartina patens*)
High Marsh

Spikegrass (*Distichlis spicata*)
Low or High Marsh

Teacher Master 1: Exercise 1 cont.

Glasswort (*Salicornia spp.*)
Bare patches throughout marsh zones

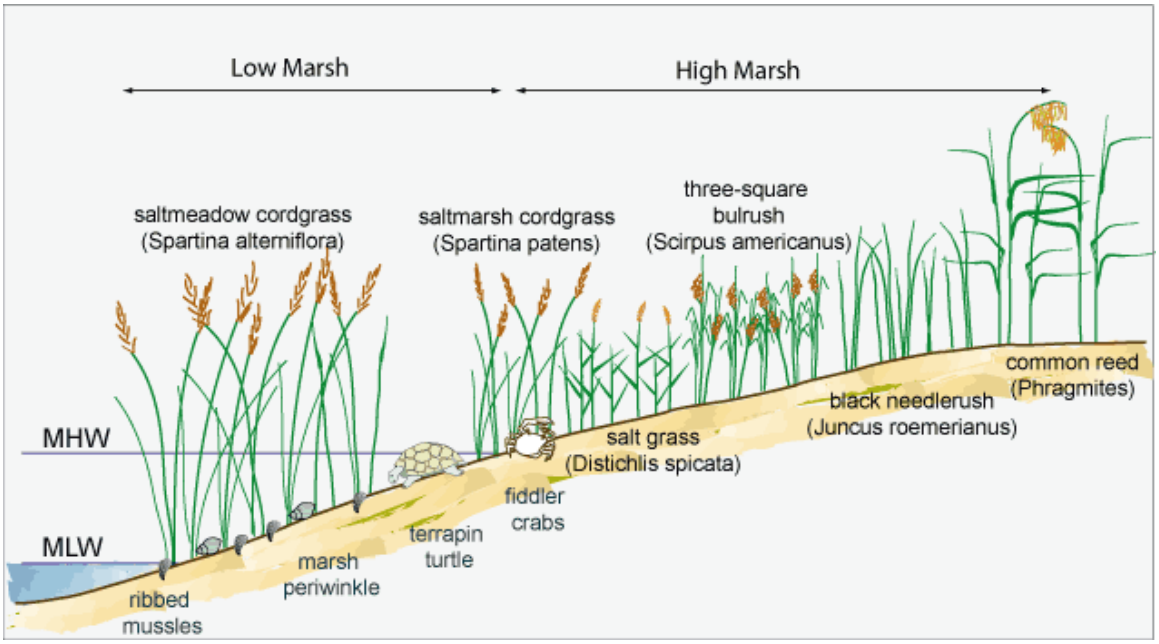
Black rush (*Juncus gerardii*)
High Marsh

Sea Lavender (*Limonium carolinianum*)
High Marsh, sometimes interspersed in low

Marsh Elder (*Iva frutescens*)
High Marsh or Upper Border

TEACHER MASTER #2
Exercise 1

Salt Marsh Profile



Courtesy USGS

Notes:

- MHW: Mean High Water
- MLW: Mean Low Water
- Some animals and plants indicated on this image may differ from what is found in New England salt marshes, as this is a generalized depiction of east coast salt marshes.

TEACHER MASTER #3
Exercise 2

Salt Marsh Vegetation Monitoring Data Sheet

Date:

Marsh/Location:

Transect and Plot Number:

Field Crew:

Place a check mark at each point where a species was encountered.

POINT	SPECIES 1:	SPECIES 2:	SPECIES 3:	SPECIES 4:	SPECIES 5:	SPECIES 6:	SPECIES 7:
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
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40							
41							
42							
43							
44							
45							
46							
47							
48							
49							
50							
TOTAL							
% Cover							

The Total line should be the number of 'hits' out of the 50 points. The % cover is the total number of 'hits' for each species and multiplied by 2. For example, if you have 15 'hits' for Species 1, then you have 30% cover of that species.

Species present but not recorded during the sampling method:

Activity 3
Sea Level Rise and Coastal Wetlands

Estuary Principle
Principle 1: Estuaries are interconnected with the world ocean and with major systems and cycles on Earth.
Principle 6: Human activities can impact estuaries by degrading water quality or altering habitats: therefore we are responsible for making decisions that protect and maintain the health of estuaries.

Research Question
How does sea level rise affect coastal wetlands?

Disciplinary Core Ideas (from Next Generation Science Standards)

- MS-LS2-2: Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.

- HS-LS2-6: Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.

Crosscutting Concept (from Next Generation Science Standards)
- **Cause and Effect:** Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.
- **Stability and Change:** For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.

Introduction
Sea level change has happened at various times in Earth history. It is a natural process that has gone on since there have been oceans on Earth. However, the increase in the global average temperature is now causing sea level to rise in some areas around the globe. Global warming affects the volume of the oceans and the height of the sea due to two factors: thermal expansion, which means that as water warms it takes up more volume than it did previously, and the melting of land-based ice such as glaciers and the ice caps in Greenland and Antarctica. Scientists predict that the oceans will rise 0.5 - 1 meter above present levels by the year 2100.

A rise of 1 meter would have a dramatic effect on our coastlines. Seventy per cent of the world's population lives within 100 miles of the coast. If the height of the oceans increases 1 meter, many coastal areas, including many cities, will be vulnerable to erosion, flooding and storm surge. Scientists estimate that two-thirds of the coastal wetlands in the United States are vulnerable and may be lost if the sea level rises 1 meter.

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TEACHER GUIDE

Sea Level Rise and Coastal Wetlands

Research Question
How does sea level rise affect coastal wetlands?

Content Objectives:
Students will understand that:

- Water expands as it warms.
- Coastlines and wetlands with a small elevation gradient will be most affected by sea level rise.

Exercises

Exercise 1: Water Expands When Heated

Students conduct an experiment that demonstrates thermal expansion. Students correlate the results of the experiment to the impact warming global temperatures have on sea level.

Exercise 2: How Sea Level Rise Affects Different Land Forms

Students build a model out of clay depicting two types of shorelines: rocky shore and a gradually sloping coastal wetland. Students add water to each model, observing potential impacts to the different types of shorelines.

Vocabulary

Estuary—a semi-enclosed body of water that has a free connection to the open sea and within which seawater is measurably diluted by fresh water derived from land drainage

Habitat—the specific environment where an animal or plant is able to survive

Sea level Rise—the rising level of the ocean due to thermal expansion caused by the warming of the oceans (since water expands as it warms) and the loss of land-based ice (such as glaciers) due to increased melting

Thermal expansion— the tendency of matter to change in shape, area, and volume in response to a change in temperature, through heat transfer

Erosion—the action of surface processes (such as water flow or wind) that remove soil, rock, or dissolved material from one location on the Earth's crust, then transport it away to another location.

Storm Surge—an abnormal rise of water generated by a storm, over and above the predicted astronomical tides

Salt marsh—coastal wetlands that are flooded and drained by salt water brought in by the tides

Ecosystem—a community of living organisms in conjunction with the nonliving components of their environment (things like air, water and mineral soil), interacting as a system

Elevation Gradient—the angle of elevation over a certain distance

Ecosystem Services—all the ways in which humankind and the environment benefit from ecosystems, such as clean drinking water, decomposition of wastes, production of food and crop pollination

Biomass—organic matter derived from living, or recently living organisms

Carbon sink—anything that absorbs more carbon that it releases

Exercise 1

Water Expands When Heated

Overview
In this exercise, students learn that sea level rise affects estuaries in different ways. Allowing salt marshes to "migrate" inland will help combat the effects of sea level rise.

Time Required
One 45-minute period

Estuary Concept
As air and ocean temperatures rise, water expands. This expansion is one cause of sea level rise. Rising seas affect all estuaries around the globe.

Focus Question
What effect do warming temperatures have on water and sea levels?

Performance Tasks
Students will:

- Conduct an experiment that demonstrates how heated water expands, much like the expansion that occurs as rising global temperatures of air and water create sea level rise.

Teacher Background
Water, like all substances is comprised of molecules. When water molecules are heated, their atoms move faster and farther away from one another. In this experiment, students create a sealed environment around the water with a channel (clear straw) for the water to expand. Once heated, water moves up the straw demonstrating how the volume of water in any location increases as it heats. Warming global temperatures are causing the water in our earth's oceans to expand, therefore causing sea levels to rise around the globe.

Procedure

Materials:

- 1 clear straw
- 1 water bottle
- food coloring
- drill or scissors
- playdough/clay
- water
- microwave or very hot tap water
- liter container or turkey baster
- large bowl

1. Share with students that there are two basic reasons why sea levels are rising.
    a. The melting of land-based ice such as glaciers and the ice caps in Greenland and Antarctica, due to an increase in average global temperatures.
    b. The volume of water in the oceans has increased due to thermal expansion caused by warming temperatures.

2. Use a drill or a pair of scissors to make a hole in the top of the bottle lid, big enough for the drinking straw to fit through.

3. Fill the bottle halfway with cold water.

4. Add a few drops of food coloring and mix (students can choose whatever color they want).

5. Screw on the bottle lid and insert the straw through it into the water, making sure that the straw does not touch the base of the bottle.

6. Seal around the hole in the lid using play dough, or clay, thereby fixing the straw in place. The seal must be completely airtight.

7. Place the bottle into a bowl with very hot water in it (you can add hot water as it cools). What happens to the liquid in the straw and why? The heat is transferred to the water in the bottle causing it to expand and rise up the straw. This is what happens to the water in our oceans as global temperatures rise.

Questions and Possible Answers

1. **What causes water to expand?**

   Most matter expands when heated and contracts when cooled, a principle called thermal expansion. The average kinetic energy of the particles increases when matter is heated and this increase in motion increases the average distance between its atoms.

2. **How do warming global temperatures cause sea level to rise as it relates to thermal expansion?**

   As temperatures rise around the globe, the water temperatures in the ocean also rise. Just a small amount of temperature increase causes water molecules to expand. The expansion of these molecules increases the volume of the water, causing the level of ocean to rise.

Conclusions

At the end of the activity, students should know that warming temperatures are causing sea levels to rise in two ways; by the increase of water entering into oceans from melting glaciers and ice caps, and by thermal expansion of molecules in ocean waters. Thermal expansion causes the volume of water to increase, causing sea level to rise.

Exercise 2

How Sea Level Rise Affects Different Land Forms

Estuary Concept
Estuaries are impacted by sea level rise differently, depending on the type and slope of the shoreline.

Focus Question
What is the effect of sea level rise on a gradually sloping salt marsh compared to a steep rocky shore?

Performance Task
Students will:

- Build two models of a shoreline; one representing a gradually sloping salt marsh, the other a steep rocky shore.
- Add various amounts of water to see what impact sea level rise has on two different habitat types.

Teacher Background
Coastal wetlands provide critical ecosystem services. They provide essential habitat for fish, birds, shrimp, crabs, and many other types of wildlife. They serve as "nurseries" for wildlife, a source of food and a resting place during migrations. About two-thirds of the species of food fish harvested from the Atlantic and most of the shellfish must live in salt marshes or estuaries for part of their life cycles. The mass of plants and animals (biomass) that is produced naturally on an acre of salt marsh is greater than that produced on fertilized farmland.

While it is well known that forests store large amounts of carbon by removing the greenhouse gas, carbon dioxide, research indicates that coastal wetlands might capture and store carbon at rates three to five times greater than forests. The ability of coastal wetlands to absorb and store tremendous amounts of carbon has received increased attention from policymakers, researchers, educators, state and federal agencies and organizations throughout the country. Understanding the carbon storage value of wetlands may lead to increased protection and restoration of these habitats.

In addition to sea level rise, coastal wetlands are vulnerable to additional pressures from climate change. The increased energy in the water cycle due to warming temperatures can cause precipitation to fall in more severe events. Intense storms can cause erosion and major damage to wetlands and other coastal ecosystems, as well as to roads, buildings, and utility structures along the coast.

The actual distance that rising sea levels bring seawater onto land is dependent on many factors including the shape of the land, type of land and amount of erosion, local ocean currents, and tides. Loss of wetlands due to sea level rise is most severe in areas with small elevation gradients. The cities of Miami, New York and New Orleans where the elevation of the coastal

land doesn't change very much or slopes gradually are particularly susceptible. Coastlines with a gradient of 20 to 1 for example, will lose 20 meters (65.6 feet) of horizontal land or wetland for every 1 meter that sea level rises. Salt marshes will be especially affected because of their gentle gradients – many have much lower gradients than 20 to 1 or are nearly level.

Salt marshes stand a better chance of keeping pace with sea level rise if they are able to migrate inland; however, this is often hindered by development like roads and buildings. As water levels rise, grasses that are periodically inundated by salt water will eventually become permanently flooded if the edge of the marsh cannot move upland. If we do not develop our coastal areas, the marsh can continue to migrate. Keeping our marshes healthy and restoring others that have been destroyed over time will assist in global efforts to combat the devastating effects of sea level rise.

Materials:

- Clear oblong storage containers
- Water
- Self-hardening clay
- Small objects to represent houses, wildlife, roads, etc.
- Images of rocky shore, wetland (included)
- Map showing different types of shorelines

Procedure:

1. Explain that global warming is happening because the burning of fossil fuels such as gas, oil and coal are causing excessive amounts of carbon dioxide to create a blanket effect around the earth. This blanket of gas is retaining more heat in the atmosphere, causing an overall warming of air and water temperatures around the globe.
2. Explain that as the ocean warms, the volume of water increases, causing sea levels to rise.
3. Explain that there are different types of shorelines: rocky, sandy, developed, salt marsh, etc. Find locations of these on a map. Ask your students what types of animals might live there.
4. Explain that some of these habitats, like salt marshes, are very important. Salt marshes are important as a habitat for many kinds of plants and animals, as a natural buffer for storms, and as a place to capture and store excess carbon from carbon dioxide. Salt marshes have been found to be extremely effective at locking up excess carbon, helping to reduce the effects of global warming. Therefore, maintaining healthy, functioning salt marshes is critical in an overall effort to reduce the amount of CO2 in the atmosphere.
5. Ask your students: "What is the effect of sea level rise on a gradually sloping wetland area, compared to a steep rocky shore?"
6. In two clear, oblong storage containers, use clay to construct models of a steep, rocky shore and a gradually sloping coastal wetland. Add small tokens or models of clay to represent wildlife such as nesting birds near the water line, houses, roads or other structures further up along the shore.
7. Add 1 liter or 10 turkey basters full of water to each model.
8. Measure the depth of water in the model using a ruler.
9. Ask your students to describe what they observe.
10. Have your students look at the diagrams of coastal areas. Ask them: "What will be affected as the water levels rise?"
11. Find a few images of the rocky shore and a coastal wetland (or use the examples included in this activity) and a map showing different types of shorelines. The image of the shorelines and home included here shows how the same amount of increase in sea level rise inundates much more land if the slope is gradual than if the slope is steep.

12. Explain to your students that salt marshes have a better chance of keeping pace with the rate of sea level rise if it is slow enough and they have the ability to "migrate" inland.

Questions and Possible Answers

1. **Which environment will suffer impacts of sea level rise more quickly?**

   Areas with a more gradual slope will be flooded before steeper areas**.**

2. **Why not just fill in all the wetlands and build up walls everywhere?**

   Saltmarshes are critical habitats and provide important ecosystem services to the environment. They provide homes for wildlife, act as giant sponges --soaking up pollutants, toxins and sediments, and serve as "carbon sinks". Excess carbon is stored in saltmarshes at rates as much as three to five times greater than forests.

Conclusions

At the end of the exercise students should know that sea level rise affects coastal environments differently. Gradual slopes will be more susceptible to flooding than steeper slopes. Wetlands are critical environments in need of protection, as they face some of the most serious threats due to sea level rise.

TEACHER MASTER #1
Exercise 2

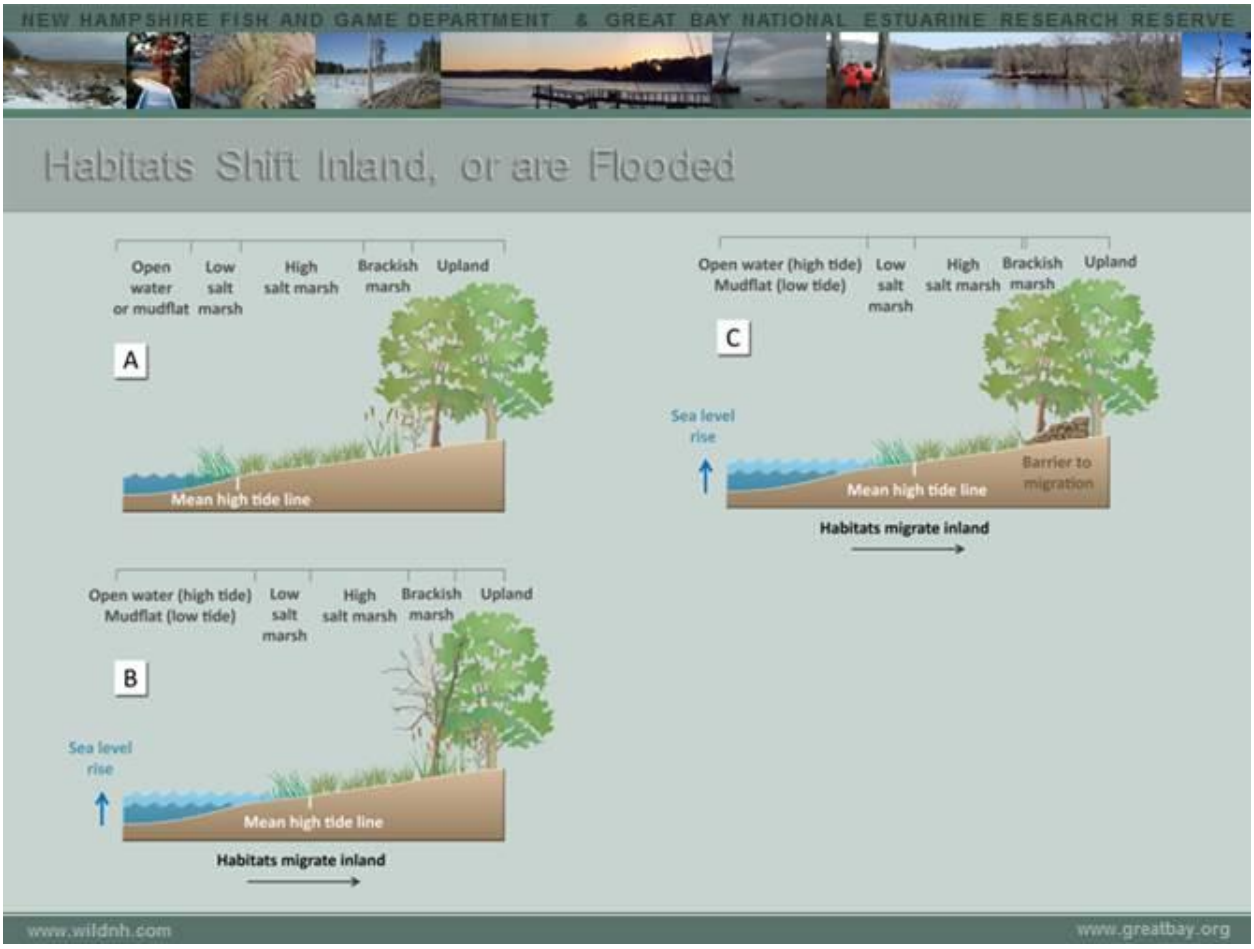
Coastal areas with a more gradual slop will be flooded before steeper areas.

Steep Slope

Gradual Slope

TEACHER MASTER #2
Exercise 2

The following graphic depicts marsh migration



This activity is by Pat Harcourt, adapted from a lesson in URI's "Discovery of Estuarine Environments" as part of the *Bringing Wetlands to Market: Curriculum Linking Wetlands and Climate Change*. For more information and activities about carbon storage check out http://www.waquoitbayreserve.org/research-monitoring/salt-marsh-carbon-project/teachers/

Activity 4
Student Sentinel Sites at Schools: Investigating a Changing Environment

Estuary Principle
Principle 4: Ongoing research and monitoring is needed to increase our understanding of estuaries and to improve our ability to protect and sustain them.
This same principle holds true for other ecosystems.

Research Question
How can we study change in our environment and why is that important?

Science Practices (from Next Generation Science Standards)
- Asking questions and defining problems
- Planning and carrying out investigations
- Analyzing and interpreting data
- Using mathematics and computational thinking
- Constructing explanations and designing solutions
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information

Disciplinary Core Ideas (from Next Generation Science Standards)
- **MS-ESS3-3:** Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.
- **MS-LS2-4:** Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations. (Emphasis is on recognizing patterns in data and making warranted references about changes in populations, and on evaluating empirical evidence supporting arguments about changes to ecosystems).

Crosscutting Concept (from Next Generation Science Standards)
- **Stability and Change:** For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of the system are critical elements of study.

Introduction

The National Estuarine Research Reserve System (NERRS) is a place-based network of 28 reserves located in estuaries along the nation's coasts and Great Lakes. Each reserve implements standardized monitoring protocols to examine short-term variability and long-term changes in estuarine ecosystems. These Sentinel Sites are intensely studied through sustained observations to detect and understand changes in the ecosystems they represent. The NERRS Sentinel Sites combine the monitoring, outreach and training capacity at each reserve into networks that address questions of impacts of climate change and human stressors on estuarine ecosystems and coastal communities. In this activity, students will be setting up their own Sentinel Sites to study change. Planning and conducting investigations is very prominent in the Next Generation

Science Standards. Whether or not students go on to become scientists, the experience of doing their own investigation will deepen their lifelong scientific literacy.

Perhaps one of the most important messages teachers can pass on to their students is to become lifelong stewards of the earth they will inherit. The best way students can learn responsible management of something entrusted to their care is to actually practice being stewards. Big or small, planning and carrying out their own project is much more memorable for students than simply learning about the concept of stewardship. You may find a ripple effect as the project touches students' friends, family, and other community members.

Table of Contents

TEACHER GUIDE

Student Sentinel Sites at Schools: Investigating a Changing Environment

Research questions:
How is your site changing over time or geographic space and what might be driving that change?

How does (students fill in one or more variables) change over (students fill in time or space) in (fill in where students will be studying). What factors are contributing to that change?

Content objectives
Students will understand that:

- Earth systems are affected by changes in global systems and cycles such as climate and weather cycles.
- Through research and monitoring in the NERRS and elsewhere, humans gather scientific data in estuaries that allows us to better understand natural processes and to track changes on the earth. For example, the System-Wide Monitoring Program allows scientists to track short-term variability and long-term change.
- Human activities within a natural system, its watershed, and in distant areas impact the biological, chemical, and physical components of that system.
- Actions that will help improve and maintain environmental health include energy conservation, water conservation, habitat protection and restoration, proper wastewater treatment, and education about these natural areas.

Exercises

Exercise 1: Setting up your own Sentinel Site:

In this exercise, students will choose an area to observe and one or more variables to monitor over time (if possible) or a geographic gradient to look for changes. They will also keep data on factors they feel may be causing the change. Once they have collected their data, they will analyze it and present it to their classmates.

Exercise 2: Becoming Stewards of your Sentinel Site:

Once your students have observed their Sentinel Site and learned more about what is impacting it, they will choose a problem to focus on and decide upon an action they can implement themselves that will benefit their own site and/or similar habitats.

Vocabulary

Monitoring – sampling of environmental factors that are compared with baseline samples to see if any changes have occurred

NERRS Sentinel Site – areas in coastal and marine environments set up for intensive study and sustained observations to detect and understand changes in the ecosystems they represent. Observational data are collected at discrete measurement stations (platforms and sensors) within each site, providing information that can be synthesized to provide an understanding of the ecological status and trends in biological and physical variables of interest.

Parameter – a characteristic, feature, or measurable factor that can help in defining a particular system

Research – systematic investigation designed to answer a question

Stewardship – a way for people, including young people, to care for or maintain something such as the environment, an estuary, or wetlands

Variable – a characteristic that changes

Exercise 1

Student Sentinel Sites at Schools: Investigating a Changing Environment

Estuary Principle:
Principle 4: Ongoing research and monitoring is needed to increase our understanding of estuaries and to improve our ability to protect and sustain them.

Overview
This is a culminating or introductory activity where students study an area over a period of time or geographic space.

Time Required
Variable. Multiple school periods or full field trip days. This activity can be scaled to fit your schedule and skill level of students.

Focus Question
How can we study change in our environment and why is that important?

Performance Tasks
Students will:

- Choose a site to observe.
- Pick one or more variables to measure, identify factors they feel may cause them to change, and monitor these over time or over a geographic gradient.
- Develop visualizations of their data.
- Analyze their data to find trends or correlations.
- Present their findings to classmates or other audiences.

Teacher Background
The National Estuarine Research Reserve System (NERRS) is a place-based network of 28 reserves located in estuaries along the nation's coasts and Great Lakes. Each reserve implements standardized monitoring protocols to examine short-term variability and long-term changes in estuarine ecosystems. These Sentinel Sites are intensely studied through sustained observations to detect and understand changes in the ecosystems they represent. The NERRS Sentinel Sites combine the monitoring, outreach and training capacity at each reserve into networks that address questions of impacts of climate change and human stressors on estuarine ecosystems and coastal communities.

In this activity, students will be setting up their own Sentinel Sites to study change.

Procedure

1. If you have not already taught your students about the National Estuarine Research Reserve System (NERRS) with previous activities, give them a brief introduction. Show them a map of the Reserve System (student page) and explain to them that these are places found in coastal and Great Lake states similar to national parks except in addition to being beautiful places people can visit,

Materials:
Variable, depending on what students decide to observe. Go to the Adopt-a-Wetland activity in the Bringing Wetlands to Market: STEM Curriculum Linking Wetlands and Climate Change for detailed information.
http://www.waquoitbayreserve.org/wp-content/uploads/teacher-adopt-a-wetland-stewardship-project-and-field-study.pdf

Reserve scientists also conduct research and monitoring to learn more about what is happening to our coasts. Ask your students why this is important. This is important because, as a result of the scientists' work, we are better able to understand, and hence, protect the nation's coasts. Discuss with your students the distinction between monitoring and research. Research is a systematic investigation to establish facts, often centered around asking a question. Monitoring is repeated sampling of the environment (air, water, soil, vegetation, animals) that is compared with baseline samples to see if any changes have occurred.

2. Write the word *Sentinel* on the board. Ask if anyone knows what it means. Allow your students to use the internet if they don't know. Write answers on the board, and you will probably get answers like "a guard whose job it is to stand and keep watch." Use this as a jumping off point to get them curious. Tell them the NERRS have a program called Sentinel Sites. What could that be? Why would they call it that? After the discussion, explain that the NERRS Sentinel Site Program has been set up at the Research Reserves to detect environmental changes of importance to resource managers. Just like sentinel guards can warn of incoming enemies, reserve scientists can provide early warning of change for a specific habitat. Why is that important? With early warning, resource managers, communities, states, and federal agencies can develop plans to protect an area. For example, the Reserves are studying changes in sea level rise to see how they will affect salt marshes, important habitats that provide many benefits to humans including food, protection from storms, and filtering of pollutants.

   You can be as brief or in-depth on this part as you would like or have time for. Here are some additional, optional resources:

   - Sentinel Site 3-minute video https://www.youtube.com/watch?v=KRRKWnmOHwo
   - NOAA Climate Change 3-minute video *Making Waves: Measuring Change in an Estuary* at Waquoit Bay Reserve http://oceanservice.noaa.gov/podcast/p0513.html
   - 2-page Sentinel Site info sheet (in student page at end of activity)

3. What follows is a process you can use that gives students the most amount of responsibility for setting up their Sentinel Site. You may decide to complete some of the steps for them depending on their maturity, skills, and the amount of time or constraints you have. It's important to guide them to choose something that will change over time. For instance, you could have students collect data from a bird feeder located so they can view it from their window and they could track changes in temperature as well as bird species over time. They could still collect data and gain practice in the NGSS science practices. Whatever your class decides to do, make sure you gain permission and coordinate with the owner and managers of the area you plan to study. For example, if it is in a wetland, are there specific regulations with which you must comply?

4. Once the students have some understanding about the NERRS Sentinel Site program, explain to them they will be setting up their own Sentinel Site that they will be keeping watch over, similar (though simpler) in concept to the NERRS Sentinel Sites. You can

have them work in small groups, as a class or individually. If they work in small groups, different groups could monitor different sites or all could monitor the same site but study different aspects.

At this point you will either need to give them guidelines which you have decided on ahead of time or let them dream, and guide them into realistic choices later.

a. What is the geographic area from which they can pick? Do you have access to buses? Can they walk off school grounds? Do they need to stay on school grounds? It's best to pick a site in the vicinity of their school in order to be able to realistically monitor it over time. If you can choose a coastal area (a salt marsh or beach), that's great. But if you're not located near the coast, possible other sites include a freshwater pond, a drainage basin, river, stream, vernal pool, meadow, pollinator garden or even a tree or woods.
b. How much time will they be able to spend on the monitoring? Are you limited by the class period? Will it be a day-long field trip? Will it be due this month or the end of the school year? Will this be an afterschool project for the students? If you can make the project last over the whole school year, that will yield the most interesting changes for the students. If you can't dedicate a lot of time for each class, can you continue the project from year to year so students can compare data from previous classes?
c. Are they limited to equipment you already have or they can scrounge for free, or do you have any funds to buy equipment if they need it?

5. Your next steps depend on your limitations. If you have time, it's best to visit the area first, but you can also do this virtually with Google Earth. Explain to your students that they will need to pick variables to study with a possibility of showing change over the period they have to study it. For example, you could monitor species richness, species composition, temperature, pH, dissolved oxygen, salinity, water levels, or changes in topography. Seasonal changes can be interesting to monitor--first snowfall, last snowfall, or when the osprey arrives at its nest. If you're making only one visit, it should change over the geographic area (for example, from the edge of the school yard to the interior of the woods).

6. Once the students have chosen the spot, have them choose something to monitor. In order to make a more compelling project, help to guide them to something that will actually change. They should monitor an outcome, something that changes, as well as a driver, something that they think may cause the change. For example, if they are observing birds at a feeder, they might monitor the numbers and types of birds (the outcomes) as well as the temperature, date, time of day, type of food (drivers or possible causes). Then they will need to make their observations. They will need to figure out how to record their data over time if they plan to monitor their site into the future. If the time you are able to be out in the field is limited, you could augment field time with a webcam.

7. Once they have made their observations, tell them they are going to need to make sense of them. Introduce the concepts of analyzing and interpreting data. This assumes they have already learned about using mathematics and computational thinking – this is where

they will practice these skills. You can supply them with some examples of data from NERRS Sentinel Sites (see student pages), which can be analyzed as a class for practice.

8. Divide the students into small groups (or have them do it individually) to create appropriate visualizations of their own data and construct explanations for what they see. This could mean graphs, tables, posters, infographics, mini video clips –whatever they feel will convey their story best utilizing and practicing their skills. (Note: The student pages at the end of this activity contain visualizations of actual data from NERRS Sentinel Sites that teachers can have students analyze and to use as examples or models).

9. Dedicate a class period for students to share their depictions of the data and explanations for what they see, through presentations for their classmates. After each group presents, allow time for feedback and questions from the rest of the group. Do any new questions pop up? How can they find the answers to those questions (Take more measurements? Internet? Interview an expert in their community)? Do they think the changes are natural or caused by people? How can they find out?

10. This activity may lead students to want to do more investigating. It is optimal if you can provide class time for them to pursue additional questions, but you could also encourage them to pursue them on their own at home for extra credit.

11. In future years, you may want to let the new students continue the tradition of the Sentinel Site or give them the experience of creating their own. One advantage of continuing a project from year to year is that students can compare their data to past years.

For more detailed information on studying a habitat, go to the Adopt-a-Wetland activity in the Bringing Wetlands to Market: STEM Curriculum Linking Wetlands and Climate Change http://www.waquoitbayreserve.org/wp-content/uploads/teacher-adopt-a-wetland-stewardship-project-and-field-study.pdf

Questions and Possible Answers

1. **What did you learn from other student presentations?**

   Answers will vary.

2. **Do you have any new questions?**

   Answers will vary.

3. **How can you find the answers to those questions?**

   They can develop a plan to make more measurements, search the internet, interview an expert in their community or at their local research reserve (a contact list can be found

here: http://estuaries.noaa.gov/Teachers/Default.aspx?ID=304 , or the students may come up with more possibilities.

4. **Do you think the changes are natural or caused by people? How can they find out?**

   See number three above.

Additional Resources: Here are some existing programs your students can join. This simplifies some of the planning steps and your students will get the satisfaction of being part of a larger project. In many cases, the data from these programs is used to make decisions to support these environments.

Picture Post link: http://picturepost.unh.edu/index.jsp
Picture Posts are installed at forests, parks, and schools. Each post guides visitors to photograph a location in nine orientations. Photos are dated, geotagged, uploaded, and shared on the Picture Post site and support environmental monitoring.

Nature's Notebook link: https://www.usanpn.org/natures_notebook *Nature's Notebook* gathers information on plant and animal phenology across the U.S. to be used for decision-making on local, national and global scales. **Phenology** is the study of periodic plant and animal life cycle events and how these are influenced by seasonal and interannual variations in climate, as well as habitat factors (such as elevation).

Aquatic Invasive Species monitoring:
http://www.mass.gov/eea/agencies/czm/program-areas/aquatic-invasive-species/

Beach profile monitoring: http://www.seagrant.umaine.edu/extension/beach-profile-monitoring/home

eBird: http://ebird.org/content/ebird/ A simple and intuitive web-interface engages participants to submit their observations or view results via interactive queries into the eBird database. eBird encourages users to participate by providing Internet tools that maintain their personal bird records and enable them to visualize data with interactive maps, graphs, and bar charts. All these features are available in English, Spanish, and French.

Tips for citizen scientists: http://newengland.stewardshipnetwork.org/resources Includes many examples of citizen science projects.

SciStarter: https://scistarter.com SciStarter connects people to citizen science projects, citizen scientists, and resources.

iNaturalist: https://www.inaturalist.org/ Students can upload photos of organisms, identify them through crowdsourcing, and record observations.

Exercise 2

Planning and Carrying Out a Stewardship Project to Help Your Sentinel Site

Overview
Students will decide upon an action that they can implement themselves that will benefit their site and/or other similar habitats.

Time Required
Variable

Estuary Concept
Human activities can impact estuaries by degrading water quality or altering habitats; therefore, we are responsible for making decisions to protect and maintain the health of estuaries.
This principle can also be applied to other habitats and ecosystems.

Focus Question
What can students do to help protect local habitats?

Performance Tasks
Students will:
- Learn about a problem (or possibility of a future problem) confronting their Sentinel Site.
- Develop a list of possible actions and decide which action(s) to undertake.
- Implement a stewardship project related to their Sentinel Site.

Teacher Background

Following are some resources about student stewardship projects.

1. http://estuaries.noaa.gov/Teachers/score.aspx
   Estuaries 101: Ways to introduce students to the concepts of stewardship and a step-by-step form to help them organize their plan.
2. http://www.waquoitbayreserve.org/wp-content/uploads/teacher-4-3-stewardship-projects.pdf
   Bringing Wetlands to Market: STEM Curriculum Linking Wetlands and Climate Change: Specific ideas for stewardship projects related to wetlands and more links for resources on how to involve students in service learning projects.

Every year, volunteers comb the milkweed plants at Wells Reserve in Maine for signs of Monarch caterpillars to remove them from fields that are to be mowed to fields that are to be left alone that year. One year they saved 38 caterpillars but the numbers change from year

Procedure

1. The students will likely begin to develop a sense of ownership for their Sentinel Site. Explain to your students that part of the mission of the NERRS is to undertake initiatives to keep estuaries healthy (further

information can be found at http://nerrs.nooa.gov/stewardship). Write the word "stewardship" on the board and ask if your students know what it means. Provide examples from one of the New England reserves (see photos and captions).

2. Tell your students that they are going to plan a project to keep their Sentinel Site healthy. Discuss how resource areas often need good management practices. Remind them of the discussion they had about their findings. Did they find any problems? If yes, is there anything that can be done about those problems? If there's nothing wrong with the Sentinel Site now, how can they help keep it that way? If they don't know, you could invite a community expert familiar with their Sentinel Site to come in to talk with them.

3. Write down all their ideas. Split them up into small groups to discuss which ideas they would like to pursue. You can then have each group put forth arguments on which idea they feel the class should pursue and have a vote or split up into two or more groups to pursue their own projects.

4. Have the students create a plan to accomplish their stewardship project (there's an example planning form in Estuaries 101 here): http://estuaries.noaa.gov/Teachers/pdf/15_Score_Ex3.pdf

High school students from Vermont came to Narragansett Bay NERR for an immersive experience in coastal and estuary education that included helping the Reserve remove invasive

Here are some ideas to get you started (make sure you coordinate with whoever manages the land):

- Pick up litter/remove trash
- Educate someone else about the value of your site (parents, other students, community members, town government, etc.) by various means (design posters, create videos to post online or broadcast through local cable TV, develop radio PSAs, bring younger students or parents on a field activity at your site, write letters to the editor or send a press release to your local paper)
- Is it a plain piece of lawn or bare dirt that you'd like to improve? How about planting native plants (pollinator gardens are especially needed) or organic vegetable gardens? You can also educate others by combining this with a student-designed educational sign.
- If erosion is a problem, the students may be able to help install water bars, plant native bushes, or put up a sign.

5. Take a photo of your students doing their project and have them create a caption that answers the following questions:
    a. Who am I? (class, grade, school, location)
    b. What am I doing?
    c. Where am I doing it?

d. Why am I doing it?
e. "I'm a steward of my watershed/estuary because……"

Even better, have them make a brief video (no more than 5 minutes) that answers these questions.

Americorps members help restore a sea run brook trout run on the Quashnet River at Waquoit Bay Reserve on Cape Cod by clearing extra sediment and blocking the vehicular traffic.

STUDENT ACTIVITY PAGE #1

Surface Elevation Table (SET) Model Activity
Introduction and Background Info

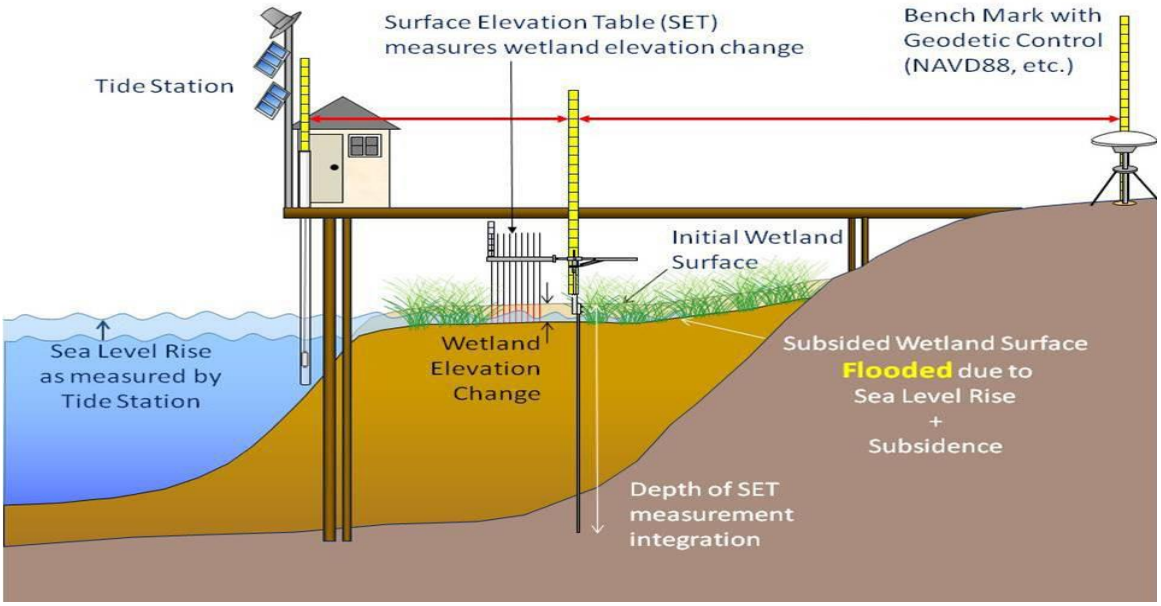
This activity will provide students with an example of how researchers at the National Estuarine Research Reserves are measuring changes in marsh elevation over time. The National Estuarine Research Reserves (NERRS) have a program called Sentinel Sites. The NERRS Sentinel Site Program was set up to detect and monitor environmental changes. By monitoring these changes, researchers can provide information about what is impacting the area and early warnings of threats to specific habitats. Why is it important to monitor salt marshes and the habitats within them?

One way researchers are studying the changing environment is by measuring how the land is changing over time. One of the biggest threats to wetlands is sea level rise and we want to know how the wetlands are responding to pressures from climate change. NERRS researchers use what is called a "Surface Elevation Table" (SET) to measure the change in elevation of the marsh over time. They do this using rods buried deep (up to 120 feet at some reserves) into the ground to serve as reference points to see if the marsh is rising or sinking. A SET is attached to the reference rod, which consists of many smaller pins that are moved up and down to measure the surface of the wetland (see diagram). Researchers can measure the change in elevation of the marsh by measuring the change in height of the SET pins.

In this activity students will create a model of a SET in order to understand how researchers can study the changing elevation of the marsh.

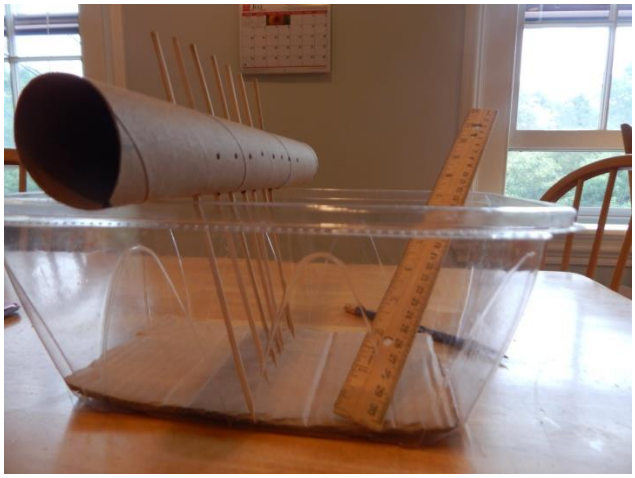
Materials:

- Paper towel roll
- Skewers
- lettuce container
- cardboard



Procedure

1. Have students punch holes into opposite sides of the paper towel roll, making sure they line up.
2. Once the holes are punched, insert the skewers into the paper towel roll.
3. Place the paper towel roll on top of the lettuce container so that the ends of the roll are resting on the edge of the container (see picture of set up).



4. Put a piece of cardboard or layer of sand at the bottom of the lettuce container and have students lower the skewers until they are just touching the cardboard or sand.
5. Measure the height of the top skewer from the top of the paper towel roll.
6. Add another layer of cardboard or sand to the container. Have students repeat steps 4 and 5.
7. In order to measure the change in elevation, students should subtract the second measurement from the first. If the change is positive, that indicates an increase in elevation and vice versa.

*Additionally, you can have students start off with several layers of cardboard or sand and remove them to show a decrease in elevation.

Questions:

1. Did you observe a positive or negative change in elevation?
2. What might a positive change in elevation of a marsh indicate?
3. What might a negative change in elevation indicate?
4. What might be some of the causes of those changes?
5. What useful information can the SET data provide and how can resource managers use it to mitigate the impacts of climate change on wetlands?

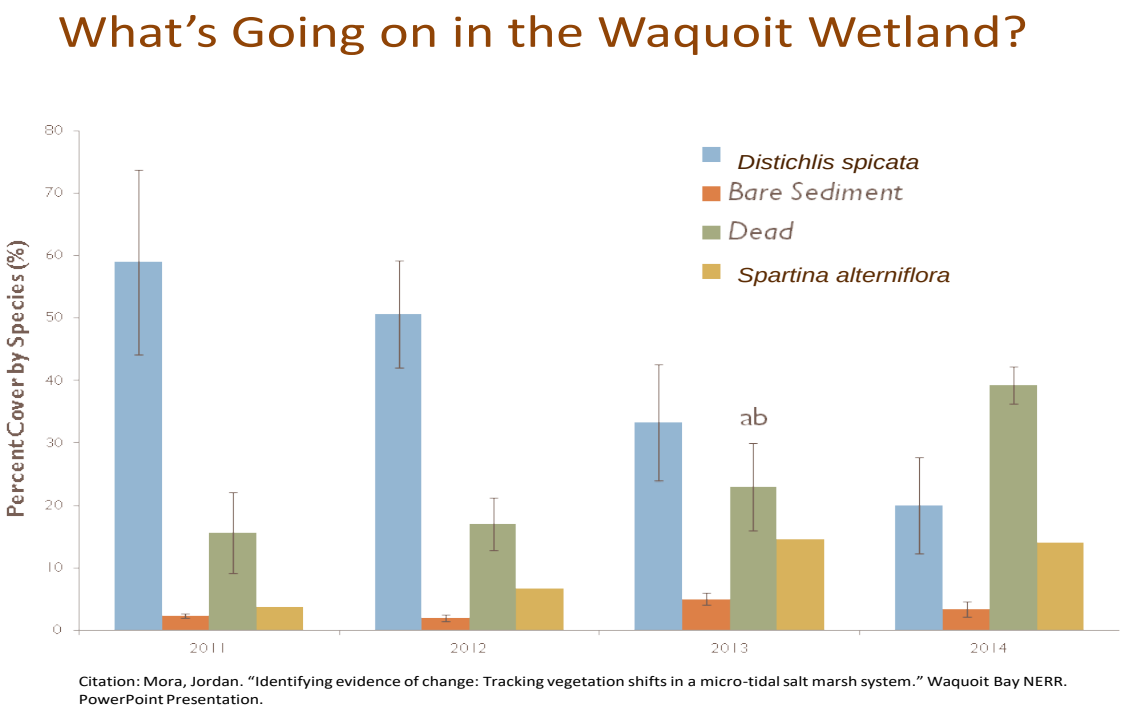
STUDENT ACTIVITY PAGE #2

Percent Cover of Plant Species Activity

In this activity we will examine real data collected by the Waquoit Bay Reserve research team on wetland plant species coverage. Two of the most common plant species in the area are Distichlis spicata (salt grass) and Spartina alterniflora (smooth cordgrass). Both species are important components of a wetland as they provide habitat for many species, protect against erosion, filter chemicals and pollutants and absorb nutrients. The graph provided shows percent cover of these two species as well as bare sediment and dead plant material from 2011-2014. Use this graph to answer the questions below. When examining the graph think about what we have learned so far about the effects on climate change on wetlands.

Questions:

1. Look at percent cover of D. spicata from 2011-2014. What was the percent cover in 2011 compared to 2014? Do the same for S. alterniflora.
2. What changes do you observe in both species over time? Come up with some ideas as to what could be causing these changes.
3. Look at the percent of dead material over the time period. What changes do you observe?
4. Thinking back to the potential effects of climate change on wetlands, could any of these effects be responsible for some of the changes observed in the data? Why or why not?
5. What are some of the potential impacts of the observed changes and future impacts if these trends continue?



Citation: Mora, Jordan. "Identifying evidence of change: Tracking vegetation shifts in a micro-tidal salt marsh system." Waquoit Bay NERR. PowerPoint Presentation.

TEACHER MASTER #1

National Estuarine Research Reserve Sentinel Sites



Effects of Changing Sea Level and Inundation on Coastal Habitats

The National Estuarine Research Reserve System is a place-based network of 28 reserves located in estuaries along the nation's coasts and Great Lakes. Through the System-Wide Monitoring Program (SWMP), each reserve examines short-term variability and long-term changes in estuarine ecosystems using standardized protocols. By doing so, the reserves serve as sentinel sites for understanding impacts from climate change and human activities.

Additional monitoring parameters assess sea level change and inundation impacts on tidal wetlands, submerged aquatic vegetation, and mangroves. The resulting data, combined with information from other systems such as the National Spatial Reference System and the National Water Level Observation Network, provide communities with the tools for climate adaptation planning, including inundation maps, integrated ecosystem models, and vulnerability assessments. In addition to providing data, each research reserve uses its outreach and training capacity to ensure that coastal communities are aware of these resources and have the skills and information needed make their communities more resilient.

Monitoring data from the reserves represent an important component of the NOAA Sentinel Site Program, a partnership consisting of NOAA and other federal, local, and regional partners committed to addressing coastal management issues by leveraging environmental observation networks.

Framing Questions

The following questions are driving the assessment of sea level change and inundation impacts on estuarine habitats:

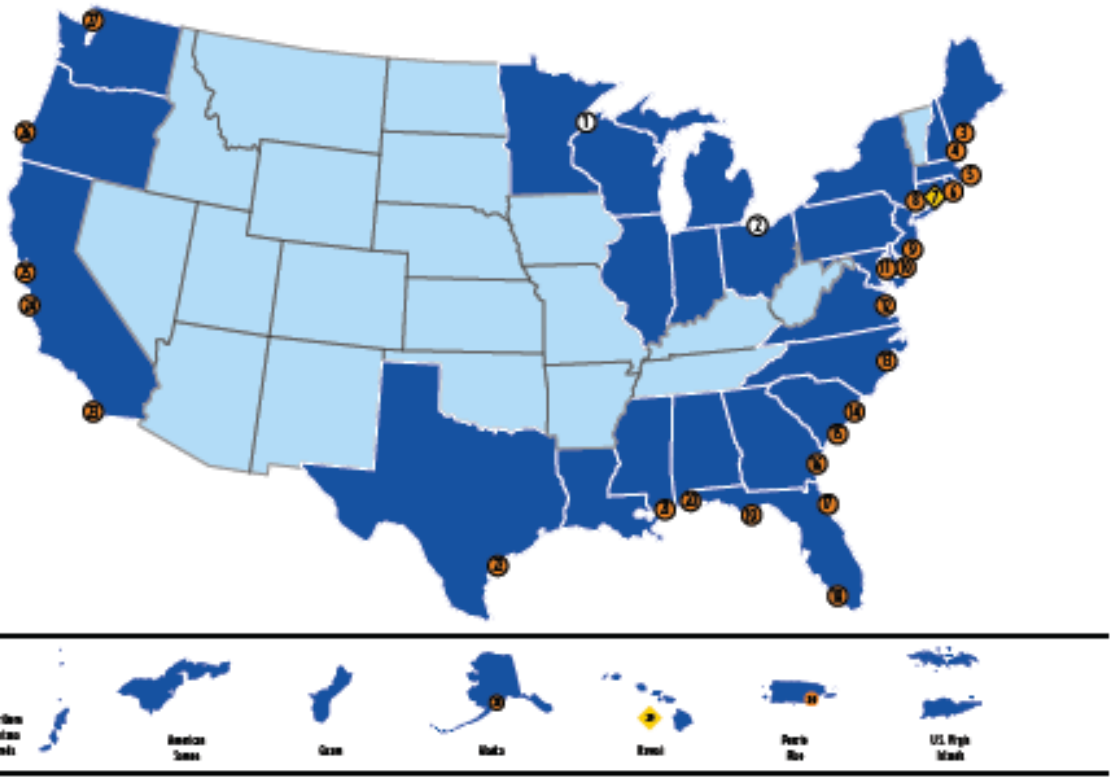
- How are vegetative communities distributed in relation to elevation and tidal range, and how sensitive are those distributions to interannual variability?
- How do vegetative communities respond, in spatial distribution and composition, to long-term changes in local water levels and inundation patterns?
- How does the vegetation elevation change in response to discrete episodic inundation events and long-term changes in local water levels and inundation patterns?

Monitoring Elements:

- Emergent marsh, mangrove, or submerged aquatic vegetation transects
- Habitat maps
- Surface elevation monitoring
- Water quality monitoring stations tied to NOAA's water level observation stations
- Local geodetic control networks tied to the National Spatial Reference System to connect all monitoring elements to the same vertical datum
- Repeated elevation surveys to detect elevation changes
- Meteorological stations

Partners

- NOAA Center for Operational Oceanographic Products and Services
- NOAA National Geodetic Survey



LIST OF RESERVES

Great Lakes
1. Lake Superior, Wisconsin*
2. Old Woman Creek, Ohio*

Northeast
3. Wells, Maine
4. Great Bay, New Hampshire
5. Waquoit Bay, Massachusetts
6. Narragansett Bay, Rhode Island
7. Connecticut (Proposed)

Mid-Atlantic
8. Hudson River, New York
9. Jacques Cousteau, New Jersey
10. Delaware
11. Chesapeake Bay, Maryland
12. Chesapeake Bay, Virginia

Southeast
13. North Carolina
14. North Inlet-Winyah Bay, South Carolina
15. ACE Basin, South Carolina
16. Sapelo Island, Georgia
17. Guana Tolomato Matanzas, Florida

Gulf of Mexico
18. Rookery Bay, Florida
19. Apalachicola, Florida
20. Weeks Bay, Alabama
21. Grand Bay, Mississippi
22. Mission-Aransas, Texas

West
23. Tijuana River, California
24. Elkhorn Slough, California
25. San Francisco Bay, California
26. South Slough, Oregon
27. Padilla Bay, Washington
28. Kachemak Bay, Alaska

Pacific
29. Hawaii (Akrahog)

Caribbean
30. Jobos Bay, Puerto Rico

* All reserves, with the exception of the Great Lakes, are participating in sentinel site monitoring to evaluate impacts from sea level change.

http://www.capenews.net/mashpee/news/listening-to-the-salt-marshes/article_e26018e9-9886-5d30-8e50-9fd0669071d9.html

Listening To The Salt Marshes

By SAM HOUGHTON 4 hrs ago

Home / Mashpee / Mashpee News

SAM HOUGHTON/ENTERPRISE

Jordan Mora, research technician at Waquoit Bay National Estuarine Research Reserve, along with volunteer Kris Bayne and interr Bergeron, survey species in the salt marsh at Sage Lot Pond, South Cape Beach. The researchers are studying the effects of climat change on salt marshes.

On a recent afternoon, a group of volunteers and scientists at Waquoit Bay National Estuarine Research Reserve stepped off a boardwalk and trudged through the black grass and sea lavender of Sage Lot Pond salt marsh, looking for signs of climate change.

The four, in high boots, knelt down into the grass and sorted through species of vegetation inside a one-meter-by-one-meter box outlined by a narrow PVC pipe.

They took notes while the wind whipped off South Cape Beach and a bright August sun beat down.

“We have already seen startling changes,” said Jordan Mora, a research technician at the national reserve.

The annual salt marsh vegetation survey is part of a long-term examination of the impacts of climate change on marshes.

The main takeaway from the study and several others in the region: some marsh species have declined, likely because of sea-level rise as species more resilient to flooding expand out to the perimeters of the marsh.

Sage Lot Pond salt marsh, like salt marshes throughout New England, provides food, sanctuary and breeding grounds for fish and birds; acts as a natural buffer to storm surge; and can mitigate pollution. All three effects are threatened by a changing climate.

Researchers and scientists from national reserves up and down the East Coast have participated in the salt marsh survey in hopes of providing relief to the fragile ecosystems. Reserves include the Great Bay National Estuarine Research Reserve in New Hampshire and the Narragansett Bay National Estuarine Research Reserve in Rhode Island. These reserves, including Waquoit, are part of a partnership program between the National Oceanic and Atmospheric Administration and coastal states.

This vegetation component of the project in Waquoit began in 2011. Since researchers began gathering data, mostly in the August months, they have seen changes in the salt marsh plant zones, which are believed to be due to sea level rise.

Scientists distinguish two zones in a salt marsh: low marsh and high marsh. The low marsh sits closer to the pools or ponds of water within a salt marsh and is dominated by Spartina alterniflora, known as saltmarsh cordgrass, or the small, green reeds common in the area.

The high marsh is dominated by marsh hay (Spartina patens), spike grass, black rush and the purple sea lavender.

Throughout Sage Lot and Flat Pond quadrants in South Cape Beach, researchers at Waquoit have set up 120 of these one-meter-by-one-meter plots, where they record the estimated percentage of each species within the small box, the stem densities and heights of the species in each plot.

The results so far show that where the low marsh transitions into the high marsh, "we have seen decreases in the dominant high marsh plant species of about 40 percent over four years, while the area of unvegetated marsh or Spartina alterniflora has increased," Ms. Mora noted.

In another study, by using aerial photos and geographic information systems, Ms. Mora and other researchers have seen the increase of pool development.

From 2004 to 2012, "we have seen over 31,000 square meters of pool development in the salt marshes within the Waquoit Bay Estuary," Ms. Mora said. "For comparison, a football field is just over 5,300 square meters."

The data collected at Waquoit Bay reflects the trend in marshes throughout at least New England.

In 2001, Jeffrey P. Donnelly and Mark D. Bertness published a scientific study in Proceedings of the National Academy of Sciences about "shoreward encroachment of salt marsh cordgrass in response to accelerated sea-level rise." The study looked at two salt marshes in New England and basically shows the increase of lower marsh species with the increase in sea-level rise.

"These results suggest that increased flooding associated with accelerating rates of sea-level rise has stressed high-marsh communities and promoted landward migration of cordgrass," the study reads. "If current rates of sea-level rise continue or increase slightly over the next century, New England salt marshes will be dominated by cordgrass. If climate warming causes sea-level rise rates to increase significantly over the next century, these cordgrass-dominated marshes will likely drown, resulting in extensive losses of coastal wetlands."

Researchers point to "soil waterlogging" in this creation of more singular salt marsh. Species in the lower levels of a salt marsh, like the S. alterniflora, are more resilient to constant flooding, while species on the higher levels have a harder time retaining sediment when flooded. And instead of the higher marshes pushing out farther to the perimeters of the marsh, man-made structures such as roads and homes impede the growth out.

A more recent publication states that the waterlogging, vegetative shifts and the eventual die-off of the high marsh species could create both beneficial and problematic scenarios for wildlife and their habitats. In a paper published in 2015 in Coastal and Estuarine Research, Kenneth B. Raposa, research coordinator at the Narragansett reserve, co-author with three other researchers, writes that

with expanding pools and more lower marsh, foraging habitat for some marine life could improve, such as for the mummichog. More mummichog, a small fish, "should in turn translate into improved foraging opportunities for wading birds that prey on these species."

However, the effects will negatively impact the habitat for other birds. "Birds use S. patens salt meadow more frequently than any other salt marsh habitat in southern New England marshes, and its loss will likely result in declines in species of concern such as the seaside sparrow (Ammodramus maritimus) and the saltmarsh sparrow (Ammodramus caudacutus)," the study reads.

"Of course, any short-term enhancement of the functional ability of marshes to provide habitat (or any other ecosystem services) will eventually become lost if sea level rise and its associated impacts to vegetated marshes leads to net losses of marsh area," the paper continues.

While climate change scientists like those on the Intergovernmental Panel on Climate Change predict that sea level will continue to increase, researchers do still have hope for the coastal marsh. Ms. Mora in Waquoit said that the local survey could lead to ways to counteract what has happened and will likely continue to happen. There have been studies begun to spray sediment into the upper regions of the marshes for the grass to sustain itself. Clearing clogged channels in estuaries could also help better drainage.

Until then, however, the signs are not good for salt marshes.

"Here we provide further evidence that southern New England salt marshes are changing rapidly and dramatically in response to accelerating sea level rise," Dr. Raposa's paper states. "In the absence of targeted marsh adaptation projects, we expect further deterioration of southern New England marshes as sea level rise continues to accelerate."

Sage Lot Pond Marsh
Sep 8, 2016

Sentinel Sites at School Activities

Next Generation Science Standards (NGSS) Alignment

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
1. Asking questions and defining problems **2. Developing and using models** 3. **Planning and carrying out investigations** 4. **Analyzing and interpreting data** **5. Using mathematics and computational thinking** **6. Constructing explanations and designing solutions** **7. Engaging in argument from evidence** 8. **Obtaining, evaluating, and communicating information**	**MS-Human Impacts** **MS-ESS3-3** Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment. *(***MS-LS2-4-** Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations. (emphasis is on recognizing patterns in data and making warranted inferences about changes in populations, and on evaluating empirical evidence supporting arguments about changes to ecosystems). **HS-Interdependent Relationships in Ecosystems** **HS-LS-2-6**- Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions but changing conditions may result in a new ecosystem. (Examples of changes in ecosystem conditions could include …. sea level rise).	**Fits the best:** **Stability and Change** For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of the system are critical elements of study. **Also fits:** **Patterns** **Cause and Effect: Mechanism and Explanation** **Scale, Proportion, and Quantity** **Systems and Systems Models** **Energy and Matters: Flows, Cycles, and Conservation** **Structure and Function**