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Marsh Migration Mania!

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Grade Level
7th Grade

Subject area
Life Science

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Activity Title: Marsh Migration Mania

Focus/Concept: Sea-level rise and marsh migration: salt marsh invertebrates in the ghost forest

Grade Level/Subject: 7th grade Life Science

2018 VA Science SOLs

LS.5: The student will investigate and understand that biotic and abiotic factors affect an ecosystem.

c) Relationships exist among producers, consumers, and decomposers

LS.8: The student will investigate and understand that ecosystems, communities, populations, and organisms are dynamic and change over time.

a) Organisms respond to daily, seasonal, and long-term changes

c) Large-scale changes such as eutrophication, climate changes, and catastrophic disturbances affect ecosystems

LS.9: The student will investigate and understand that relationships exist between ecosystem dynamics and human activity.

c) Variations in biotic and abiotic factors can change ecosystems

Learning Objectives

- Students will be able to explain how rising sea levels cause salt marsh to migrate inland.
- Students will identify how two salt marsh species' habitat requirements potentially affect their ability to migrate inland.
- Students will draw their predictions for how coastal forest will change because of sea-level rise.

Total length of time required: 90-100 minutes

- Advance preparation: 30 minutes
- Lesson implementation: 60-70 minutes

Key words

- **Salt marsh**: an intertidal grassland ecosystem found where the ocean meets land
- **Intertidal zone**: an area that is flooded by the high tide but left exposed (dry) by the low tide
- **Invertebrate**: an animal that does not have a backbone
- **Invertebrate community**: a group of invertebrate species that interact with each other in the same habitat
- **Amphipod**: an order of crustaceans with some species found in salt marshes

- **Generalist**: an animal that does not have a specific required diet but will eat a variety of items based on what it can find

- **Rate of sea-level rise**: the speed at which the ocean's surface level is rising and causing it to move inland, usually measured in millimeters per year

- **Marsh migration**: a horizontal shift in salt marsh into the inland habitat that neighbors it (often forest). Marsh migration is one important way that a salt marsh can survive sea-level rise

- **Ghost forest**: a habitat formed by standing, dead trees (usually killed by saltwater intrusion or saltwater flooding during a storm) and marsh grasses that have migrated inland. A sign that salty water is affecting coastal forest

- **Coastal squeeze**: loss of salt marsh habitat that happens when development keeps marsh from migrating inland

Background information

Marsh migration and ghost forests

The surface of the ocean (sea level) around the world is rising because of melting polar ice sheets and warming waters caused by global warming. When sea level rises, salty ocean water moves inland, and areas that used to be dry are flooded with saltwater. There is a lot of salt marsh around the Chesapeake Bay. A salt marsh is a grassland that floods with saltwater at high tide and dries out at low tide. Sea-level rise causes some salt marshes to stay flooded all the time, even during low tide. When this happens, the marsh plants and animals in these areas cannot survive, and the marsh drowns. Farther inland from the salt marsh, we often find forest. When ocean sea levels rise, the soil in the forest might become salty from increased flooding. The saltwater flooding is bad for trees in the forest but good for marsh plants and animals. Trees will die when they are flooded with saltwater, but salt marsh plants can migrate inland and grow where the forest used to be. This is called marsh migration. Although the marshes closest to open water will drown because of sea-level rise, marsh migration is one important way that salt marshes might be able to expand farther inland. Trees that have been killed by saltwater do not fall over right away. They stay upright as standing dead trees and create a new habitat called a ghost forest. When sea-level rise happens more quickly, saltwater moves inland faster and creates more ghost forest.

Salt marsh and ghost forest invertebrates

Scientists are just beginning to do research on ghost forests. We still do not know which marsh plants and animals use the ghost forest. Based on our field observations, we think that salt marsh species migrate into the ghost forest habitat at different speeds. Some animals, like the saltmarsh amphipod *Orchestia grillus*, are generalists. They can live wherever there is salty soil and enough food to survive, so they migrate into the ghost forest right away. Amphipods are found in the salt marsh and ghost forest, and even in parts of the live forest that are close to the marsh. Other animals are pickier about their habitat because they are sensitive to salinity or they need a specific type of food. The saltmarsh snail *Melampus bidentatus* is an example of this type of animal. It will probably not migrate into the ghost forest until the habitat is exactly right for it. This means that it might only live in the salt marsh, even though other marsh animals already live in the ghost forest.

Why does it matter?

Trees in the ghost forest fall over several years after they die. When the dead trees fall over, there is less shade, and more algae grows in the sunlight. Over time, sea-level rise continues to increase salinity and flooding. The ghost forest starts to look more like regular salt marsh. Animals that need specific food and abiotic conditions can now move into the habitat because it matches salt marsh habitat. When sea level rises slowly, the ghost forest has time to "age" and turn into salt marsh before all of the old salt marsh drowns. When sea level rises faster, it drowns salt marsh faster. The ghost forest might not have time to turn into good salt marsh habitat before all of the existing salt marsh drowns. This is a problem for salt marsh plants and animals that need specific salt marsh conditions! They may lose their habitat without gaining a replacement. Physical barriers are also a challenge to marsh migration. When marsh plants and animals cannot migrate because roads or houses block their path, we call it coastal squeeze. Marshes are drowned on the low elevation side and blocked by development on the high elevation side.

Student handouts/worksheets

- Appendix A: Organism cards
- Appendix B: Student worksheet
- Appendix C: Student worksheet key

Materials and supplies, technology support

- Projector setup for slides
- For optional demonstration of sea-level rise/marsh migration:
    - Plastic tub (e.g., large, clear Tupperware)
    - Clay or playdough
    - Toothpicks
    - Two (2) colors of pipe cleaners (ideally green and brown)
    - Water in a pitcher (or anything to pour out of)
- Two (2) lengths of rope (or a substitute, such as yarn), ~20ft each
- Printed cards for each student (option to laminate or turn into lanyard to avoid damage/loss)

Classroom/lab/field set-up

- <u>Slides and Model Demonstration</u>: This can be done as one large group in the classroom. Students should gather around the model to see how water moves inland when sea level rises. If additional time and supplies are available, students may work in groups to create their own models. This could also be done as a virtual demonstration over Zoom.
- <u>Game</u>: Students will all work together in a relatively large, open space (e.g., outside, gym, empty room). See below for virtual adaptations.

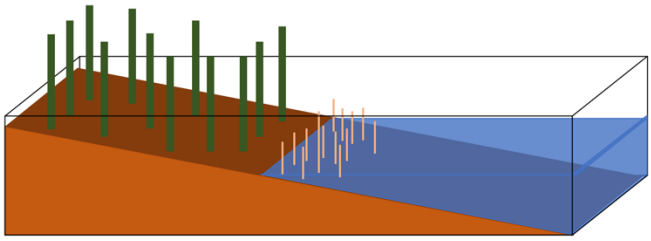
Procedure outline & details

<u>Advance Preparation</u>

Set up marsh migration demonstration in the classroom (optional)

- Mold clay/playdough into slope over bottom of container

- Pour water in so that it covers ~1/2 of clay
- Place toothpicks (marsh grass) below the water's edge and green pipe cleaners (trees) above the water



Example setup for marsh migration demonstration

Prepare for marsh migration game

- Print an organism card for each student. Four students will control the location of the ropes (water and salinity lines). All other students will play the role of a plant or animal.
- Print student worksheets.
- Establish an empty space where students can spread out to the length of your pieces of yarn/rope (ideally outside).

Classroom: PowerPoint and Marsh Migration Demonstration

Before beginning the powerpoint

- Ask students to picture a forest in their mind.
- Ask: Any dead trees in their forests?
    - It's normal for some trees to be dead in the forest.
- Ask: Has anyone ever seen a forest where all of the trees at the edge of the forest were dead? How could this happen?
    - Possible answers: disease, storm, construction/development, etc.
    - Possible that some students have seen ghost forests at marsh edge (common in eastern Virginia)
- Today, we are going to learn about one way that all of the trees at the edge of a forest can die without any visible pest or destruction.

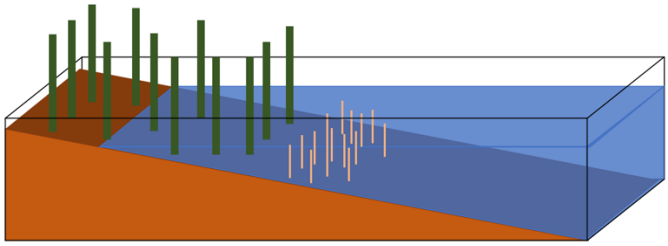
Begin with the accompanying PowerPoint to introduce salt marsh ecosystems, marsh migration, and ghost forest.

- Slide notes contain specific information to share
- Where indicated, pause for optional clay model demonstration (procedure below). Alternatively, facilitate a similar discussion based on the PowerPoint animations.

Optional: demonstrate how marsh migration occurs using the clay model.

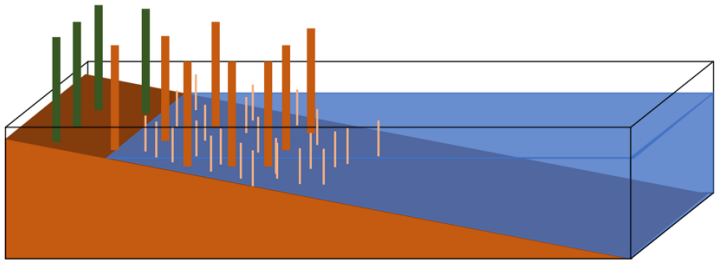
- In the model that you created, the current water level represents the highest high tide (optional opportunity to discuss spring/neap tides), which controls where marsh grasses and trees grow.
- Ask students: why aren't there trees in the salt marsh?
    - Possible answer: most plant species require fresh water. Only certain salt-tolerant plants can grow in the salt marsh.

- Using a permanent marker or piece of colored tape, mark the location of water's edge on the side of the container.
- Slowly add in enough water that some of your "trees" (pipe cleaners) are submerged (the amount of water will vary depending on size of container). This represents sea-level rise.
- Students should observe how the *vertical* increase in water (sea-level rise) caused the salty water to move *horizontally*, into the forest (note difference from prior marked edge)



Marsh migration demo after adding water (sea-level rise)

- Ask students: what changes do they expect because of the change in sea level?
    - Possible answer: trees will likely die but not fall over right away. Marsh grasses will move inland with the water. Some marsh grasses may die in the deeply flooded area (if it doesn't drain at low tide)
- Make adjustments to the model based on their answers: swap out green pipe cleaners for brown to represent standing dead trees. Add marsh grasses (toothpicks) to newly flooded areas.



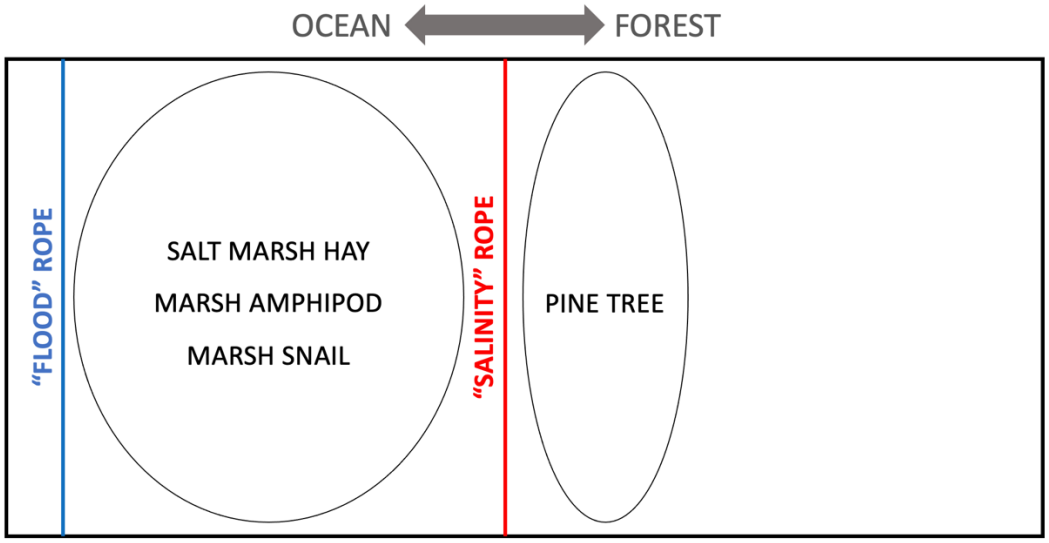
Marsh migration demo after trees "die" and marsh "migrates" inland

- Ask students: identify where the marsh, ghost forest, and forest habitats are located.
    - Answer: ghost forest = where there are dead trees and marsh grass

<u>Marsh Migration Game</u>

- Before going outside, give each student an organism card that assigns them a role. Four students will control the ropes. At least four students should be trees. The remaining students can be divided into salt hay, saltmarsh amphipod, saltmarsh snail, and additional trees.
- Students should break into groups (one group per card type) and create a simple hypothesis for (a) how their assigned species will be affected by sea-level rise and marsh migration (for plant and animal groups) or (b) how they will affect marsh migration (for flood and salinity line groups) based on the information on their card. The hypothesis can be very simple—the goal is to ensure students read and understand the material on their cards.
    - Alternatively, this could be done in pairs.
- One person of each card type should briefly share their hypothesis with the class.

- Emphasize that these are only examples of organisms found in the marsh and ghost forest. There is a lot that is unknown about what types of organisms use these habitats and how communities in the marsh and ghost forest are different.
- Lay ropes on the ground parallel to each other about 30 ft apart. Explain the habitats found on each side of the rope (below the "flood" rope is open water. Above the "salinity" rope is forest (salinity rope = high water line in the clay model). In between the ropes is habitat that is salty but only flooded part of the time (salt marsh). Make sure students understand which direction is toward forest vs. ocean.
- Students spread out in their organisms' designated habitats. Make sure marsh organisms (salt hay, amphipod, and snail) are spread out between the ropes. At least some of the forest trees should stand fairly close to the salinity rope (trees can grow right next to the marsh!) with plenty of room behind them. Trees should stand with their arms up to show they are alive.



Starting setup of different student roles

- Once students are positioned, the game can begin! Remind students with the ropes to be gentle when they are moving and to allow time for students to sit down or duck below the rope if necessary.
- In this game, the flood and salinity lines (ropes) will move slowly inland toward the forest to simulate sea-level rise. Trees that are touched by the salinity line will die and form a ghost forest. Salt marsh organisms that are touched by the flood line will die, BUT the marsh organisms will have the ability to migrate inland behind the salinity line. The amount of time an organism must wait before migrating (meant to simulate the waiting period for a newly formed ghost forest marsh to become suitable for them) is different for each species and is meant to show that some species are able to migrate into the ghost forest sooner than others. Marsh migration will affect different marsh species in different ways.
- General structure of the game:
    - Everyone will count time periods out loud together slowly (1, 2, 3, etc.) to make sure everyone is moving at the same time. You can vary how long to wait between time periods (~5-10 seconds) to make sure students have enough time to move.
    - At each time period, the students holding the flood and salinity lines move forward one step.

    - Any marsh organism (snail, amphipod, or salt hay) that is touched by the flood line and "dies" should duck under the rope, walk around the outside of the game area, and join the back of the forest as a living tree.
    - Any living tree that is touched by the salinity line and "dies" should put their arms down to show that they are now a dead, standing tree. Note: they will have to duck under the salinity rope.
    - After their designated wait period, salt marsh organisms move forward one step at each time period.
    - After several time periods (~10), pause and have students make observations about any changes in habitat (e.g., formation of ghost forest) and the habitat each species is found in (e.g., marsh vs. ghost forest).
    - Ask students: what will eventually happen to the dead trees that currently make up the ghost forest? (Answer: they will fall over)
- Optional 1st Round: No Migration
    - The flood and salinity lines move forward one step per time period, but none of the organisms can move. Salt marsh organisms will all be killed by the flood line.
    - Ask students: Is this realistic? What might their salt marsh organisms do instead? (Answer: move where their habitat is migrating)
- Round 1: Slow Sea-Level Rise
    - Students return to the starting places for their organisms.
    - The flood and salinity lines move one step per time period. The salt marsh organisms also move one step per time period (after their designated waiting time, as specified on each card).
    - Continue for ~10-15 time periods
    - Ask students: which organisms died? Which organisms are in a different habitat than they were at the start of the round?
- Round 2: Fast Sea-Level Rise
    - Flood and salinity lines move **two** steps per time period to represent faster sea-level rise. After their specified waiting period, salt marsh organisms can also move two steps per time period.
    - Ask students: why does the **rate** of sea-level rise matter (i.e., 2 steps vs 1 step)? What happened with fast sea-level rise that did not happen in the previous round? (Possible observations: some species died before they could ever migrate because the flood line was moving faster than the salt marsh was becoming good habitat. More of the forest turned into ghost forest.)
- Optional Round: Coastal Squeeze
    - Repeat the game with "coastal squeeze" represented by replacing the forest with a barrier (e.g., sidewalk or side of building).
    - Ask students: what happens when the marsh is bordered by developed land instead of forest? (Possible answer: When marsh migration is blocked by development, the salt marsh cannot migrate and marsh organisms lose their habitat. We sometimes see marsh plants growing in people's yards where the marsh has tried to migrate inland or see marsh crabs in the street when the marsh is right next to the road. Could also bring up agricultural land next to the marsh that can't grow crops when it becomes too salty.)
    - Ask students: what are some possible solutions to this problem? (Answer: open-ended question, plenty of room for creative responses. In general, it's important to have undeveloped land at the coast to allow for inland marsh migration.)
- Consider:

    - Switching students' roles between rounds
    - Having ghost forest trees "fall over" (sit down) after 5 time periods as a dead tree to show that the ghost forest is turning into salt marsh.
    - Recording the number of each species found in each habitat at the end of each round (teacher can record and put data on the board to guide the student reflection) for students to graph later
    - Recording students' verbal observations between rounds to discuss in the classroom after the activity is over
- Virtual adaptation
    - For a virtual or hybrid class, students could replicate this activity by building their own clay model (as in the first part of the lesson) and acting to raise sea level (by pouring in water) and move different organisms (in the form of different colored beads) following the instructions on the species cards.
    - In lieu of using physical materials, students could manipulate a simple digital model (e.g., different colored shapes arranged to represent the marsh and forest in a pre-made PowerPoint slide) to move the water level and different organisms at each time step according to the species cards.

<u>In-class Discussion</u>

- Back in the classroom, students should reflect on what they acted out through the game. They can share their thoughts out loud or write down for a collected assignment.
    - Ask a student to comment on their own organism's experience with sea-level rise—were they successful at migrating into the new marsh? Why or why not?
    - Ask a student who played a different organism to compare their experience—was it the same for all plants and animals?
    - Ask students to support their answers with the background information given in the PowerPoint and model demonstration.
- If verbal observations were recorded between rounds of the game, they could be written on the board to help students in answering their questions.
- Worksheet could be completed independently or with a partner/group (or Zoom breakout room), either in class or as a homework assignment.

Assessment

Students will be assessed by their participation in the game and follow-up discussion and by completing the worksheet. For virtual adaptation, students can post a reflection on FlipGrid or a similar platform.

References

<u>Scientific journal article that discusses the formation of ghost forests</u>:
Kirwan, M.L., & Gedan, K.B. (2019). Sea-level driven land conversion and the formation of ghost forests. *Nature Climate Change, 9*: 450-457.

<u>General information on sea level rise</u>:

NASA, Global Climate Change: Vital Signs of the Planet. “Sea Level.” https://climate.nasa.gov/vital-signs/sea-level/

Short video showing aerial footage of ghost forests and scientists conducting fieldwork:

Newsy. “Ghost Forest: Dying trees show climate change’s advance.” https://www.youtube.com/watch?v=kQozp2xZ3Q0

Virtual tours of a ghost forest and an art gallery featuring ghost forest artwork:

University of Virginia Coastal Research Center. “Ghosts of the Coast: A Virtual Art Experience.” https://www.coastaleducation.virginia.edu/wp/?page_id=1389

Appendix A: Organism Cards (separate document)

Appendix B: Worksheet

1. How do you think the saltmarsh snail and the saltmarsh amphipod will respond to sea-level rise and marsh migration?

_____

_____

_____

2. In the game, how did the speed of sea-level rise affect marsh organisms?

_____

_____

_____

3. You're walking in the forest near a salt marsh and see a saltmarsh amphipod (*Orchestia grillus*) on the ground! Explain why the amphipod would be in the forest.

_____

_____

4. You come back to the same forest (from #3) 10 years after you saw the amphipod. Draw what the forest looks like now.

Appendix C: Worksheet Answer Key

1. How do you think the saltmarsh snail and the saltmarsh amphipod will respond to sea-level rise and marsh migration?

The saltmarsh snail (*Melampus bidentatus*) requires specific salt marsh conditions, will likely not migrate into the ghost forest, and may lose much of its habitat because of sea-level rise. The saltmarsh amphipod (*Orchestia grillus*) is more of a generalist and will migrate into the ghost forest before it has the exact same characteristic as the salt marsh. As long as the salt marsh has room to migrate inland, the amphipod will probably have habitat.

2. In the game, how did the speed of sea-level rise affect marsh organisms?

When sea-level rise was faster, more ghost forest was created at the same time that marsh habitat was lost. Organisms that needed older marsh (i.e., the saltmarsh snail *Melampus bidentatus*) were probably killed more quickly by the flooding line because there wasn't time for the ghost forest to develop the characteristics they needed before sea-level rise flooded all of their current marsh habitat.

3. You're walking in the forest near a salt marsh and see a saltmarsh amphipod (*Orchestia grillus*) on the ground! Explain why the amphipod would be in the forest.

Because amphipods are generalists and can live in a variety of habitats, they are one of the first animal indicators of marsh migration. Seeing an amphipod in the forest indicates that the forest soil must be wet and a little bit salty, suggesting that it has been flooded by the tides or a major storm.

4. You come back to the same forest 5 years after you saw the amphipod. Draw what the forest looks like now.

This will of course be different for each student, but they should draw something resembling a ghost forest (i.e., dead trees and marsh grasses). The amphipod indicated that the marsh was beginning to migrate inland.

Saltmarsh snail

Melampus bidentatus

Habitat: salt marsh

Requirements: needs higher moisture, salinity, and the food found in the salt marsh. Dies in permanently flooded marsh.

Game instructions: Start in salt marsh. Wait **5** time periods before migrating toward the ghost forest.

Saltmarsh amphipod

Orchestia grillus

Habitat: salt marsh, ghost forest

Requirements: can live anywhere with some salinity (generalist). Dies in permanently flooded marsh.

Game instructions: Start in salt marsh. Migrate toward the ghost forest as soon as salinity line moves.

Salt hay

Spartina patens

Habitat: salt marsh, ghost forest

Requirements: Can migrate as soon as salinity kills other plants that grow in the ghost forest. Dies in permanently flooded marsh.

Game instructions: Start in salt marsh. Wait **1** time period before migrating toward the ghost forest

Pine tree

Pinus taeda

Habitat: forest (live), ghost forest (dead)

Requirements: Cannot survive in salty soil. Dies after salt exposure.

Game instructions: Start in the forest with arms raised. When touched by salinity line, lower arms to become a dead tree in the ghost forest.

Salinity Line

- The salinity line is the border of salt marsh and forest habitats.
- With sea-level rise, the salinity line will move slowly toward the forest.
- When salinity touches trees, they will die and form ghost forest.

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- When salinity touches the trees, they will die and form ghost forest.

Flood Line

- The flood line is the border between open water and intertidal salt marsh.
- With sea-level rise, the flood line will move slowly into the marsh, causing it to drown.
- When the flood line touches marsh organisms, they will die.

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