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KEEPING UP WITH SEA-LEVEL RISE: SALT MARSH ACCRETION

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Grade Level
High School

Subject area
Earth Science

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1. Keeping Up with Sea-Level Rise: Salt Marsh Accretion

2. **Focus:** Coastal Resilience: Natural Responses of Salt Marshes to Sea-Level Rise

3. **Grade Levels/Subject:** High School Earth Science

4. VA Science Standards addressed:
ES.7 The student will investigate and understand geologic processes including plate tectonics. Key concepts include

a) **geologic processes and their resulting features;** and
b) tectonic processes

ES.10 The student will investigate and understand that oceans are complex, interactive physical, chemical, and biological systems and are subject to long- and short-term variations. Key concepts include

a) **physical and chemical changes related to tides, waves, currents, sea level and ice cap variations, upwelling, and salinity variations;**
b) **importance of environmental and geologic implications;**
c) systems interactions;
d) features of the sea floor as reflections of tectonic processes; and
e) economic and public policy issues concerning the oceans and the coastal zone including the Chesapeake Bay.

5. Learning objective/outcomes:
a) Students will compare accretion capability of salt marshes with different grass abundance
b) Students will predict the effect different animal types will have on accretion capability
c) Students will predict accretion capability of salt marshes with different sediment availability

6. **Total length of time:** 1 hr 30 minutes

7. Key words, vocabulary:
a) <u>Accretion</u> – vertical build-up
b) <u>Facilitation</u> – interaction between organisms where one is affected positively, and one neutrally
c) <u>Coastal squeeze</u> – when rising sea levels push coastal habitats landward, but areas landward have physical barriers preventing migration
d) <u>Herbivory</u> – eating of plants
e) <u>Sediment deposition</u> – settling of sediment particles suspended in the water onto a surface (i.e. the marsh surface)

8. Background Information:

Accelerated sea-level rise poses a threat to coastal ecosystems. Salt marshes, a coastal ecosystem, are one of the most productive in the world and provide many ecosystem services such as food production, carbon storage, storm protection, and nursery habitat for commercially important fish species (Barbier et al. 2011). However, salt marshes can persist in the face of sea- level rise through landward migration and vertical accretion. Landward migration is the lateral movement of salt marsh plants into upland habitats (Kirwan et al. 2016). However, when sea walls, steep upland slopes, or other barriers to marsh migration are present, coastal squeezes occur. A coastal squeeze is when a natural migration of a coastal habitat is prevented by physical barriers (Pontee 2013).

Vertical accretion allows salt marshes to move up vertically as sea-level rises. This process relies on the contribution of belowground organic matter and sediment deposition on the marsh surface (Fagherazzi et al. 2013). Sediment deposition can occur through the physical trapping of sediments by salt marsh plants, and by plants slowing flow velocities so that sediment particles can settle out of the water column. Changes in marsh plant abundance and biomass can affect sediment deposition, and ultimately vertical accretion (Fagherazzi et al.
2013). For example, when there are more stems, more sediment is trapped, and the marsh accretes more, but when there are less stems, less sediment is trapped, and the marsh accretes less. Sediment deposition also relies on the amount of sediment availability. When there is more sediment in the water column, there is more sediment to be deposited on the marsh surface, and aid in vertical accretion. However, when sediment supply is limited, accretion is slowed or inhibited.

Animals can affect plant abundance through ecological interactions, such as herbivory and facilitation. Herbivory in marshes is performed by the purple marsh crab (*Sesarma reticulatum*). This crab feeds on marsh roots and stems, reducing its abundance. Because this crab reduces marsh plant abundance, it can also reduce sediment deposition, and ultimately inhibit accretion. Other animals, like the marsh fiddler crab (*Uca pugnax*) can promote the growth of marsh plants through facilitation. Facilitation occurs when two animals interact, and one is affected positively, and the other neutrally. Because this crab can increase marsh plant abundance, it can indirectly increase sediment deposition, and ultimately promote marsh accretion.

9. Student handouts and other materials:

Figures that can be used in the background slides are included in the figures section of this lesson. These figures include two pictures of salt marshes and two picture of specific crabs discussed in the lesson.

Handout 1 can be distributed to students as a supplementary material. This handout briefly summarizes the concepts explored throughout the lesson. A PDF version can be downloaded here: https://bethanylwilliams.files.wordpress.com/2017/01/salt-marsh- infographic_williamsb1.pdf

Additionally, a musical parody for the concepts presented during this lesson plan can be used as introduction to the lesson, as the teacher sees fit. This parody (created by lesson author) is available on youtube at: https://www.youtube.com/watch?v=8OCwgC6sb4A

10. Materials and Supplies

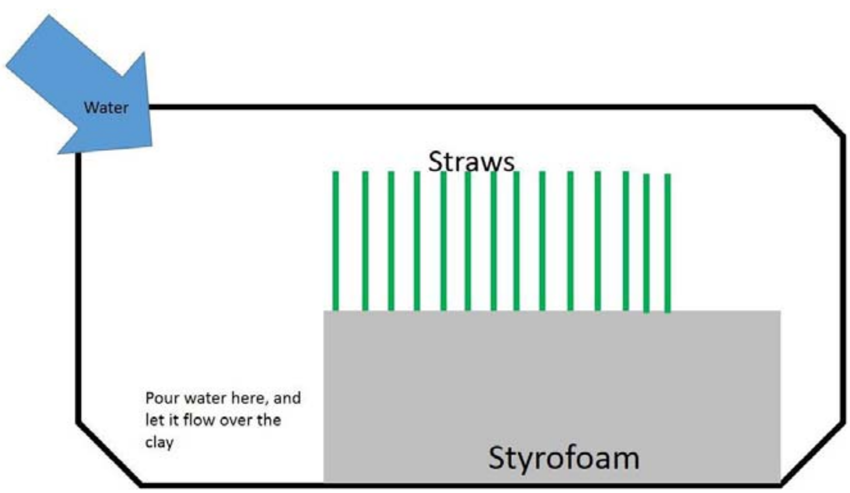
- plastic bins – 4 (1 for each group)
- straws (green, if possible)
- water
- dirt
- large clay blocks (size of plastic bins) – 4
- Toy crabs (something like this: http://www.carnivalsource.com/store/p/243635-Mini-Crabs-Dozen.html?feed=Froogle&gclid=CND628_5s8wCFQZZhgodCJMCTA)
- 25 mm glass fiber filters (4 for each group)
- Weighing scale (fine scale preferred)

11. Classroom Set Up

Slides should be up in the background during the presentation to orient students to understanding the physical attributes of salt marshes and to show pictures that enhance their understanding.

For the lab portion of the lesson, students should be separated into four groups.

Mock Marshes:
Set up of plastic bins (representing marshes) should be done prior to lesson. Each bin will have a rectangle piece of thick Styrofoam (representing the marsh surface). In each of the bins, stick straws (representing marsh grass) into the Styrofoam. In one of the four bins, place less straws (grass) than there is in the other bins. The below diagram would be an example of the bins with more grass. Significantly less straws (1/2 or less) should be used in the bin with less grass. Use the following diagram for bin setup:



Water with sediment:
Create four separate water sources, one for each "marsh." There must be enough water to cover the clay ("marsh surface"). Mix dirt in with the water so that you can see the particles in the water. In one of the water sources, put less dirt than there is in the other three. These will be used to show the effects of sediment availability on accretion.

25 mm glass fiber filters:
Filters should be pre-weighed using a scale (using a fine scale with 4 decimal points is best). Filters can be labeled with sharpie or similar, to determine which weight goes with each filter.

12. Procedure
Advance Prep of lab materials – 15 min
Lab set up – 30 min
Introduction – 10 min
Activity – 45 min
Discussion – 15 min
Assessment – 10 min
Breakdown and clean-up – 10 minutes

Engagement:
Introduce students to the topic by first asking if they've ever seen a salt marsh. After listening to answers from students, show picture of salt marsh (Figure 1). Then ask students why this ecosystem may be important (looking for answers like storm protection, habitat for animals, etc.). Once enough students have come up with solid reasons, ask class how they think sea-level rise will affect these habitats. Look for answers that mention salt marshes may be lost, or drown, etc. with sea-level rise. Then say that while that is the case, salt marshes have ways to keep pace with sea-level rise, and that's what we will demonstrate today.

Exploration (part 1):
Students should be split into four groups for this portion (if more than 4 students per group, create more groups, each with their own bin setup). Each group will receive one mock marsh (bin/clay/straw setup). Have the students place 2 filters amidst the straws (grass) on top of the clay. Each group will also be given a water source. Students will slowly pour the water into the bin, until the water is up over the clay (marsh surface). While students are doing this, orient them to what the straws, clay, and water represent (marsh plants, marsh surface, and tides, respectively).

After all the students have pour their water into the bins, let the water sit for a few minutes (so the dirt can settle out onto the clay and filter). While waiting for the dirt to settle out, have the students count the "stems" in their individual bins, to quantify stem density. After dirt has settled out, scoop the water out from the end the clay isn't covering, so that there is no standing water on the clay. Some of the dirt should be left on the clay, filter, and straws.

Have the students weigh the filters, and compare values between the bins with lower "sediment" in the water. Have the students compare their stem density values to the weight of the filter + the sediment deposited on it. They should have heavier filters in the bins with higher stem density.

Explanation:
Now, discuss with the students why there is dirt on the clay, straws, and filter. Look for answers like, particles settled out of the water and that the dirt just stuck to the straws. Then introduce the concept of vertical accretion as a way that salt marshes keep pace with sea-level rise. Discuss how the buildup of dirt on the surface allows the marsh to move up vertically, with sea-level rise. Ask students why less dirt was left on the filters in bins with only a few straws. Look for answers that determine the observed result was driven by the lack of straws (grass). Explain that the amount of grass can control how much sediment is deposited, and how much the marsh can accrete.

Elaboration:
Now that the students know the amount of grass is important, introduce them to ecological interactions. Show a picture of the purple marsh crab, *S. reticulatum* (Figure 2), and label it as an herbivore. Ask the class to tell you what an herbivore is. Look for answers that discuss their eating habits on plants.

Now show them a picture of the fiddler crab, *U. pugnax* (Figure 2), and label it as a facilitator. Ask the students to try to define a facilitator. A facilitator is an organism that has a positive effect on another organism, but itself is not affected positively or negatively.

Exploration (part 2):
Then, distribute the toy crabs to the students, two groups receiving a fiddler crab and two groups receiving a purple marsh crab (or something representative). Have them put the crabs in their marsh, and tell them to change the grass abundance based on what they know about their crab.
Groups with the fiddler crab should add more straws to the bin, while groups with the purple marsh crab should remove straws from their bin. Give the students new filters to place on the clay. Repeat the water-dirt settling process. Weigh the new filters again, and have the students compare these weights across the ecological interaction they simulated (herbivory or facilitation).

Elaboration:
Now discuss the role of sediment deposition in marsh accretion, and relate this to the greater context of sea-level rise. Ask the students question about why this process is important when we're thinking about sea-level rise. Look for answers like, the marsh needs to keep pace and build up, or that marshes are important and provide services. Ask the students what will happen to the marsh is they can't keep pace with sea-level rise.

Evaluation:
To evaluate the students understanding of the concepts, a short quiz will be administered.

Quiz questions and answers:

1. What are two ways salt marshes can respond to sea-level rise?

   Vertical accretion and landward migration

2. How do plants affect accretion?

   Plants trap sediment particles out of the water column. Plants slow the water down as it comes into the marsh so particles can settle out onto the marsh.

3. How will the herbivorous snail (pictured below) affect marsh accretion and why?

   This snail will decrease marsh plant abundance, so accretion would be slower because less sediment would be deposited on the marsh surface.

4. How does the presence of fiddler crabs contribute to sediment deposition and accretion?

   The fiddler crab will increase marsh plant abundance, so accretion will be faster, because more sediment would be deposited on the marsh surface.

5. What is the role of accretion when we consider sea-level rise?

   Accretion helps the marsh keep pace with sea-level rise. Sea-level rise threatens to drown these systems, but accretion can help them move up with the sea.

13. Assessment

Assessment of student understanding of concepts will be determined through the administered quiz.

14. References:

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