**The Effect of Sea Level Rise on Salt Marshes**

Student Activity Sheet

Name ____________________________________ Date_______________Class_____________

The global climate is changing at a rate never seen before in the Earth's history. Climate change has caused ***global warming.*** Global warming means that the atmosphere gets warmer, but so does the ocean. Global warming affects the volume of the oceans and the height of the sea because of ***thermal expansion*** and the melting of ***land-based ice***. Scientists predict that the oceans will rise 1 meter by the year 2100 because of global warming. A rise of 1 meter will 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 of the world's largest cities will be under water. Scientists also estimate that approximately two-thirds of the coastal ***wetlands*** in the United States will be lost if the sea level rises 1 meter.

Climate changes can also cause fluctuations in the temperature and the amount of precipitation falling. These changes along with rising sea level will threaten the survival of all wetlands. Wetlands are important because they stabilize the global environment. Wetlands have a rich food supply that supports many species. In this way wetlands add greatly to global biodiversity. Wetlands provide such a safe place for the young animals that they are called the nurseries of the sea. The thick plant growth in wetlands traps sediments, filters out pollutants, and controls flooding. The plants in wetlands that grow above the surface of the water take up carbon dioxide ($CO_2$) from the air and release oxygen back into it. These large areas of vegetation are an important part of the ***carbon cycle*** because they act as large ***carbon sinks***. When wetlands are destroyed and the plants are not there to remove the carbon (or $CO_2$) from the atmosphere, the amount of $CO_2$ in the atmosphere will increase. Since higher levels of $CO_2$ lead to global warming, the problem of rising sea level will only worsen.

Loss of wetlands, due to sea level rise, will be most severe in areas with small ***gradients.*** This means that the elevation of the coastal land doesn't change very much. Coastlines with a gradient of 20 to 1, for example, will lose 20 meters (65.6 feet) of land or wetland for every 1 meter that the sea level rises. ***Salt marshes*** will be especially affected because of their gentle gradient. Salt marshes, depending on their location, may be drastically changed or even drowned by an increase (rise) in the global sea level. Salt marshes are wetland ***ecosystems*** found along an open coastline or within an ***estuary***. The mass of plants and animals (biomass) that is produced naturally on an acre of salt marsh is greater than what is produced on fertilized farmland.

Organisms need specific conditions to thrive or survive. Scientists predict these conditions will be altered as the climate changes. In a salt marsh, there is a delicate balance between ***salinity***, ***dissolved oxygen, turbidity***, ***bottom composition***, and temperature. A change in any of these factors may affect the health and survival of the marshes themselves but may also lead to the death, ***migration***, or ill health of the organisms living in the marshes.

Not only the people living on the coasts will be affected if salt marshes die or are destroyed. Because a large number of fish species and shellfish depend on salt marshes for food and shelter during some part of their life, all consumers of these products will be affected. From one-half to two-thirds of the food fish harvested from the Atlantic and Pacific Oceans spent part of their lives in salt marshes or estuaries. To protect our salt marshes and other wetlands, we must first recognize their importance and then understand how what we do will affect these areas.

In this activity you will build a model of a salt marsh and the land surrounding it out of clay. You will use this model to see what happens to salt marshes when the sea level rises and how the slope of the land and the location affect the marshes survival.

**Objectives:**

- Observe the effects on salt marshes from global climate change and sea level rise.
- Use a clay model to simulate a salt marsh.
- Discover that the shape and the gradient of a salt marsh determines how the marsh will be affected by rising sea level.

**Materials:**

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| Shoe box with sea level lines | Metric ruler (Student or teacher supplied) |
| Toothpicks | Colored pencils (Student or teacher supplied) |
| Salt marsh card | Colored clay |
| Plastic spoon (to shape clay) | Water and container to transport water |
| Graph paper | Paper towels (Teacher supplied) |

**Procedures:**

1. Divide into teams or groups and look over the salt marsh card that you have been given. The card shows the ***elevation*** of the salt marsh and surrounding areas. Take time to understand the card and what it represents. Gather all the other supplies you will need.
2. Your teacher will demonstrate how you will use the elevation map of your salt marsh to make a plot map. A plot map is what the area would look like if you were looking at it from above, say from an airplane. The plot map together with the elevation map will help you build an accurate clay model. Your teacher has examples of what the plot map should look like for your area. Once the demonstration is finished, make your own plot map of the different areas shown on your team's card. Use colored pencils to color each of the different areas (example: green for upland) in your map. Your teacher will tell you what shades to color in the different areas. When you build your salt marsh model, you will use the color clay that corresponds with the color you shade the various areas.
3. Get the colors of clay that match the colors you used for the plot map. Place the plot map under the shoe box (you should be able to see the map through the bottom of the box).
4. Start to place colored clay in the bottom of the tub to match colors on the map. Use the plastic spoon or your fingers to help shape the clay. Higher elevations must have more clay placed in the box area so that the model and elevation map match in height. Water regions should be left empty. The uplands area's should have clay built well above the black line. The black line represents current global sea-level. You will fill the water bodies with water to the black line, so make sure the salt marshes are only a small bit above this line and that the ponds, rivers, estuary, and ocean are below the line. Remember that salt marshes are pretty well covered by water at high tide, but exposed at low tide. Use the other graduated lines above sea level to make the elevations of your model match those on your map. Use a ruler instead of the lines on the box if it is easier. When you are finished, remove the map from beneath the shoebox.
5. Add water to the areas that should contain water (such as the salt pond, estuary, or river). Make sure that the water level reaches the black line.
6. Discuss with your team members what will happen when water is added to the first red line (at 0.5 cm). What do you think will be the highest point on land that the water will reach? Use a toothpick to draw a fine line from left to right across the clay wherever you think this high point will be. This line will represent where you think the new shoreline or waterline will be.
7. Look at your plot map and elevation map. Try to find the corresponding place on these maps to match where you marked the clay in the box. Make a mark on the plot map and elevation

map and put P1 next to the marks. These marks are your predictions for the first water level rise.

8. Add enough water to bring the water level up to the 0.5 cm line (first red line). This is the actual sea level rise.
9. Record the actual sea level rise on your plot map and elevation map using marks as you did for your predictions. Place the letters SLR1 (sea level rise 1) next to these marks. Your teacher will have an example of this if you are confused.
10. Look at the marks you made for P1 (prediction) and SLR1 (actual sea level rise 1) on your maps. Are the prediction marks close to the actual sea level, or were they too low or too high? Discuss this with your team members.
11. Repeat steps 6 through 10 for the 1 cm (second red line) sea level rise. Record the 1 cm sea level prediction as P2 and the 1 cm actual sea level rise as SLR2.
12. You will repeat steps 6 through 10 for sea levels 1.5 and 2 cm. Make your predictions on your model and maps for each of these sea levels. Continue recording your predictions and the actual sea level rise (P3, SLR3, P4, and SLR4).
13. When you have finished, look at all the other team's models to see how their marshes compared to yours. Remove the water and pat the clay model dry using a paper towel.
14. Answer the discussion questions.

**Discussion Questions:**

1. How did your predictions compare with what you observed after the water was added?

2. Since different students had different salt marsh cards, some of you lost more or less salt marsh as the water level rose. Which models lost the most area? Which models lost the least? In which model will the marsh most likely "drown?" Why will it drown?

3. What will happen to coastal communities when the global sea level rises 1 m (as is predicted for the year 2100)?

4. Can global sea-level rise be prevented?

## Vocabulary

**Global warming:** Global climate and environmental changes cause the temperature of the atmosphere and water around the Earth to increase.

**Thermal Expansion:** As ocean water heats up, it becomes less dense and takes up more space. This causes the volume to increase so that the level of the water will increase or rise.

**Land-based ice:** Large areas of ice on the continents, such as the polar ice caps of the Arctic and Antarctica as well as the ice sheet covering Greenland. This also includes mountain glaciers.

**Coastline:** The area where the land and an ocean or lake meet.

**Wetlands:** An area of land that has wet spongy soil and whose water table is at or above the soil surface for part of the year. These swampy, bogy, or marshy areas can contain fresh or salt water. These areas are very rich in life and are often called nurseries because so many animal species spend time in wetlands when they are young. Wetlands are very important, not only because they provide a safe area for young animals to develop, but also because they filter out many water pollutants and sediments and clean the water.

**Carbon cycle:** One of the major cycles of chemical elements on Earth. In this cycle, the element carbon is taken out of the atmosphere by plants in the form of carbon dioxide. The carbon then passes through animals that have eaten the plants. Through decomposition and respiration of both plants and animals, carbon dioxide is returned to the atmosphere.

**Carbon sink:** A substance capable of absorbing large quantities of $CO_2$. In the carbon cycle there are carbon sinks and carbon sources. Examples of a carbon sink are the oceans, rain forests and salt marshes.

**Gradient:** The slope of a land area or how the height of the land changes with distance. Gradients are often given in ratios, which represent the amount of distance and how much height change is associated with that distance. For example, a gradient of 20:1 (20 to 1) would mean that for every 20 feet or meters of land you travel, the elevation or height or the land would change by 1 foot or meter.

**Salt marsh:** A low-lying marsh near an ocean or an estuary that is bathed by tidal saltwater every day. A marsh differs from a swamp because of the type of plants growing in each. Emergent or grass-like plants grow in a marsh but trees and shrubs grow in a swamp.

**Ecosystem:** All the living organisms (plants, animals, fungi, and bacteria) in a particular area as well as the physical environment surrounding that area. Ecosystems can be very large, like the Earth, or very small, like your backyard.

**Estuary:** A partially enclosed body of water along the coast that is open to the ocean wherein fresh and salt water mix. Fresh water usually enters the estuary from a river or runoff. Estuaries are very rich in plant and animal species and provide shelter and breeding grounds for many species.

**Salinity:** The salt content of water or how salty water is. Seawater is generally 3.5% salt and 96.5% fresh water. Salinity is usually measured with a hydrometer, by titration (a chemical procedure) or with an instrument called a salinometer.

**Dissolved oxygen:** The amount of oxygen dissolved in fresh or salt water. This oxygen is necessary to most living organisms in oceans, ponds, lakes, and streams. Fish, for instance, take in the dissolved oxygen in water through their gills. The amount of dissolved oxygen indicates how much biological life there should be in that body of water.

**Turbidity:** The cloudiness of water, caused by small or large solid particles suspended in it. The particles prevent light from penetrating very far into turbid water. Plants need light to grow, so few plants will grow in very turbid water.

**Bottom composition:** The sediments that make up the bottom of a body of water. This includes rocks, sand, mud, or clay.

**Migration:** The movement of an organism from one area to another, usually to mate or to feed.

**Elevation:** The height an area of land above sea level.

## Teacher Strategy

**Prior Preparation:**

Since large quantities of clay are required for this activity, school art departments should supply standard clay, that you will mix with the colored clay in this kit. Make sure you a different color of clay prepared for each of the different types of land areas. For instance, the upland areas may be yellow, the salt marshes green, etc. It makes the activity more fun if you add food coloring to the water that will be added to the shoebox models.

**Instructional Hints and Strategies:**

There is a great deal of material given in the background or introductory material. Make sure your students have some familiarity with salt marshes and the concepts of global climate change and global sea level rise before engaging in this activity. Several figures have been included which you may wish to use in a preactivity discussion about salt marshes. Two of these figures show the location of salt marshes around the U.S. as well as the cities along the coast of the U.S. that will be impacted by sea level rise. These figures are particularly pertinent to the background information and have not been included there as you may wish to make overheads of these figures. Photocopies of several salt marshes have also been included as some of your students may not know what a salt marsh looks like. Students should understand the difference between relative sea level rise (due to factors such as changing tides, glacial rebound, and subsidence) and global sea level rise (due to thermal expansion and land-based ice melt, i.e., global climate change). This activity is concerned only with global sea level rise. This activity can begin with a discussion of the location of salt marshes and their varying gradients. All students should be presented with the five salt marsh cross sections. Discuss with your class what the effects of rising global sea level will be on each of the five salt marshes. Go over the vocabulary list to make sure all your students understand the concepts and terms in this activity.

Each team will be given a plastic shoebox in which they will build their salt marsh model. The plastic shoe boxes have been marked with a black line 1 cm from the bottom. Above this line, red lines are 0.5, 1, 1.5, and 2 cm above the black line. The black line represents current sea level and the red lines represent subsequent sea level rises.

Divide your students into 5 teams; one team for each of the five salt marsh cards. Copies of the elevation and plot maps for each of the five salt marshes have been included for your benefit. Each team will make their own plot map of the salt marsh they were assigned. It is a good idea to have them copy the elevation map on the bottom of a sheet of graph paper with the plot map on top, according to the sample maps. Remind your students that the plot map is an aerial view of the elevation map. You may want to show them an example to get them started. Decide whether to have each team make just one plot and elevation map for the whole team to use, or have each student make their own map. Your students should color in the respective areas on their maps. Remind them what type of land area each of the clay colors represents so they can color their maps accordingly. Alternatively, you may decide that making the plot maps is too difficult for your students or too time consuming. If this is the case, you can photocopy the maps provided for your use and just have the students color the land areas the appropriate colors.

The students should use the lines on the shoebox to depict accurate elevations when building their models. Sculpting tools may speed the model building process. Check all the models to make sure the teams are building them accurately and to scale. You should demonstrate how prediction and actual water marks are to be made using a toothpick. Marks must not go deeply into the clay. One of the sample plot and elevation maps prepared for your use has prediction and actual sea level marks indicated. You may wish to use this to show your students how to add the marks to their maps.

**Answers to Discussion Questions:**

1. This will depend upon the predictions the teams made.
2. The models that should lose the most salt marsh are Models 3 and 4 and possibly 5. Models 1 and 2 should lose the least marsh land and the salt marsh will most likely drown in Model 4. The Model 3 marsh will likely drown because it is on an estuary and not protected by mud flats or a salt pond. The marsh in Model 3 is probably further up at the top of the estuary and will not be affected as soon as the marsh in Model 4.
3. Most coastal communities will be partially or totally destroyed by the advancing water unless they can build protective levies or dikes as they have in New Orleans, LA and in the Netherlands.
4. There are many things we can do to slow or stop the predicted sea level rise due to global warming. We can stop burning so many fossil fuels which produce more $CO_2$ and we must stop destroying rain forests and salt marshes that take up $CO_2$ from the atmosphere. If we develop alternative energy sources we can lessen our dependence on fossil fuels.

**Approximate Time Required:** Two, possibly three, class periods.

**Target Audience:** Science.

**Extensions:**

**Grades 4-6**

1. Take a trip to a salt marsh. Have them bring a notepad and pen with them and record what they see at the marsh. Encourage students to be very observant. They should listen for different sounds, be aware of different smells, and notice what plants and animals live there. While at the marsh, ask your students how a rise in global sea level would affect this salt marsh? Students should realize that a rise in sea level could drastically alter or drown salt marshes, depending on their location (review background information). You may want to have a salt marsh worksheet already formatted for students to help keep them focused on why they are there.
2. Have your students create a poster or mural depicting a salt marsh. They can draw the plants and animals that live in the salt marsh. They can research which organisms only spend part of their life in the marsh and which spends their entire life there. Your students can make another poster or mural showing what it would be like if the sea level rose due to global climate change.

**Grades 9-12**

1. Have each team calculate the area depicted on their plot map. The students can calculate the area of land mass exposed (in $cm^2$) when the sea level is: current (normal), and 0.5 cm, 1 cm, 1.5 cm, and 2 cm above normal. Students should then calculate the land mass lost (in $cm^2$) by sea level rise by subtracting the land masses at the various heights from the original land mass at sea level. They should then convert this land mass loss to percentage of total mass. Have the students share their data with other groups. The students can then answer the following questions:
   a. In what model was the original land mass ($cm^2$ and %) the greatest? The least?
   b. Which salt marsh type will experience the greatest land mass loss if sea level rise continues? Will some salt marshes be drowned? Will some be protected?
   c. What are the implications of sea level rise for coastal communities?
2. Investigate a Rhode Island salt marsh community. Using this salt marsh, try to create a model with the actual salt marsh features and predict the effects of a 1 m sea level rise on that community.
3. List all the organisms found in a salt marsh community. Organisms should be grouped by the region of the salt marsh they inhabit. Which habitat what organisms would be affected first

by sea level rise? If these organisms die, what will be the effects be on other salt marsh inhabitants? Could the affected organisms adapt or migrate? Explain.