PROTECTING OUR BEACHES: THE SEAGRASS SOLUTION

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Grade Level
High School

Subject Area
Environmental Science

The Virginia Scientists & Educators Alliance (VA SEA) is a project of William & Mary's Batten School & VIMS Office of Outreach and Engagement. The VA SEA project is made possible through funding from VIMS, Virginia Sea Grant, the National Science Foundation, and the MacWhorter Family.

Title: Protecting Our Beaches: The Seagrass Solution

Focus: Students will relate the thermal resilience of coastal habitats with the ability to hold soil in place, preventing nearby habitat loss. To do so, students will simulate waves over seagrass habitats at varying levels of percent cover and density, then graph the resulting soil movement.

Grade Level: Environmental Science

Virginia Standards of Learning:

Science and Engineering Practices, ENV.1: The student will demonstrate an understanding of scientific and engineering practices by

a) asking questions and defining problems
   - ask questions that arise from careful observation of phenomena, examination of a model or theory, or unexpected results, and/or to seek additional information
   - determine which questions can be investigated within the scope of the school laboratory or field experience
   - generate hypotheses based on research and scientific principles
   - make hypotheses that specify what happens to a dependent variable when an independent variable is manipulated

b) interpreting, analyzing, and evaluating data
   - construct and interpret data tables showing independent and dependent variables, repeated trials, and means

c) constructing and critiquing conclusions and explanations
   - make quantitative and/or qualitative claims based on data
   - apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena or design solutions
   - construct arguments or counterarguments based on data and evidence

The Physical World, ENV.4: The student will investigate and understand that major ongoings processes and systems leads to the formation and change of Earth's surface. Key content includes

- water, living things, and rock processes impact the shape of landforms;
- both natural and manmade events may alter the Earth's land surface

The Living World, ENV.5: The student will investigate and understand that the Earth is one interconnected system through which energy and matter flow. Key content includes

- Earth's terrestrial and aquatic biomes have distinct characteristics and components;
- an ecosystem is composed of both biotic and abiotic factors

Humans Impacts, Global Climate Change, and Civic Responsibility, ENV. 11: The student will investigate and understand that global climate change is occurring. Key content includes

- scientific evidence such as changes in average global temperature, greenhouse gases, quantities of arctic and land ice, ocean temperature, ocean acidification, and sea level rise are indicators of climate change;
- there exists a relationship between global climate change and the frequency and magnitude of extreme weather events;
- consequences of climate change will affect the biosphere on many levels including species migration and extinction, disease spread, and ecosystem health (e.g. bleaching corals and dying forests).

Learning Objectives:

Students will be able to...

- … relate declining seagrass heat tolerance with decreased ability to provide shoreline protection.
- … be able to describe seagrasses and the role they play within the Chesapeake Bay regarding shoreline protection.
- … develop a hypothesis about how global climate change will affect other heat-sensitive habitats and some potential consequences for loss.

Total length of time required for the lesson:

First-time material preparation: 1-3 hours, after which materials are reusable

Lab preparation: 5-10 minutes before classes begin

Activity time: 30-40 minutes

Vocabulary:

Cosmopolitan: a species that is present worldwide, often due to its highly adaptive nature to a variety of environmental conditions

Ecosystem: a community of organisms and habitats that interact with each other and the environmental conditions in which they live

Ecosystem services: the direct or indirect benefits humans gain from an ecosystem's natural resources and functions

Erosion: the loss or removal of soil and rock from one location through natural means (ex., water, wind) which are then transported to another location

Habitat: where an organism lives – the scale of a habitat can range in size from the individual (ex., a single dead log) to the group (ex., a forest)

Resilience: the ability of an ecosystem to maintain its structure and function during and after disturbances such as storms, fires, or heatwaves

Thermal resilience: the ability of an organism to withstand temperatures higher than those typical to the local environment

Background Information:

Seagrasses are flowering marine plants and form interwoven habitats along the intertidal to subtidal regions of 191 countries. The lush meadows contribute many direct and indirect benefits to humans, called ecosystem services. These benefits range from acting as habitat and food for many marine animals – including threatened species such as turtles and manatees – to providing ample fishing opportunities for humans, even to filtering many known pollutants out of our waterways. Unfortunately, seagrasses face a growing threat, putting our shorelines at increased risk.

Worldwide, many species of seagrasses are declining due to the rise in water temperatures caused by global climate change, including here in Virginia. Within the Chesapeake Bay, two species are present: the eelgrass *Zostera marina* and the widgeon grass *Ruppia maritima*. Where eelgrass exists in the Atlantic from the Arctic Circle to North Carolina, widgeon grass is cosmopolitan, growing along the shorelines of all continents except Antarctica. Over the last century in the Chesapeake Bay, the heat-sensitive eelgrass has seen major declines from warming waters and summertime marine heatwaves. Despite its cosmopolitan nature, widgeon grass has been unable to fill in the increasing number of gaps, resulting in an overall rate of loss.

Rising water temperatures aren't the only threat caused by climate change: rising sea level, storm surge, and wave action all threaten our coastal communities. Fortunately for us, seagrasses have been found to reduce wave intensity, trap sediment, and retain soil, causing an overall reduction in coastal erosion. While seagrasses are still experiencing some declines, researchers around the globe are working hard not only to restore seagrass habitats but to increase overall seagrass thermal resilience! With restored seagrass meadows on our side, we can reduce erosion to save our coastal communities from further loss.

Materials & Supplies:

NOTE: a diagram of the "habitat" totes + grids is available on page 7.

During preparation only:

- For the "habitat" totes
  - Permanent marker
  - Tape measure or ruler
  - 3 clear plastic totes, at least 15 x 11 x 5 in
- For the "habitat" grids
  - Scissors
  - Green curling ribbon, 3/16th or 1/5th inch width, at least 100 yards

- 3 plastic, rubber, or rubber-bound wire grids (1/2 to 1 in spacing preferred), close to dimensions of tote bottom
  - Alternatives: aquarium panels, 4-6 count mesh plastic canvases for needlework, chicken wire (note: wire may scratch if not cut well)
- Wire cutters for grid, if needed
- Fishing weights and line, if needed

During active lesson plan:

- Habitat totes
- Habitat grids
- Aquarium gravel, 5lbs – pieces should be roughly pea-sized, can be sourced from any pebbled/shelled soil to which you have access (e.g., backyard, a beach) if you rinse away soil to retain only the pebbles/shells
- 1 stopwatch or timer
- 1-3 trowels or kitty litter scoops (appropriate for aquarium gravel size)
- Scale for weighing materials
- Weigh boat(s) or paper bowl/dish
- 1 density ring (material could be anything such as a plastic pool toy ring, the inside of a roll of tape, a ring made of wire, or a short cardboard tube, so long as the diameter is consistent between all 3 habitats – recommended diameter is 4-8 in)
- 1 bucket or container to transport water, if needed
- 1 mesh bag or sieve to assist in clean-up, if desired
- Towels to assist in clean-up, if desired
- Water

Teacher Preparation:

A diagram of an assembled habitat tote + grid is available on page [8] for reference.

Preparation of the habitat totes:

Using a tape measure or ruler and permanent marker, draw a line halfway down the longest edge of the tote. For best results, draw this line on the inside and outside of the tote, then set aside to let the ink set. Repeat for each tote.

Preparation of the habitat grids:

Adjust the instructions below according to the materials you are using.

First, measure the length and width of the inside bottom of the tote(s) you will use as the habitat totes. The grid should be approximately half the length of the tote's longest edge and slightly smaller than the short edge of the tote (for example, a tote measuring 1 x 2 ft will work well with a grid measuring 11 x 11 in). If the measurements of your grids are too large to fit neatly on the bottom of the tote, preferably with a little give for easy removal, pieces may need to be removed using the wire cutters. Sharp ends can be cut down or covered using other materials such as waterproof tape or hot glue.

To make the "eelgrass," cut the ribbon into varying lengths from 4 to 12 inches – don't feel the need to be precise or consistent. For example, if using plastic embroidery mesh with 5 square holes per inch, only 1-2 ribbons can be tied onto each intersection point for each habitat type. You are shooting for *roughly* 90 % (high thermal resilience), 50 % (moderate), and 15 % (poor) coverage of the entire grid. Take 1-3 cut ribbon pieces (depending on the grid's "thermal resilience," as described in the next paragraph) at once and tie them onto the grid so that the center of the ribbon is tied around an intersection on the grid. Tying them around intersections will prevent the ribbons from sliding during use, "rooting" them in place to prolong reusability. Tie the ribbons such that both ends of the ribbon are on one side of the grid, creating two "shoots" per ribbon above the grid.

Using the above method, create one "high thermal resilience" habitat by tying cut ribbons to nearly all spaces on the grid, skipping only 1-2 intersections per row on the grid. When creating this grid, try to use 2-3 ribbons to create 4-6 "shoots" per intersection. Next, create a "moderate thermal resilience" habitat by tying cut ribbons to approximately 40-50% of the grid. Here, use 2-3 ribbons per intersection, skipping at least every other intersection. Finally, create a "poor thermal resilience" habitat by tying cut ribbons to 10-20% of the grid. Here, use only 1-2 ribbons per intersection. When all 3 grids are completed, they should look visually distinct, with an observer able to easily identify which grid would be considered the most and least "heat tolerant."

Following construction of each grid, you may wish to attach small fishing weights to the corners of each grid using fishing line or another material. This will help prevent excessive movement of the grid during the activity and is recommended for grids made of lightweight plastic. Experiment with your grids by placing them in a habitat tote with enough water to cover the tallest shoots, if able. Then use your hands to create waves. If the grid moves without you touching it, weights are advisable.

Author's note: while creating the grid, I recommended watching a show or listening to a podcast or audiobook. For me, after the first few "shoots" were tied on, the process quickly became meditative. It was easy and enjoyable to listen to my audiobook to keep my brain occupied while my hands went through the repetitive motions of tying on the ribbons. Take breaks to stretch your hands and wrists often, at least every 15 minutes.

Classroom preparation:

On the day of the activity, set up the habitat totes. It is recommended to keep them on one side of the classroom where water is easily accessible and spilled water will not be an issue, such as near a sink and/or floor drain.

Lay out the 3 habitat totes with the short edge closest to where students will be standing. Label one as "high thermal resilience," one as "moderate thermal resilience," and one as "poor thermal resilience." Measure out **roughly** one-third of the aquarium gravel (about 1.66 lbs or roughly 750 g if using a 5 lbs bag) using the scale. Remember that it does not need to be exactly one-third each. Record the weight according to which habitat grid will be placed over it, then place the weighed gravel into the bottom of the respective habitat tote, making sure to keep all gravel on the side of the permanent marker line closest to the participants. If any gravel travels onto or across the line, push it back into place. The gravel should be **roughly** equally distributed across the bottom of the tote half, but some mounds or gaps should not be an issue during the activity.

Once the aquarium gravel is distributed, place the respective habitat grid such that the grid (plus fishing weights, if attached) is directly over the gravel and the ribbon "shoots" pointed upward. Using a hose, bucket, or other container, gently fill each habitat tote with water. The water level should be above the ribbon "shoots" but slightly below the rim of the habitat tote. Place a stopwatch next to each habitat tote and the kitty litter scoop(s) nearby.

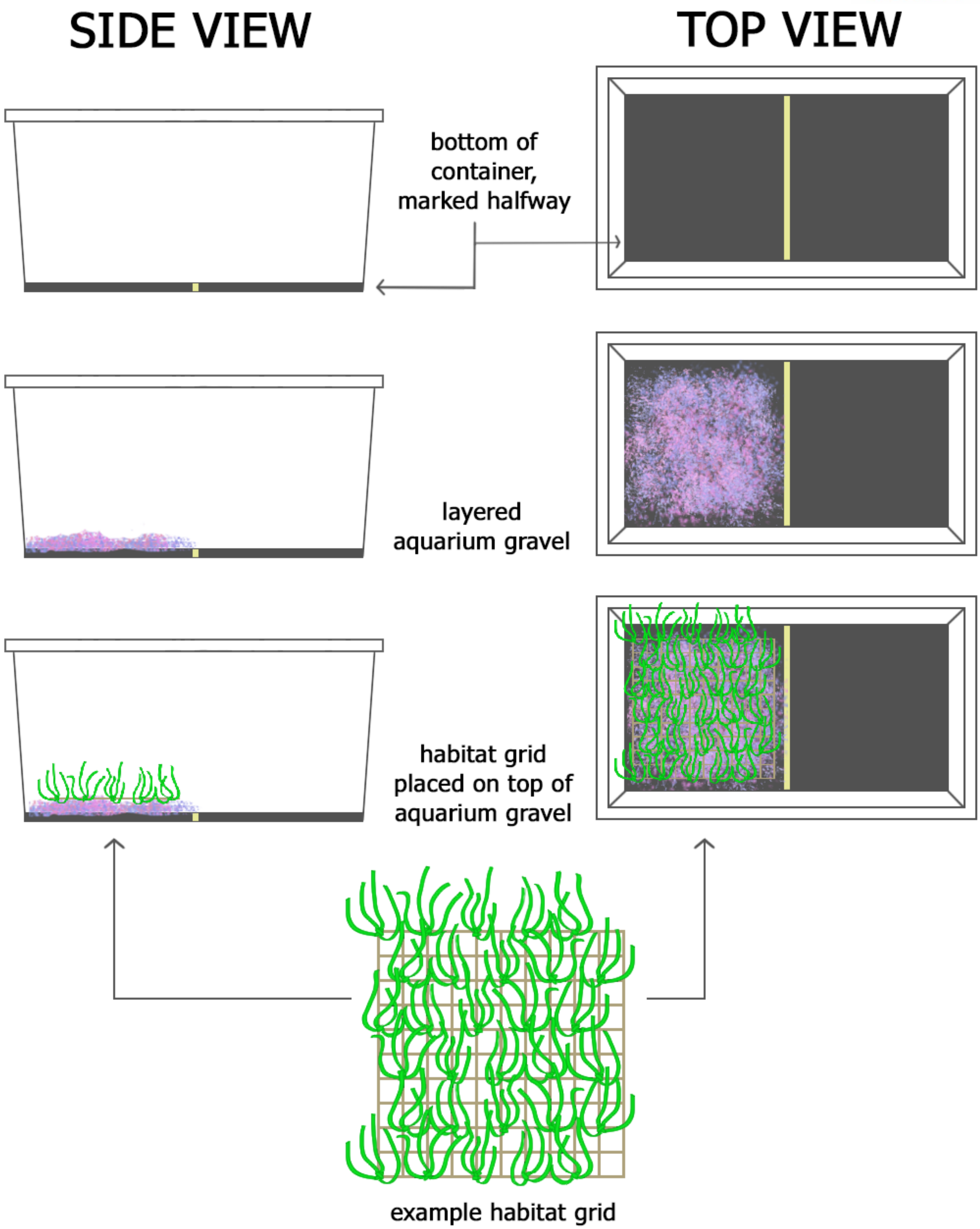

Diagram of an assembled habitat tote: the tote, gravel, and grid layered.
Attribution: Charlotte Henderson, 2025.

On a chalkboard, whiteboard, or other writing area in view of all students, create a table for the class. As groups finish with the habitat totes, have them record their findings for each habitat type on the table. This will help them create a graph using the data from the whole class, like the example below. Before doing so, decide whether you want weights recorded in pounds (lbs) or grams (g) – make sure this matches what is listed on their worksheets to reduce confusion. Currently, all tables are listed with weights in g.

Group number	Thermal resilience	Scooped gravel weight (g)	Total gravel weight (g)	Percent gravel moved (g)	Percent Cover	Density
1	High				90	
1	Moderate				45	
1	Poor				15	
2	High				90	
…	…				…	

Procedure:

Introduction

This lesson plan is introduced in full by a PowerPoint presentation (5-10 minutes in length). It begins with establishing what seagrass habitats and ecosystem services are. From there, it discusses the ecosystem services provided by seagrass habitats at large with some concrete examples. The two seagrass species common to Virginia – the eelgrass *Zostera marina* and the widgeon grass *Ruppia maritima* – are introduced, as well as the broad idea of thermal resilience.

Core Activity

This activity is intended to be done in revolving groups with 3 habitat totes and 3 grids per class but can be scaled-up if you are willing to make many habitat totes and grids. Groups should have 3-5 students each. When a group is not using the habitat totes, they should be working on the activity sheet.

Assign each student to a task according to group size. If the group is composed of…

- 3 students, assign the students as…
  - 1 student: uses stopwatch
  - 1 student: uses scale
  - 1 student: uses habitat totes
- 4 students, assign the students as…
  - 1 student: uses stopwatch and scale
  - 3 students: use habitat totes, 1 student per tote
- 5 students, assign the students as…
  - 1 student: uses stopwatch
  - 1 student: uses scale
  - 3 students: use habitat totes, 1 student per tote

Only one student uses a habitat tote at a time. Here, students will have 30 seconds to make waves using their hands or a waterproof object such as a plastic clipboard or folder. The waves should move from the area over the eelgrass toward the empty bottom and then back again in an attempt to move gravel across the line using the wave energy. Students should not attempt to touch or move the grid.

Once the 30 seconds have elapsed, the students stop making waves and let the water settle. Once it has done so, use the kitty litter scoop(s) or drainable trowels to scoop all of the aquarium gravel that has moved **across** the line. If there is gravel **on** the line, it should be moved back under the grid. All scooped gravel can then be drained of water – giving it a few gentle taps against the side of the tote will help to shake and drain the water. The scooped gravel can then be placed in a weigh boat and measured on the scale. The students should record the weight of the scooped gravel as well as the starting gravel weight per tote. Once the scooped gravel weight is recorded, it should be placed back under the habitat grid from which it originally came. All habitat totes should be reset with all gravel back across the line and roughly underneath the grid to be ready for the next group.

Here are the instructions again, step by step:

1. Call groups up to use the habitat totes one at a time.
2. Assign each student to a task, as above. When more than 1 student is using a habitat tote, they should be encouraged to make waves at the same rate as the other student(s) in their group doing the same task.
3. For 30 seconds, have each habitat tote student make waves using their hands or a waterproof object such as a plastic clipboard or folder. Do not attempt to touch or move the grid!
4. Once 30 seconds have elapsed…
   a. Stop making waves.
   b. Use kitty litter scoop(s) or drainable trowel(s) to remove all of the gravel that moved across the permanent marker line.
   c. Gently tap the scoop against the side of the tote to remove excess water.
5. Using the scale…

a. Place a weigh boat on the scale and tare to zero.
b. Place the scooped gravel from 1 habitat tote into the weigh boat.
c. Record on the worksheet the weight of the scooped gravel according to habitat tote.
d. Record on the worksheet the weight of the total gravel the habitat tote contained.
e. Return the scooped gravel back to the scoop/trowel and then back into the tote from which it came.
f. Record the weight of the other 2 totes following steps 5.a-d above.

6. Reset the habitat tote to its original state by:
    a. Returning all gravel back under the habitat grid
    b. Ensuring no gravel is on or across the line into the empty tote half
    c. Making sure the gravel is relatively even on the bottom half of the tote
7. Count each habitat grid's density (number of shoots within a ring)
    a. Place the density ring near the center of the habitat grid
    b. Clear all ribbon "leaves" from the edges – only shoots with centers inside the ring should remain
    c. Count the number of shoots inside the ring – for simplicity's sake, each ribbon "leaf" will count as 1 shoot. Note: a shoot should not be counted if its origin is not inside the ring's area, such as if it a ribbon "leaf" is caught under the edge of the ring
    d. Record the density on the worksheet
8. Gently replace the habitat grid over the gravel
9. Record the group's weights per habitat type up on the class table.
10. When all groups are complete, take pictures of the class table to distribute to students to complete their worksheets.

Assessment:

During the activity, students will work in groups to complete the in-class group worksheet (4 pages). This worksheet includes conceptual questions to guide the formation of a hypothesis. An additional at-home worksheet asks students to provide support for their hypothesis using data and graphs from the in-class activity. Students are intended to complete this at-home worksheet individually but could complete it in groups if desired.

Recommendations from the author

Although this lesson plan is best utilized with an advanced class of high schoolers, much of its content can be cut down to fit different classroom needs. Consider any/all of the following:

- Have shorter class periods?
    - Make group sizes larger (5+ students per group)
    - Have each group run only 1 meadow type: group 1 uses only the high thermal resilience meadow, group 2 the moderate, and group 3 the poor. The same tote can be used repeatedly, swapping out only the "meadow" grid each time
    - Use only the high and poor thermal resilience meadows

- Have less advanced classes?
    - Make the at-home worksheet an in-class group activity; discuss as a class
    - Use 2 days for the lesson plan: day 1 covers the in-lab activity using the habitat totes, day 2 covers the at-home worksheet together as a class
    - Give each student an in-class worksheet to reference the background/vocabulary
    - Use the provided combined worksheet or choose only the questions that you find valuable for your classroom from the worksheets; remove questions as desired
- Don't have as much prep time on your schedule?
    - Offer extra credit opportunities to create the high, moderate, and poor thermal resilience meadow grids – you only need 1 high and one poor at minimum!
    - Ask the students to help you set up the lab (e.g., distribute and weigh the total amount of gravel in the totes)

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Handouts/Worksheets:

- 1 long in-class group worksheet (5 pages, used with at-home worksheet)
- 1 long at-home worksheet (6 pages, used with in-class worksheet)
- 1 shorter combined worksheet (7 pages, less advanced questions overall)
- 1 answer key (uses fabricated data for examples; may not include all possible answers)

The Seagrass Solution: In-Lab Day 1 Group Worksheet

Names: ____ **Date**: ___________________

Introduction

During the presentation, you learned about the two seagrass of Virginia: the eelgrass *Zostera marina* and the widgeon grass *Ruppia maritima*. The heat-sensitive eelgrass grows from the Arctic Circle down to North Carolina in the Atlantic Ocean. Meanwhile, the widgeon grass *Ruppia maritima* is **cosmopolitan**, meaning it grows in nearly every country in the world due to its adaptability to environmental conditions. Remember the marathon runner metaphor.

Form a hypothesis:

We will be running an experiment using 3 "habitat totes." Each tote contains an eelgrass habitat that either exhibits high, moderate, or poor thermal resilience (ability to withstand higher temperatures than those typical of the local environment). A heatwave recently rolled through the totes, causing high water temperatures and thus eelgrass loss. Now each tote contains a differing amount of remaining live eelgrass. The amount of loss each tote experienced is reflected in the percent cover column of the table on the last page of this worksheet.

Answer the following questions before your group uses the totes.

1. You will be simulating waves in the totes, causing the gravel underneath to move if the eelgrass cannot retain it. This will mirror coastal erosion. Do you think the 3 totes will vary or stay the same in the amount of gravel they retain during wave action? Explain your reasoning.

2. Write your prediction as a hypothesis using an "If-then" statement. Don't forget the rationale for your prediction.

During the activity:

Answer these questions while other groups are using the totes.

3. During the lecture slides, you learned about **ecosystem services**, including services provided to non-human animals. Many fish species that humans like to eat use seagrass habitats as nurseries, meaning those fish lay eggs and raise young within the seagrass meadows. Why might seagrass provide good **nursery habitat** to young fish? Consider what resources fish need to survive.

4. With the help of your group, think of at least 2 ecosystem services that might be provided by each of the ecosystems listed below. Remember the 4 service types: **provisioning** (goods or products produced), **cultural** (non-material benefits for humans), **regulating** (natural resource processes that support humans), and **supporting** (natural resource processes that support other organisms).

    a. Forest

    b. Prairie

    c. River

    d. Desert

5. What other animals, plants, or ecosystems have you heard about that might be experiencing loss due to poor thermal resilience in our warming climate?

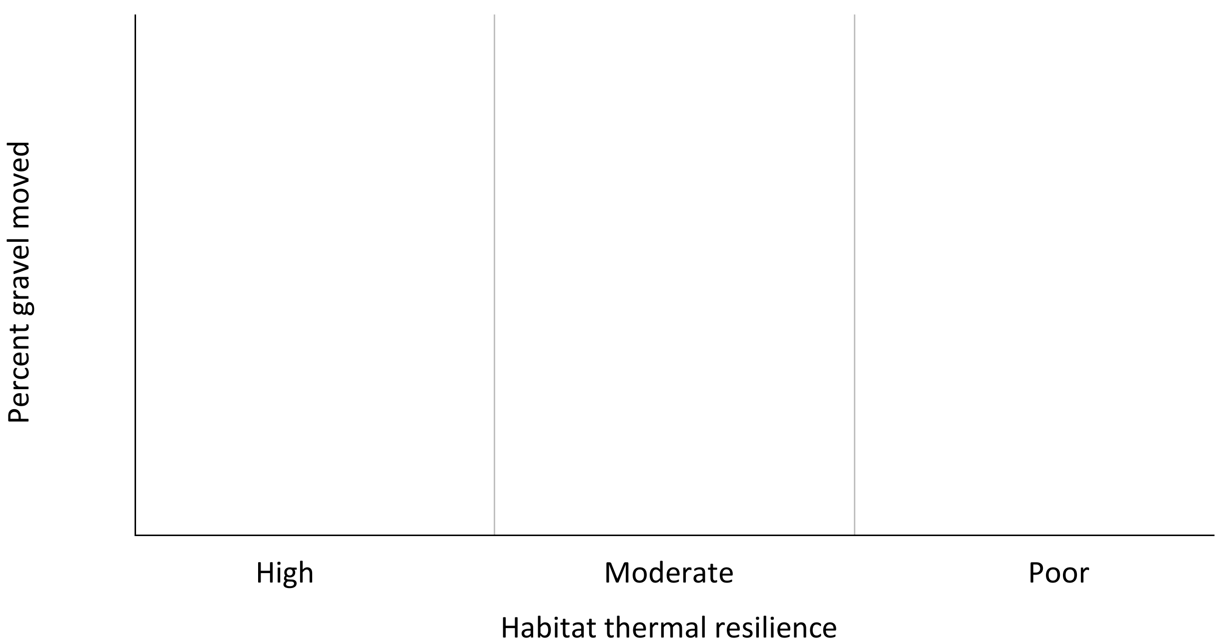
    e. What might we as humans do in an attempt to increase the thermal resilience of the ecosystem(s) or species you listed above?

6. Record the following weights for your group, then copy it to the class table. Percent cover is already provided. To determine the density (# of shoots counted in ring), place

the ring within the tote and count the number of shoots within the ring's area.

Habitat Type	Scooped gravel weight (g)	Total gravel weight (g)	Percent gravel moved (= scooped/total x 100)	Percent Cover	Density (# of shoots counted in ring area)
High thermal resilience				90	
Moderate thermal resilience				50	
Poor thermal resilience				15	

7. Using the class table, fill-in the **bar graph** provided. Don't forget titles and scales.



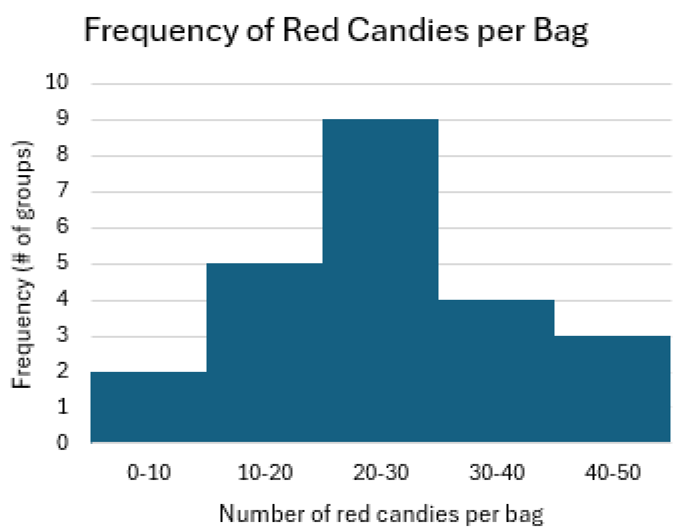
Take a picture of the class data table. You will need it for the take-home worksheet.

The Seagrass Solution: At-Home / In-Lab Day 2 Worksheet

Name: ____ **Date**: ____________________

1. Imagine a class of students, each with their own bag of colored candy, who were asked to split the candy up by color. The class was then asked to count the number of each candy to create a **histogram**. Each time a student had a number of red candies that fell within a certain range, called a bin, the class added 1 to the frequency column. The bins for this class were split into groups of 10, such that a student with 6 red candies in their bag would add 1 to the 0-10 bin but a student with 38 red candies would add 1 to the 30-40 bin. As a result, their class data looked like the following, with the table on the left and its corresponding histogram on the right:

Number of red candies per bag	Frequency (# of students)
0-10	2
10-20	5
20-30	9
30-40	4
40-50	3

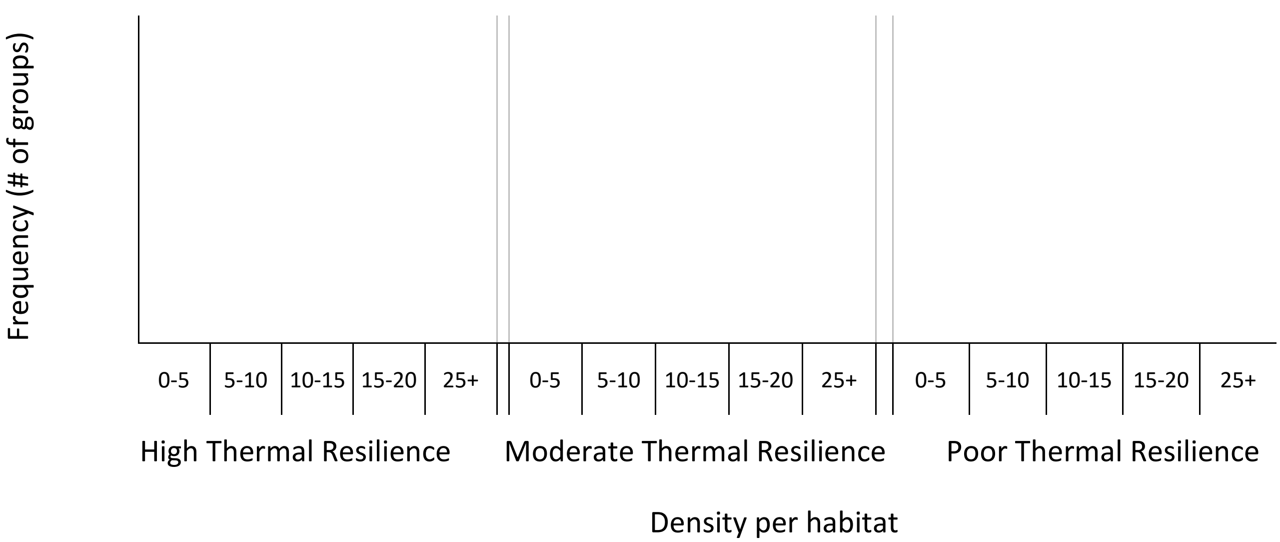


On the next page, you will create a similar table and histogram using the class data. This table and histogram will compare the density (# of shoots per ring) of each habitat with the frequency (# of groups).

2. Create a table similar to the one on the last page using the class data. Note that the bins for density are split into groups of 5.

Density (# of shoots counted in ring area)	Frequency (# of groups) in high thermal tolerance habitat	Frequency (# of groups) in medium thermal tolerance habitat	Frequency (# of groups) in poor thermal tolerance habitat
0-5			
5-10			
10-15			
15-20			
25+			

3. Using the table you created above, fill in the histogram below. Before you begin, make notes of its axes. The Y axis is *frequency (# of groups*). The X axis is *density per habitat* (the number of shoots counted within that habitat's density ring), split into bins of 5. Each time a group has a density that fits within a bin, +1 is added to frequency's bin. Use the example of the class counting red candies from problem #1 to guide you.

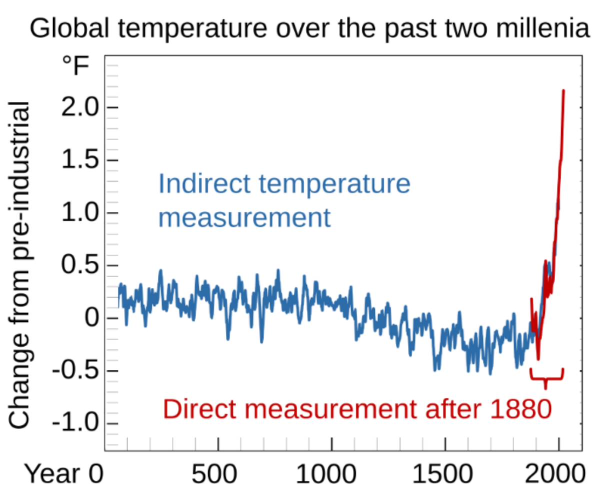


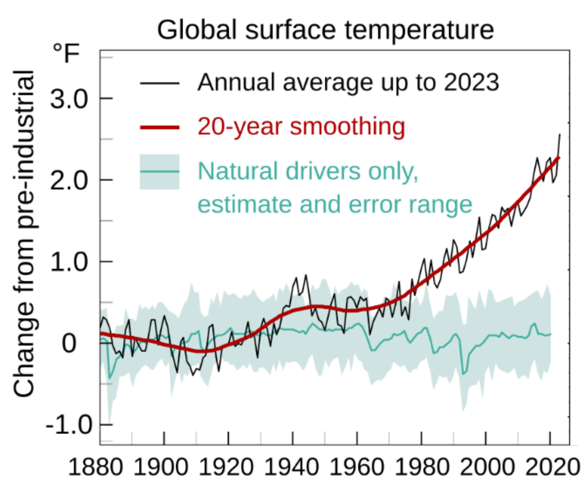
4. Was your original hypothesis supported or unsupported? Provide evidence.

5. Percent cover and density often work together to indicate the overall health of a habitat – when the values of both are higher, this typically indicates higher health. Which habitat tote appears healthier? Use evidence from the table and your histogram.

6. Why do you think seagrass prevents soil movement during wave action? Hint: there are 2 common answers. Provide at least 1 with consideration for physics and/or plant structure.

7. **Global climate change** shows evidence of increasing global temperatures, as depicted in the two graphs below.





a. Over what time scale and temperature scale does each graph take place?

b. Why is knowing the difference in scales important to understanding the messages of these two graphs?

c. Increased carbon dioxide levels are a major contributor to global climate change. Seagrasses, like many plants, require carbon dioxide to power photosynthesis. As a result of photosynthesis, oxygen is released back into the atmosphere. If global climate change causes temperature-sensitive seagrasses such as eelgrass to decline due to temperature, what happens to the carbon dioxide and oxygen levels?

d. What does this mean for the fish that live in seagrass meadows, especially those that use seagrass as nursery habitat?

e. What will this mean for fishermen, either commercially or recreationally?

f. What can we do to reduce the loss of temperature-sensitive species?

The Seagrass Solution: In-Class Group Worksheet

ANSWER KEY

Introduction

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Form a hypothesis:

We will be running an experiment using 3 "habitat totes." Each tote contains an eelgrass habitat that either exhibits high, moderate, or poor thermal resilience (ability to withstand higher temperatures than those typical of the local environment). A heatwave recently rolled through the totes, causing high water temperatures and thus eelgrass loss. Now each tote contains a differing amount of remaining live eelgrass. The amount of loss each tote experienced is reflected in the percent cover column of the table on the last page of this worksheet.

1. You will be simulating waves in the totes, causing the gravel underneath to move if the eelgrass cannot retain it. This will mirror coastal erosion. Do you think the 3 totes will vary or stay the same in the amount of gravel they retain during wave action? Explain your reasoning.

   The 3 totes will vary because they have differing levels of thermal resilience. The higher the thermal resilience, the more the eelgrass remains during and after the heatwave. As waves pass through eelgrass meadows, their intensity decreases as the blades/shoots/leaves break up the motion, preventing soil movement. The roots of the eelgrass provide additional stability to the soil. The less shoots in the water column and the less roots holding onto the soil, the more the gravel is exposed to wave action.

2. Write your prediction as a hypothesis using an "If-then" statement. Don't forget the rationale for your prediction.

   If an eelgrass habitat has higher thermal resilience, then it will be able to retain more soil because the shoots will break up the waves and the roots will hold the soil in place.

During the activity:

3. During the lecture slides, you learned about **ecosystem services**, including services provided to non-human animals. Many fish species that humans like to eat use seagrass habitats as nurseries, meaning those fish lay eggs and raise young within the seagrass meadows. Why might seagrass provide good **nursery habitat** to young fish? Consider what resources fish need to survive.

   Any of the following: seagrass habitats provide oxygen to the water, hiding places for young fish to avoid predators, food for young fish in the form of smaller animals and/or seagrass shoots, and filtration of pollutants/diseases that might affect fish.

4. With the help of your group, speculate on at least 2 ecosystem services that might be provided by each of the ecosystems listed below. **Any of the following** (**2 each**):

   f. Forest – timber, medicinal plants, hunting grounds, recreational activity, oxygen production, carbon storage (in soil or in photosynthesis), pollination/agriculture

   g. Prairie – hunting grounds, oxygen production, soil stability, carbon storage, insect habitat, fodder for livestock, pollination/agriculture

   h. River – fresh drinking water, fishing/recreation area, water cycle, fish/amphibian habitat, drainage/flood control, hydropower generation, transport/navigation

   i. Desert – more likely to preserve archaeological artifacts than other habitats, plants for food/drink (e.g., water-retaining cacti, figs, dates, olives, pistachios, acacia), mineral resources (e.g., salts, borates), habitat for endemic species, underground aquifers, excellent source of renewable solar energy

5. What other animals, plants, or ecosystems have you heard about that might be experiencing loss due to poor thermal resilience in our warming climate?

   Common examples include: corals, polar bears, Chinook salmon, sea turtles, dugongs, manatees, Adélie penguins, bees, whales, sharks, elephants, migratory birds, migratory insects (e.g., monarch butterflies), boreal/cold-weather forests

   j. What might we as humans do in an attempt to increase the thermal resilience of the ecosystem(s) or species you listed above?

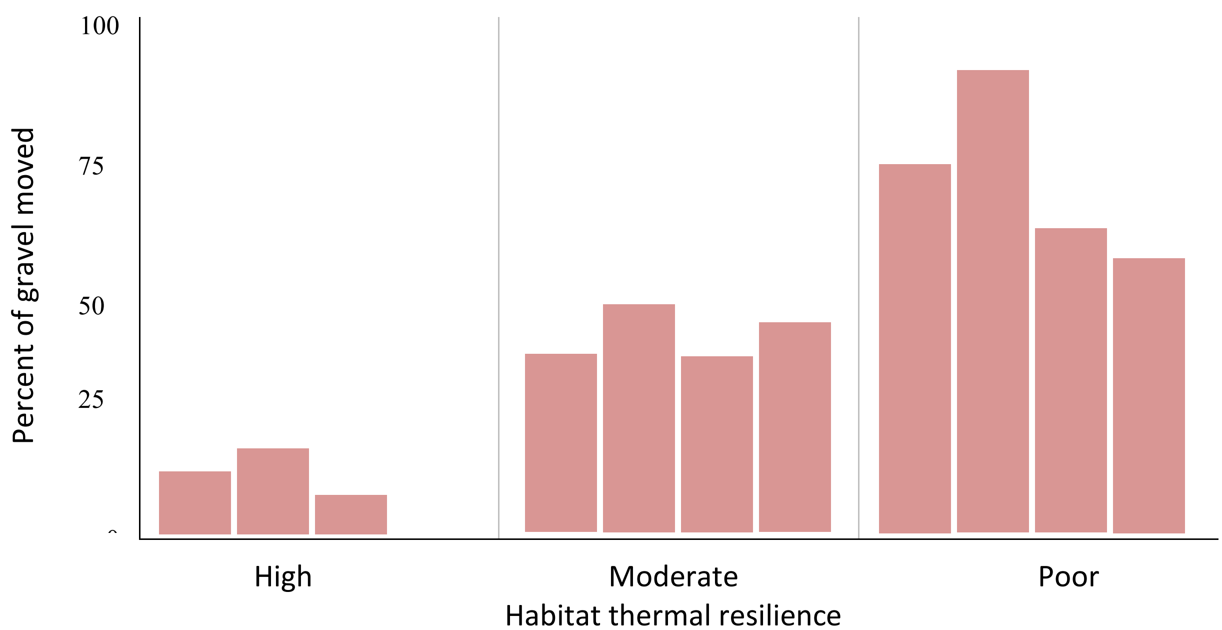
      Common examples include: find and breed organisms that have higher thermal resilience, engage in climate change-fighting actions (e.g., reduce reliance on fossil fuels, increase use of renewable energy sources, recycle plastics, regulate corporate heat waste disposal), assisted migration (this is controversial), increase environmental regulations, increase awareness of loss

6. Record the following weights for your group, then copy it to the class table.

The following data was fabricated for the purposes of this answer key. Results will vary.

Habitat Type	Scooped gravel weight (g)	Total gravel weight (g)	Percent gravel moved (= scooped/total x 100)	Percent Cover	Density
High thermal resilience	50	600	8.33	90	21
Moderate thermal resilience	130	600	21.66	50	18
Poor thermal resilience	250	600	41.66	15	6

8. Using the class table, fill-in the **bar graph** provided. Don't forget titles and scales.

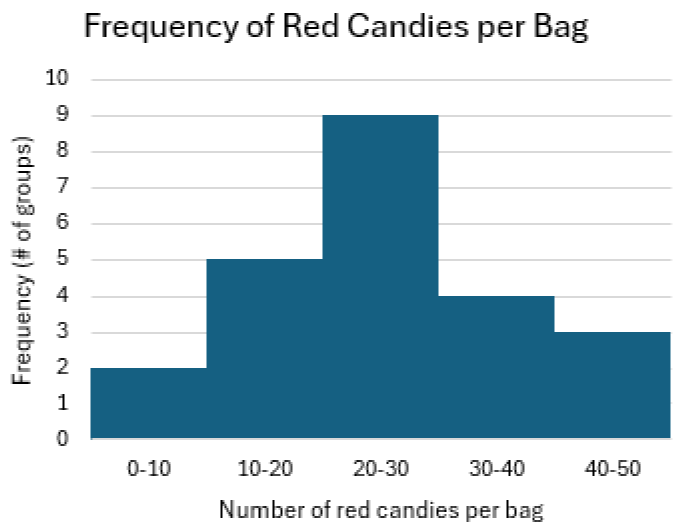


The Seagrass Solution: At-Home Worksheet

ANSWER KEY

1. Imagine a class of students, each with their own bag of colored candy, who were asked to split the candy up by color. The class was then asked to count the number of each candy to create a **histogram**. Each time a student had a number of red candies that fell within a certain range, called a bin, the class added 1 to the frequency column. The bins for this class were split into groups of 10, such that a student with 6 red candies in their bag would add 1 to the 0-10 bin but a student with 38 red candies would add 1 to the 30-40 bin. As a result, their class data looked like the following, with the table on the left and its corresponding histogram on the right:

Number of red candies per bag	Frequency (# of students)
0-10	2
10-20	5
20-30	9
30-40	4
40-50	3



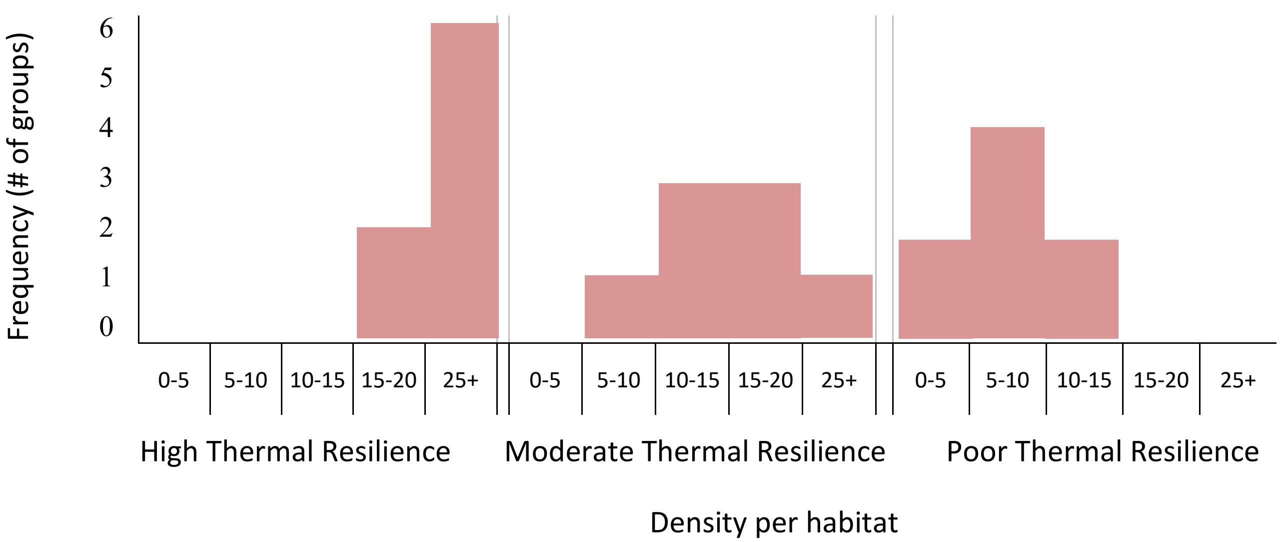
There are no answers here – this is just an example.

On the next page, you will create a similar table and histogram using the class data. This table and histogram will compare the density (# of shoots per ring) of each habitat with the frequency (# of groups).

2. Create a table similar to the one on the last page using the class data. Note that the bins for density are split into groups of 5.

Density (# of shoots counted in ring area)	Frequency (# of groups) in high thermal tolerance habitat	Frequency (# of groups) in medium thermal tolerance habitat	Frequency (# of groups) in poor thermal tolerance habitat
0-5	0	0	2
5-10	0	1	4
10-15	0	3	2
15-20	2	3	0
25+	6	1	0

3. Using the table you created above, fill in the histogram below. Before you begin, make notes of its axes. The Y axis is *frequency (# of groups*). The X axis is *density per habitat* (the number of shoots counted within that habitat's density ring), split into bins of 5. Each time a group has a density that fits within a bin, +1 is added to frequency's bin. Use the example of the class counting red candies from problem #1 to guide you.



4. Was your original hypothesis supported or unsupported? Provide evidence.

   Our original hypothesis was supported. As the thermal resilience decreased, the amount of gravel moved during wave action increased because the eelgrass could not retain the soil.

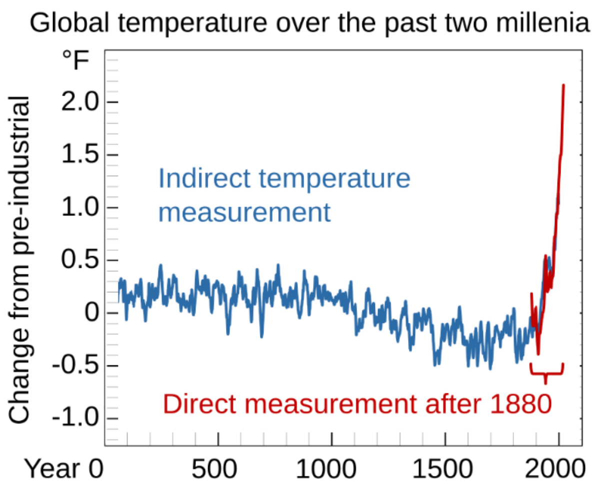
5. Percent cover and density often work together to indicate the overall health of a habitat – when the values of both are higher, this typically indicates higher health. Which habitat tote appears healthier? Use evidence from the table and your histogram.

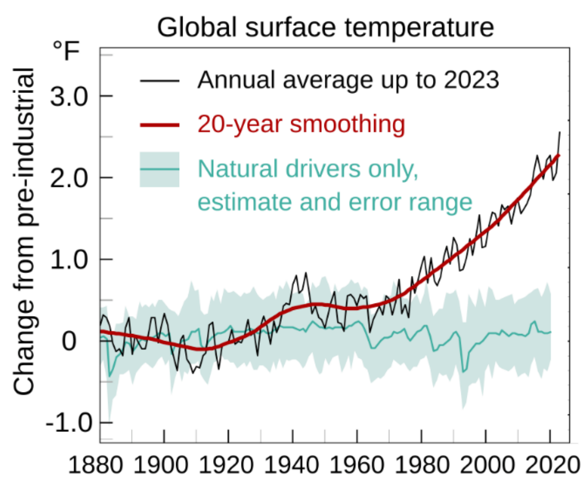
   The high thermal resilience habitat appears to be the healthiest. It has the highest percent cover and density.

6. Why do you think seagrass prevents soil movement during wave action? Hint: there are 2 common answers. Provide at least 1 with consideration for physics and/or plant structure.

   The shoots floating in the water column break up wave energy as the wave passes by, reducing wave intensity overall. The roots also physically hold soil in place.

7. **Global climate change** shows evidence of increasing global temperatures, as depicted in the two graphs below.





   g. Over what time scale and temperature scale does each graph take place?

      Left: from year 0 to year 2000. Right: from year 1880 to year 2020.

h. Why is knowing the difference in scales important to understanding the messages of these two graphs?

The left graph shows a broader timescale. The right shows more detail in recent years. This helps to establish just how much temperatures have changed recently.

i. Increased carbon dioxide levels are a major contributor to global climate change. Seagrasses, like many plants, require carbon dioxide to power photosynthesis. As a result of photosynthesis, oxygen is released back into the atmosphere. If global climate change causes temperature-sensitive seagrasses such as eelgrass to decline due to temperature, what happens to the carbon dioxide and oxygen levels?

Oxygen will decline while carbon dioxide increases due to lack of photosynthesis.

j. What does this mean for the fish that live in seagrass meadows, especially those that use seagrass as nursery habitat?

Fish will be less likely to live in seagrass meadows because there will be less oxygen available in the water. There will be less refuge/area to hide from predators.

k. What will this mean for fishermen, either commercially or recreationally?

There will be less fishing opportunities in seagrass habitats because there will be less fish available.

l. What can we do to reduce the loss of temperature-sensitive species?

Common answers include: find and breed individuals with high thermal resilience, increase awareness of loss, increase environmental regulations, reduce corporate polluting, assisted migration (controversial)

The Seagrass Solution: In-Class Group Worksheet

Names: ______________________________________ Date: _________________

Introduction

During the pre-lab presentation, you learned about the two seagrass of Virginia: the eelgrass Zostera marina and the widgeon grass Ruppia maritima. The heat-sensitive eelgrass grows from the Arctic Circle down to North Carolina in the Atlantic Ocean. Meanwhile, the widgeon grass Ruppia maritima is cosmopolitan, meaning it grows in nearly every country in the world due to its adaptability to environmental conditions. Remember the marathon runner metaphor.

Learning Objectives

Students will be able to…

1. relate declining seagrass heat tolerance with decreased ability to provide shoreline protection.
2. be able to describe seagrasses and the role they play within the Chesapeake Bay regarding shoreline protection.
3. develop a hypothesis about how global climate change will affect other heat-sensitive habitats and some potential consequences for loss.

Vocabulary:

Cosmopolitan: a species that is present worldwide, often due to its highly adaptive nature to a variety of environmental conditions

Ecosystem: a community of organisms and habitats that interact with each other and the environmental conditions in which they live

Ecosystem services: the direct or indirect benefits humans gain from an ecosystem's natural resources and functions

Erosion: the loss or removal of soil and rock from one location through natural means (ex., water, wind) which are then transported to another location

Habitat: where an organism lives – the scale of a habitat can range in size from the individual (ex., a single dead log) to the group (ex., a forest)

Resilience: the ability of an ecosystem to maintain its structure and function during and after disturbances such as storms, fires, or heatwaves

Thermal resilience: the ability of an organism to withstand temperatures higher than those typical to the local environment

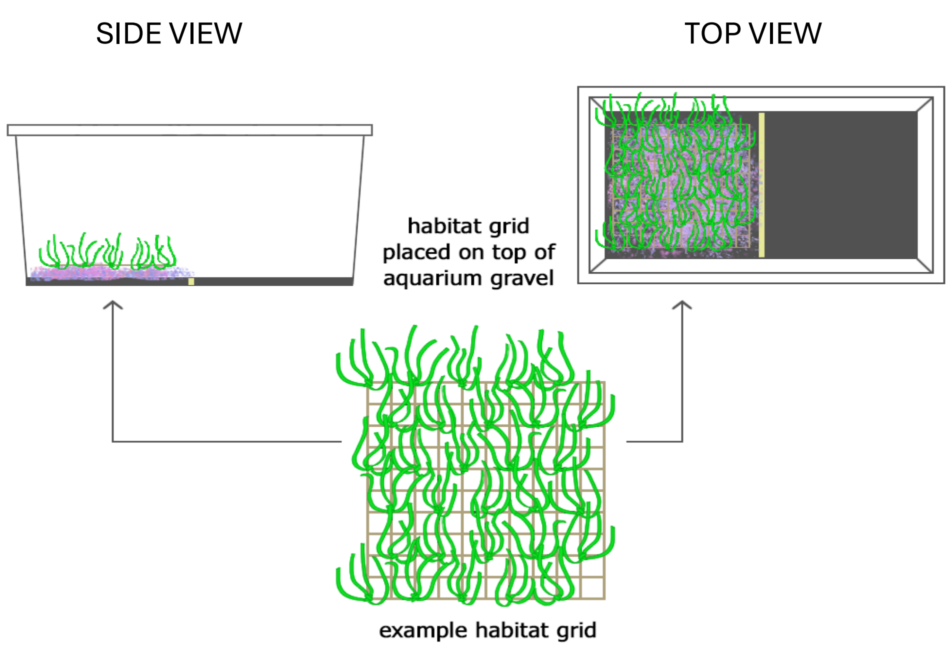
Background Information:

Seagrasses are flowering marine plants and form interwoven habitats along the intertidal to subtidal regions of 191 countries. The lush meadows contribute many direct and indirect benefits to humans, called ecosystem services. These benefits range from acting as habitat and food for many marine animals – including threatened species such as turtles and manatees – to providing ample fishing opportunities for humans, even to filtering many known pollutants out of our waterways. Unfortunately, seagrasses face a growing threat, putting our shorelines at increased risk.

Worldwide, many species of seagrasses are declining due to the rise in water temperatures caused by global climate change, including here in Virginia. Within the Chesapeake Bay, two species are present: the eelgrass Zostera marina and the widgeon grass Ruppia maritima. Where eelgrass exists in the Atlantic from the Arctic Circle to North Carolina, widgeon grass is cosmopolitan, growing along the shorelines of all continents except Antarctica. Over the last century in the Chesapeake Bay, the heat-sensitive eelgrass has seen major declines from warming waters and summertime marine heatwaves. Despite its cosmopolitan nature, widgeon grass has been unable to fill in the increasing number of gaps, resulting in an overall rate of loss.

Rising water temperatures aren't the only threat caused by climate change: rising sea level, storm surge, and wave action all threaten our coastal communities. Fortunately for us, seagrasses have been found to reduce wave intensity, trap sediment, and retain soil, causing an overall reduction in coastal erosion. While seagrasses are still experiencing some declines, researchers around the globe are working hard not only to restore seagrass habitats but to increase overall seagrass thermal resilience! With restored seagrass meadows on our side, we can reduce erosion to save our coastal communities from further loss.

This lab will use stimulated seagrass meadows that look like the figure below:



Form a hypothesis:

We will be running an experiment using 3 "habitat totes." Each tote contains an eelgrass habitat that either exhibits high, moderate, or poor thermal resilience (ability to withstand higher temperatures than those typical of the local environment). A heatwave recently rolled through the totes, causing high water temperatures and thus eelgrass loss. Now each tote contains a differing amount of remaining live eelgrass. You will simulate how coastal erosion can change following seagrass loss due to a heatwave.

Answer the following questions BEFORE your group uses the totes.

1. You will be creating waves in the totes, causing the gravel underneath to move (erode) if the eelgrass cannot break up the wave energy and retain the soil below. This will mirror coastal erosion. Do you think the 3 experimental totes will vary or stay the same in the amount of gravel they retain during wave action? How so? Explain your reasoning.

2. Write your prediction as a hypothesis using an "If-then" statement. Don't forget the rationale for your prediction.

During the activity:

Answer these questions while other groups are using the totes.

3. During the lecture slides, you learned about ecosystem services, including services provided to non-human animals. Many fish species that we like to eat use seagrass habitats as nurseries, meaning those fish lay eggs and raise young within the seagrass meadows. Why might seagrass provide good nursery habitat to young fish? Consider what resources fish need to survive.

4. With the help of your group, think of at least 2 ecosystem services that might be provided by each of the ecosystems listed below. Remember the 4 service types: provisioning (goods or products produced), cultural (non-material benefits for humans), regulating (natural resource processes that support humans), and supporting (natural resource processes that support other organisms).

    a. Forest

    b. Prairie

    c. River

    d. Desert

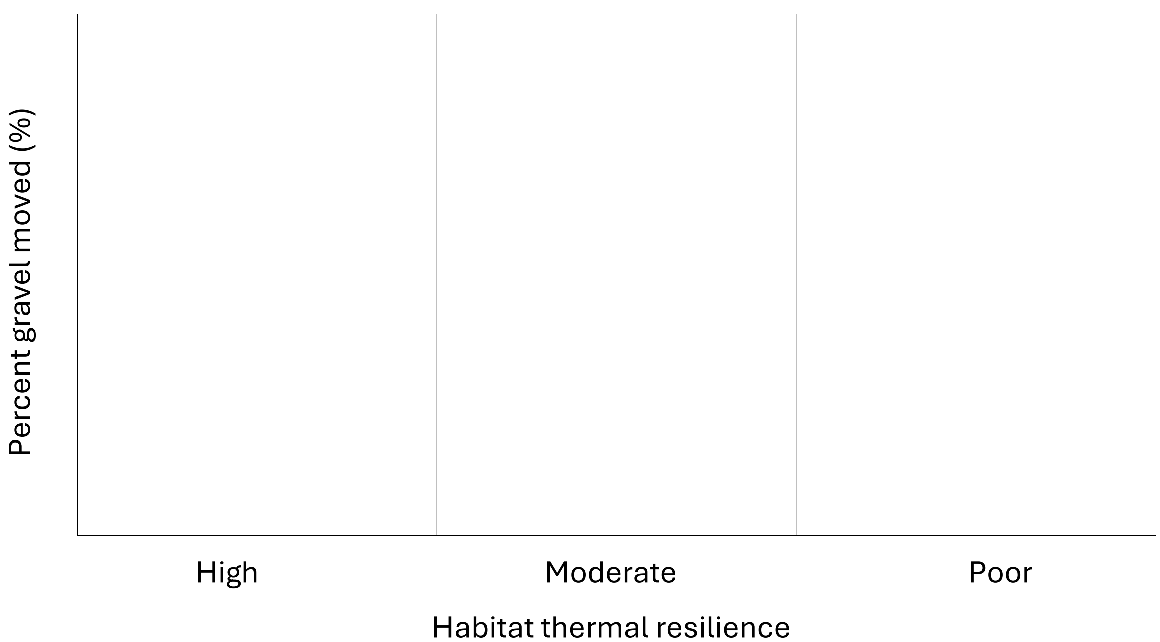
5. What other animals, plants, or ecosystems have you heard about that might be experiencing loss due to poor thermal resilience in our warming climate?

    e. What can we as humans do to increase the thermal resilience of the ecosystem(s) or species you listed above?

6. Record the following weights for your group, then copy it to the class table. Percent cover is already provided. To determine the density (# of shoots counted in ring), place the ring within the tote and count the number of shoots within the ring's area.

Habitat Type	Scooped gravel weight (g)	Total gravel weight (g)	Percent gravel moved (= (scooped/total) x 100)	Percent Cover	Density (# of shoots counted in ring area)
High thermal resilience				90	
Moderate thermal resilience				50	
Poor thermal resilience				15	

7. Using all of data from the class table, fill-in the bar graph provided. Don't forget titles and scales.



The Seagrass Solution: At-Home Worksheet

Name: ______________________________________ Date: _________________

1. Imagine a class of students, each with their own bag of colored candy, who were asked to split the candy up by color. The class was then asked to count the number of each candy to create a histogram. Each time a student had a number of red candies that fell within a certain range, called a bin, the class added 1 to the frequency column. The bins for this class were split into groups of 10, such that a student with 6 red candies in their bag would add 1 to the 0-10 bin but a student with 38 red candies would add 1 to the 30-40 bin. As a result, their class data looked like the following, with the table on the left and its corresponding histogram on the right:

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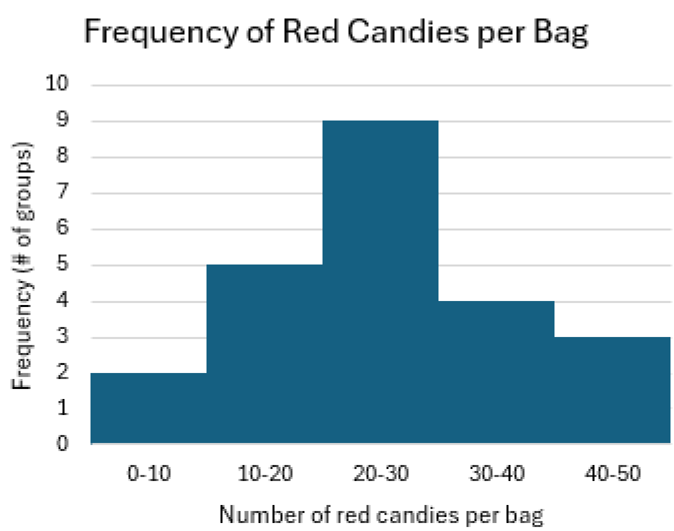
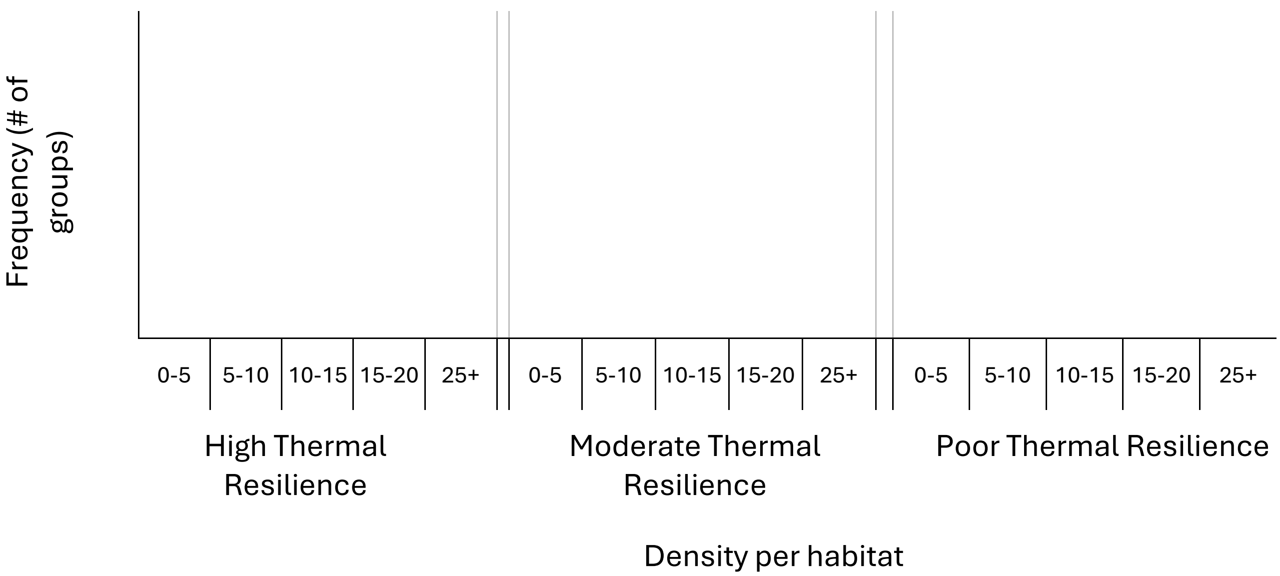


On the next page, you will create a similar table and histogram using the class data. This table and histogram will compare the density (# of shoots per ring) of each habitat with the frequency (# of groups).

2. Create a table similar to the one on the last page using the class data. Note that the bins for density are split into groups of 5.

Density (# of shoots counted in ring area)	Frequency (# of groups) in high thermal tolerance habitat	Frequency (# of groups) in medium thermal tolerance habitat	Frequency (# of groups) in poor thermal tolerance habitat
0-5			
5-10			
10-15			
15-20			
25+			

3. Using the table you created above, fill in the histogram below. Before you begin, make notes of its axes. The Y axis is frequency (# of groups). The X axis is density per habitat (the number of shoots counted within that habitat's density ring), split into bins of 5. Each time a group has a density that fits within a bin, +1 is added to frequency's bin. Use the example of the class counting red candies from problem #1 to guide you.



4. Was your original hypothesis supported or unsupported? Provide evidence.

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6. Why do you think seagrass prevents soil movement during wave action? Hint: there are 2 common answers. Provide at least 1 with consideration for physics and/or plant structure.

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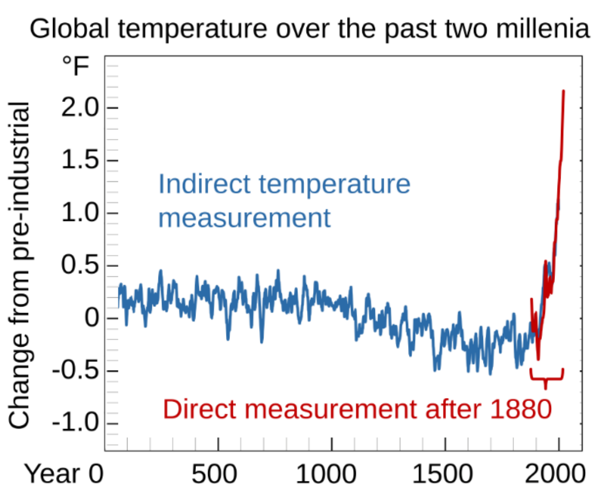

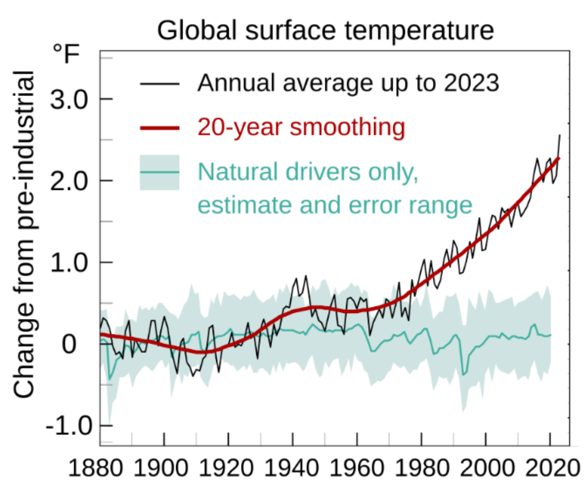

a. Over what time scale and temperature scale does each graph take place?

b. Why is knowing the difference in scales important to understanding the messages of these two graphs?

c. Increased carbon dioxide levels are a major contributor to global climate change. Seagrasses, like many plants, require carbon dioxide to power photosynthesis. As a result of photosynthesis, oxygen is released back into the atmosphere. If global climate change causes temperature-sensitive seagrasses such as eelgrass to decline due to temperature, what happens to the carbon dioxide and oxygen levels?

d. What does this mean for the fish that live in seagrass meadows, especially those that use seagrass as nursery habitat?

e. What will this mean for fishermen, either commercially or recreationally?

f. What can we do to reduce the loss of temperature-sensitive species?

The Seagrass Solution: Combined Worksheet

Names: ____ Date: __________________

Introduction

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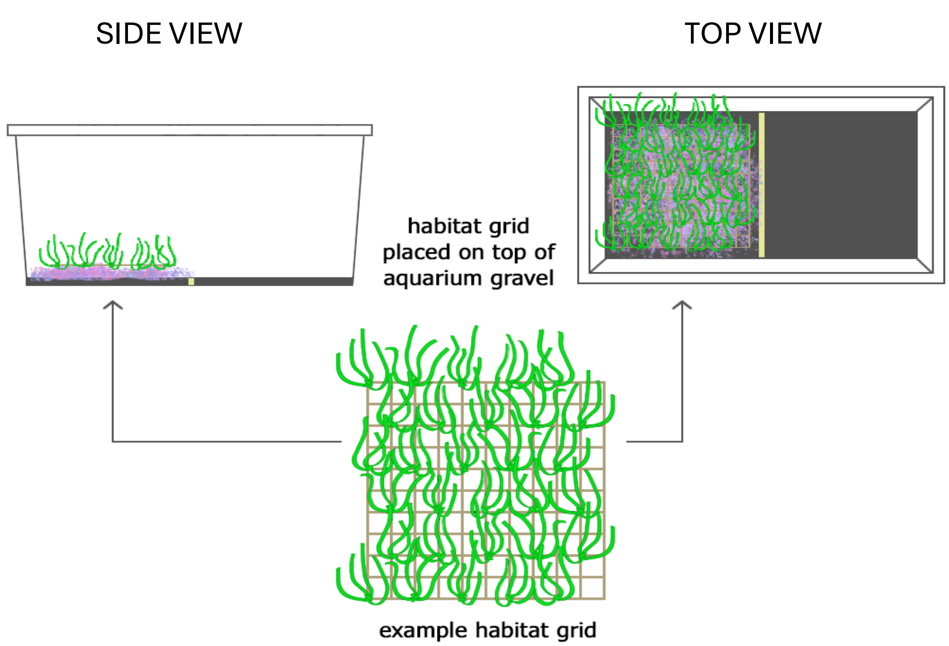

Form a hypothesis:

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Answer the following questions BEFORE your group uses the totes.

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2. Write your prediction as a hypothesis using an “If-then” statement. Don’t forget the rationale for your prediction.

3. During the lecture slides, you learned about ecosystem services, including services provided to non-human animals. Many fish species that we like to eat use seagrass habitats as nurseries, meaning those fish lay eggs and raise young within the seagrass meadows. Why might seagrass provide good nursery habitat to young fish? Consider what resources fish need to survive.

4. What can we, as humans, to increase the thermal resilience of seagrass meadows?

5. Record the following weights for your group, then copy it to the class table. Percent cover is already provided. To determine the density (# of shoots counted in ring), place the ring within the tote and count the number of shoots within the ring's area.

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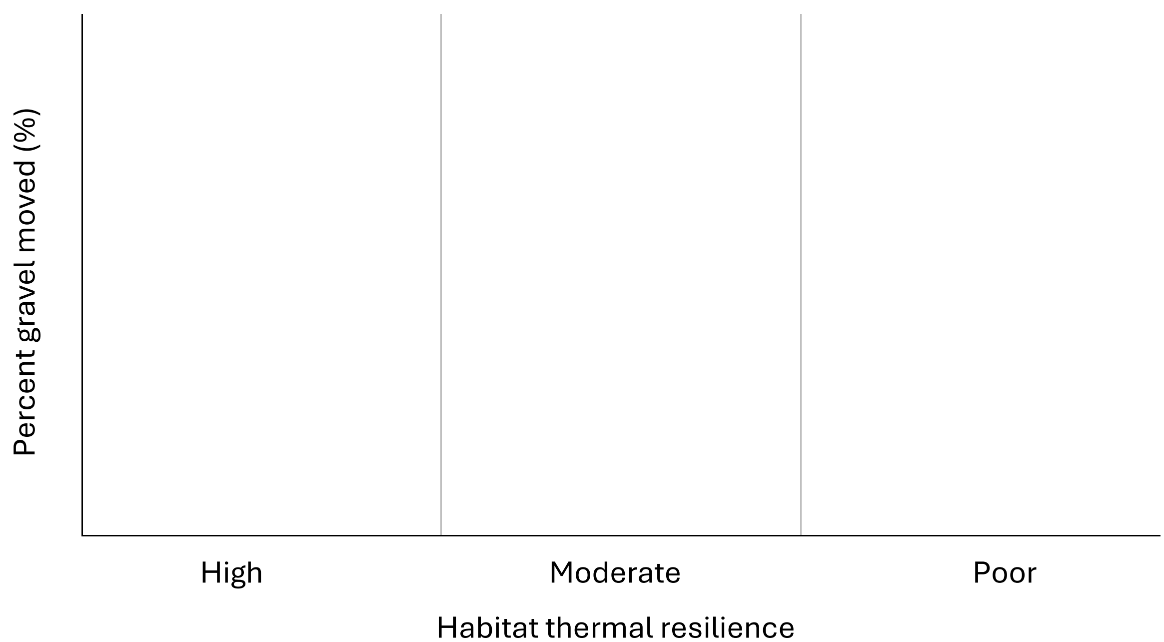

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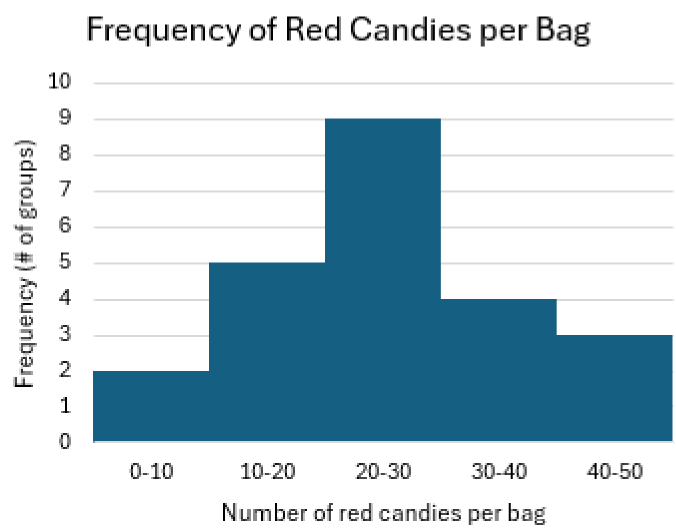

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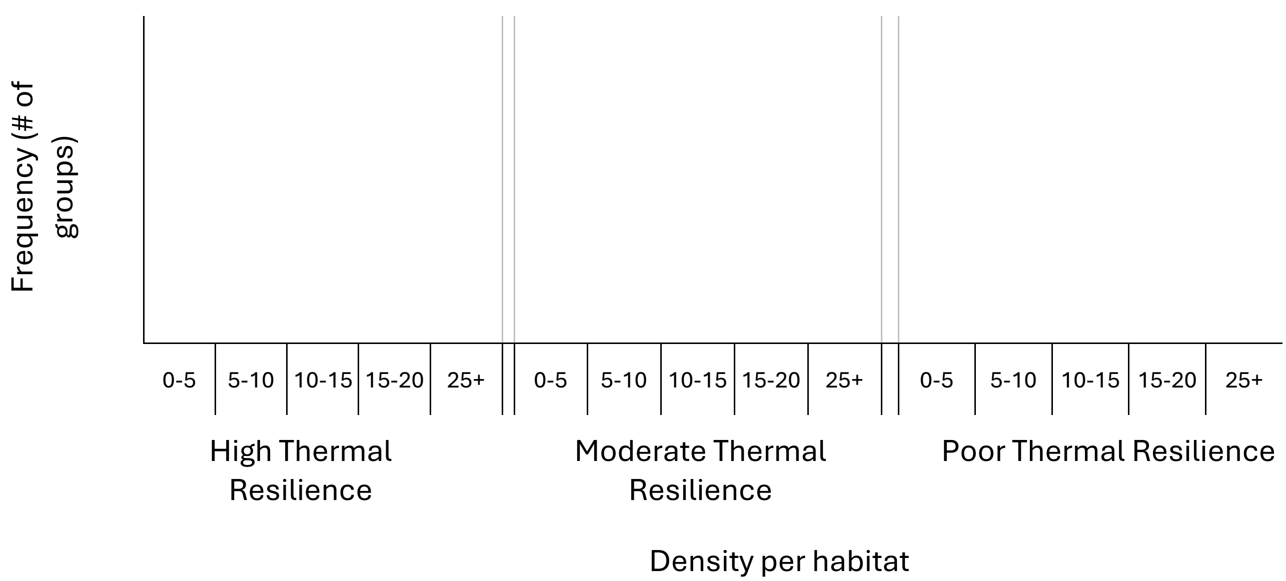


9. Was your original hypothesis supported or unsupported? Provide evidence.

10. Percent cover and density often work together to indicate the overall health of a habitat – when the values of both are higher, this typically indicates higher health. Which habitat tote appears healthier? Use evidence from the table and your histogram.

11. Why do you think seagrass prevents soil movement during wave action? Hint: there are 2 common answers. Provide at least 1 with consideration for physics and/or plant structure.

12. What does this mean for the fish that live in seagrass meadows, especially those that use seagrass as nursery habitat?

13. What will this mean for fishermen, either commercially or recreationally?

The Seagrass Solution: In-Class Group Worksheet

ANSWER KEY

Introduction

During the presentation, you learned about the two seagrass of Virginia: the eelgrass Zostera marina and the widgeon grass Ruppia maritima. The heat-sensitive eelgrass grows from the Arctic Circle down to North Carolina in the Atlantic Ocean. Meanwhile, the widgeon grass Ruppia maritima is cosmopolitan, meaning it grows in nearly every country in the world due to its adaptability to environmental conditions.

Form a hypothesis:

We will be running an experiment using 3 "habitat totes." Each tote contains an eelgrass habitat that either exhibits high, moderate, or poor thermal resilience (ability to withstand higher temperatures than those typical of the local environment). A heatwave recently rolled through the totes, causing high water temperatures and thus eelgrass loss. Now each tote contains a differing amount of remaining live eelgrass. The amount of loss each tote experienced is reflected in the percent cover column of the table on the last page of this worksheet.

1. You will be simulating waves in the totes, causing the gravel underneath to move if the eelgrass cannot retain it. This will mirror coastal erosion. Do you think the 3 totes will vary or stay the same in the amount of gravel they retain during wave action? Explain your reasoning.

   The 3 totes will vary because they have differing levels of thermal resilience. The higher the thermal resilience, the more the eelgrass remains during and after the heatwave. As waves pass through eelgrass meadows, their intensity decreases as the blades/shoots/leaves break up the motion, preventing soil movement. The roots of the eelgrass provide additional stability to the soil. The less shoots in the water column and the less roots holding onto the soil, the more the gravel is exposed to wave action.

2. Write your prediction as a hypothesis using an "If-then" statement. Don't forget the rationale for your prediction.

   If an eelgrass habitat has higher thermal resilience, then it will be able to retain more soil because the shoots will break up the waves and the roots will hold the soil in place.

During the activity:

3. During the lecture slides, you learned about ecosystem services, including services provided to non-human animals. Many fish species that humans like to eat use seagrass habitats as nurseries, meaning those fish lay eggs and raise young within the seagrass meadows. Why might seagrass provide good nursery habitat to young fish? Consider what resources fish need to survive.

   Any of the following: seagrass habitats provide oxygen to the water, hiding places for young fish to avoid predators, food for young fish in the form of smaller animals and/or seagrass shoots, and filtration of pollutants/diseases that might affect fish.

4. With the help of your group, speculate on at least 2 ecosystem services that might be provided by each of the ecosystems listed below. Any of the following (2 each):

   f. Forest – timber, medicinal plants, hunting grounds, recreational activity, oxygen production, carbon storage (in soil or in photosynthesis), pollination/agriculture

   g. Prairie – hunting grounds, oxygen production, soil stability, carbon storage, insect habitat, fodder for livestock, pollination/agriculture

   h. River – fresh drinking water, fishing/recreation area, water cycle, fish/amphibian habitat, drainage/flood control, hydropower generation, transport/navigation

   i. Desert – more likely to preserve archaeological artifacts than other habitats, plants for food/drink (e.g., water-retaining cacti, figs, dates, olives, pistachios, acacia), mineral resources (e.g., salts, borates), habitat for endemic species, underground aquifers, excellent source of renewable solar energy

5. What other animals, plants, or ecosystems have you heard about that might be experiencing loss due to poor thermal resilience in our warming climate?

   Common examples include: corals, polar bears, Chinook salmon, sea turtles, dugongs, manatees, Adélie penguins, bees, whales, sharks, elephants, migratory birds, migratory insects (e.g., monarch butterflies), boreal/cold-weather forests

   j. What might we as humans do in an attempt to increase the thermal resilience of the ecosystem(s) or species you listed above?

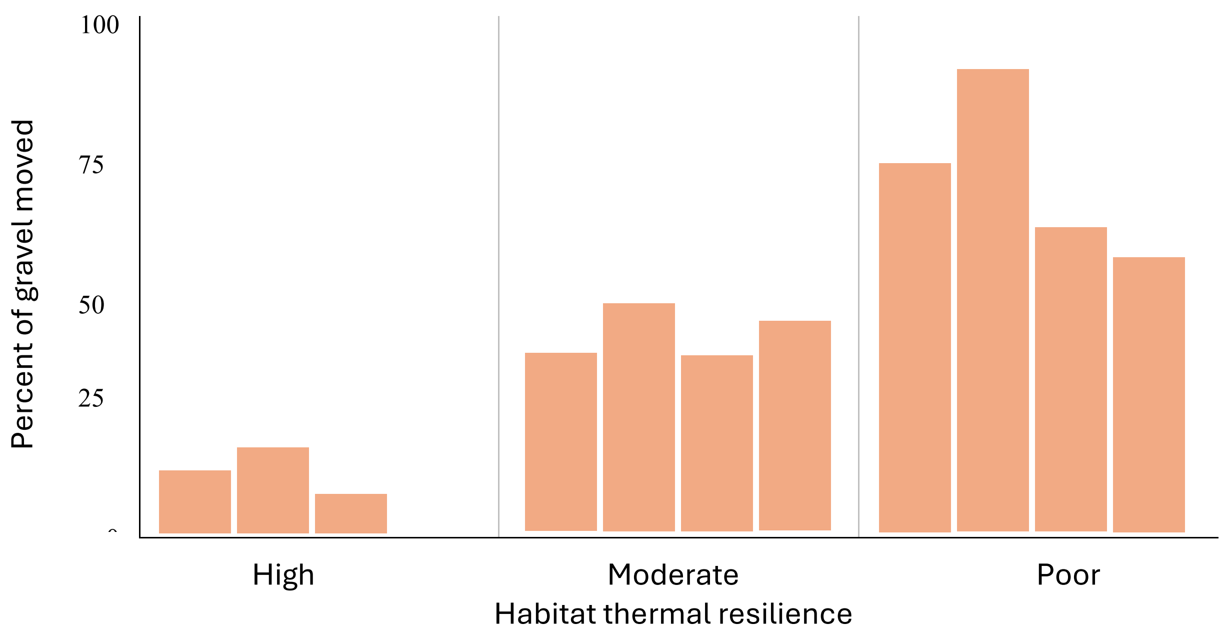
      Common examples include: find and breed organisms that have higher thermal resilience, engage in climate change-fighting actions (e.g., reduce reliance on fossil fuels, increase use of renewable energy sources, recycle plastics, regulate corporate heat waste disposal), assisted migration (this is controversial), increase environmental regulations, increase awareness of loss

6. Record the following weights for your group, then copy it to the class table.

The following data was fabricated for the purposes of this answer key. Results will vary.

Habitat Type	Scooped gravel weight (g)	Total gravel weight (g)	Percent gravel moved (= scooped/total x 100)	Percent Cover	Density
High thermal resilience	50	600	8.33	90	21
Moderate thermal resilience	130	600	21.66	50	18
Poor thermal resilience	250	600	41.66	15	6

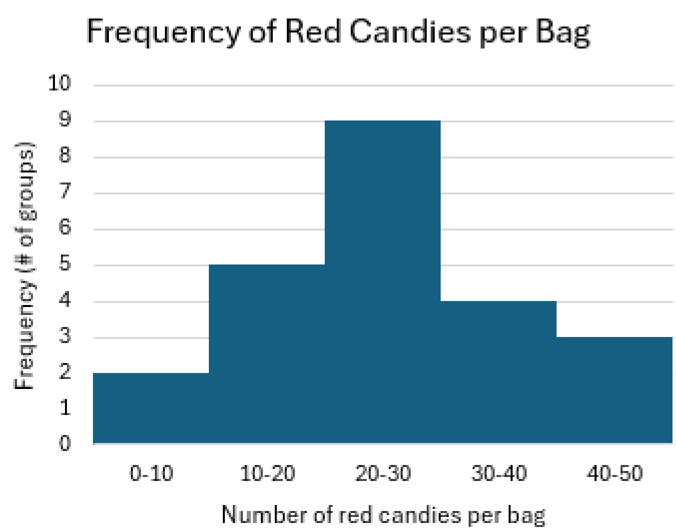
14. Using the class table, fill-in the bar graph provided. Don't forget titles and scales.



ANSWER KEY

1. Imagine a class of students, each with their own bag of colored candy, who were asked to split the candy up by color. The class was then asked to count the number of each candy to create a histogram. Each time a student had a number of red candies that fell within a certain range, called a bin, the class added 1 to the frequency column. The bins for this class were split into groups of 10, such that a student with 6 red candies in their bag would add 1 to the 0-10 bin but a student with 38 red candies would add 1 to the 30-40 bin. As a result, their class data looked like the following, with the table on the left and its corresponding histogram on the right:

Number of red candies per bag	Frequency (# of students)
0-10	2
10-20	5
20-30	9
30-40	4
40-50	3



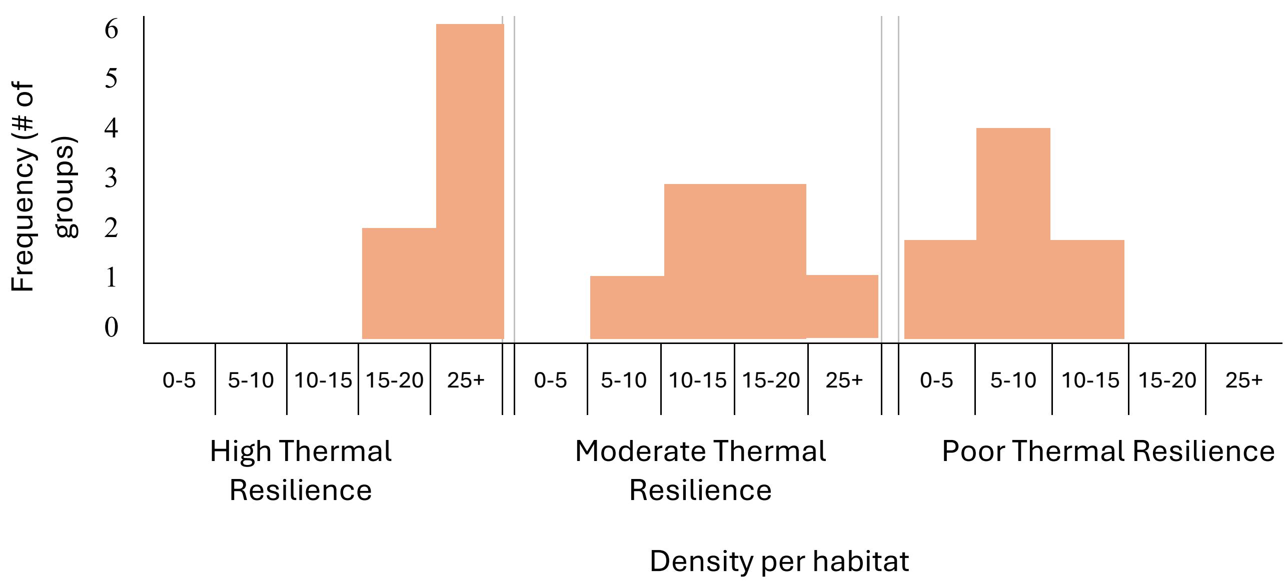
There are no answers here – this is just an example.

On the next page, you will create a similar table and histogram using the class data. This table and histogram will compare the density (# of shoots per ring) of each habitat with the frequency (# of groups).

2. Create a table similar to the one on the last page using the class data. Note that the bins for density are split into groups of 5.

Density (# of shoots counted in ring area)	Frequency (# of groups) in high thermal tolerance habitat	Frequency (# of groups) in medium thermal tolerance habitat	Frequency (# of groups) in poor thermal tolerance habitat
0-5	0	0	2
5-10	0	1	4
10-15	0	3	2
15-20	2	3	0
25+	6	1	0

3. Using the table you created above, fill in the histogram below. Before you begin, make notes of its axes. The Y axis is frequency (# of groups). The X axis is density per habitat (the number of shoots counted within that habitat's density ring), split into bins of 5. Each time a group has a density that fits within a bin, +1 is added to frequency's bin. Use the example of the class counting red candies from problem #1 to guide you.



4. Was your original hypothesis supported or unsupported? Provide evidence.

   Our original hypothesis was supported. As the thermal resilience decreased, the amount of gravel moved during wave action increased because the eelgrass could not retain the soil.

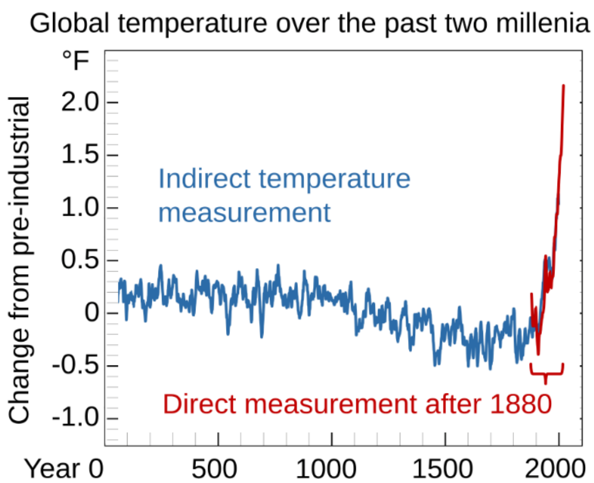
5. Percent cover and density often work together to indicate the overall health of a habitat – when the values of both are higher, this typically indicates higher health. Which habitat tote appears healthier? Use evidence from the table and your histogram.

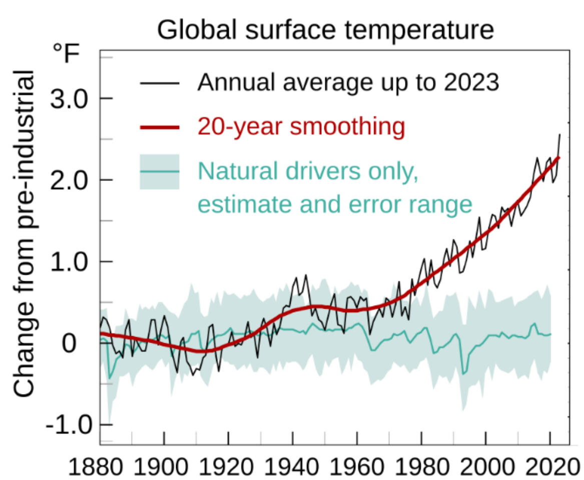
   The high thermal resilience habitat appears to be the healthiest. It has the highest percent cover and density.

6. Why do you think seagrass prevents soil movement during wave action? Hint: there are 2 common answers. Provide at least 1 with consideration for physics and/or plant structure.

   The shoots floating in the water column break up wave energy as the wave passes by, reducing wave intensity overall. The roots also physically hold soil in place.

7. Global climate change shows evidence of increasing global temperatures, as depicted in the two graphs below.





   g. Over what time scale and temperature scale does each graph take place?

      Left: from year 0 to year 2000. Right: from year 1880 to year 2020.

h. Why is knowing the difference in scales important to understanding the messages of these two graphs?

The left graph shows a broader timescale. The right shows more detail in recent years. This helps to establish just how much temperatures have changed recently.

i. Increased carbon dioxide levels are a major contributor to global climate change. Seagrasses, like many plants, require carbon dioxide to power photosynthesis. As a result of photosynthesis, oxygen is released back into the atmosphere. If global climate change causes temperature-sensitive seagrasses such as eelgrass to decline due to temperature, what happens to the carbon dioxide and oxygen levels?

Oxygen will decline while carbon dioxide increases due to lack of photosynthesis.

j. What does this mean for the fish that live in seagrass meadows, especially those that use seagrass as nursery habitat?

Fish will be less likely to live in seagrass meadows because there will be less oxygen available in the water. There will be less refuge/area to hide from predators.

k. What will this mean for fishermen, either commercially or recreationally?

There will be less fishing opportunities in seagrass habitats because there will be less fish available.

l. What can we do to reduce the loss of temperature-sensitive species?

Common answers include: find and breed individuals with high thermal resilience, increase awareness of loss, increase environmental regulations, reduce corporate polluting, assisted migration (controversial)

The Seagrass Solution: Combined Worksheet

ANSWER KEY

Introduction

During the pre-lab presentation, you learned about the two seagrass of Virginia: the eelgrass Zostera marina and the widgeon grass Ruppia maritima. The heat-sensitive eelgrass grows from the Arctic Circle down to North Carolina in the Atlantic Ocean. Meanwhile, the widgeon grass Ruppia maritima is cosmopolitan, meaning it grows in nearly every country in the world due to its adaptability to environmental conditions. Remember the marathon runner metaphor.

Learning Objectives

Students will be able to…

4. relate declining seagrass heat tolerance with decreased ability to provide shoreline protection.
5. be able to describe seagrasses and the role they play within the Chesapeake Bay regarding shoreline protection.
6. develop a hypothesis about how global climate change will affect other heat-sensitive habitats and some potential consequences for loss.

Vocabulary:

Cosmopolitan: a species that is present worldwide, often due to its highly adaptive nature to a variety of environmental conditions

Ecosystem: a community of organisms and habitats that interact with each other and the environmental conditions in which they live

Ecosystem services: the direct or indirect benefits humans gain from an ecosystem's natural resources and functions

Erosion: the loss or removal of soil and rock from one location through natural means (ex., water, wind) which are then transported to another location

Habitat: where an organism lives – the scale of a habitat can range in size from the individual (ex., a single dead log) to the group (ex., a forest)

Resilience: the ability of an ecosystem to maintain its structure and function during and after disturbances such as storms, fires, or heatwaves

Thermal resilience: the ability of an organism to withstand temperatures higher than those typical to the local environment

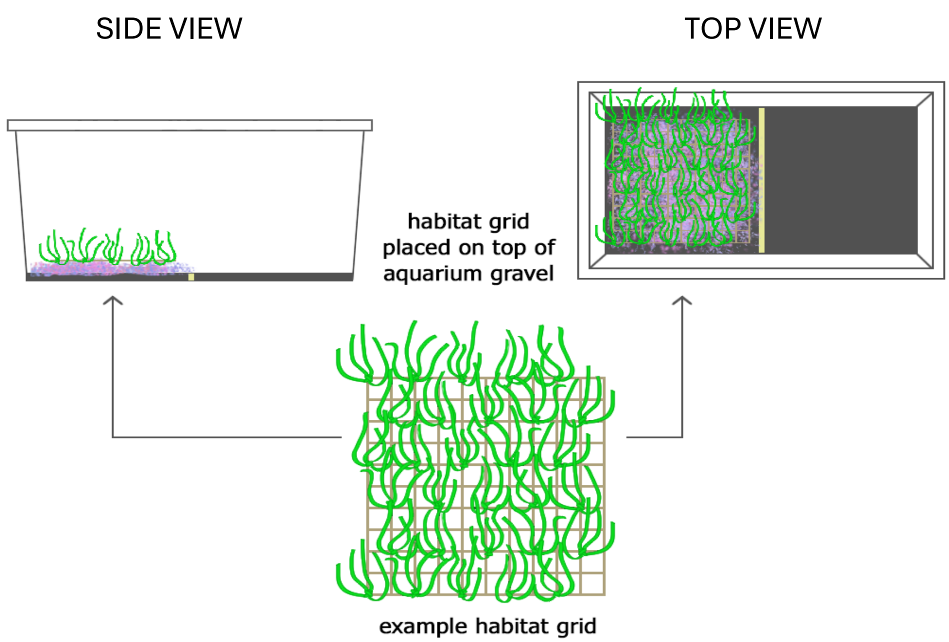
Background Information:

Seagrasses are flowering marine plants and form interwoven habitats along the intertidal to subtidal regions of 191 countries. The lush meadows contribute many direct and indirect benefits to humans, called ecosystem services. These benefits range from acting as habitat and food for many marine animals – including threatened species such as turtles and manatees – to providing ample fishing opportunities for humans, even to filtering many known pollutants out of our waterways. Unfortunately, seagrasses face a growing threat, putting our shorelines at increased risk.

Worldwide, many species of seagrasses are declining due to the rise in water temperatures caused by global climate change, including here in Virginia. Within the Chesapeake Bay, two species are present: the eelgrass Zostera marina and the widgeon grass Ruppia maritima. Where eelgrass exists in the Atlantic from the Arctic Circle to North Carolina, widgeon grass is cosmopolitan, growing along the shorelines of all continents except Antarctica. Over the last century in the Chesapeake Bay, the heat-sensitive eelgrass has seen major declines from warming waters and summertime marine heatwaves. Despite its cosmopolitan nature, widgeon grass has been unable to fill in the increasing number of gaps, resulting in an overall rate of loss.

Rising water temperatures aren't the only threat caused by climate change: rising sea level, storm surge, and wave action all threaten our coastal communities. Fortunately for us, seagrasses have been found to reduce wave intensity, trap sediment, and retain soil, causing an overall reduction in coastal erosion. While seagrasses are still experiencing some declines, researchers around the globe are working hard not only to restore seagrass habitats but to increase overall seagrass thermal resilience! With restored seagrass meadows on our side, we can reduce erosion to save our coastal communities from further loss.

This lab will use stimulated seagrass meadows that look like the figure below:



Form a hypothesis:

[Instructions from the handout; cut for space.]

Answer the following questions BEFORE your group uses the totes.

1. You will be creating waves in the totes, causing the gravel underneath to move (erode) if the eelgrass cannot break up the wave energy and retain the soil below. This will mirror coastal erosion. Do you think the 3 experimental totes will vary or stay the same in the amount of gravel they retain during wave action? How so? Explain your reasoning.

   The 3 totes will vary because they have differing levels of thermal resilience. The higher the thermal resilience, the more the eelgrass remains during and after the heatwave. As waves pass through eelgrass meadows, their intensity decreases as the blades/shoots/leaves break up the motion, preventing soil movement. The roots of the eelgrass provide additional stability to the soil. The less shoots in the water column and the less roots holding onto the soil, the more the gravel is exposed to wave action.

2. Write your prediction as a hypothesis using an "If-then" statement. Don't forget the rationale for your prediction.

   If an eelgrass habitat has higher thermal resilience, then it will be able to retain more soil because the shoots will break up the waves and the roots will hold the soil in place.

3. During the lecture slides, you learned about ecosystem services, including [...] Why might seagrass provide good nursery habitat to young fish? Consider what resources fish need to survive.

   Any of the following: seagrass habitats provide oxygen to the water, hiding places for young fish to avoid predators, food for young fish in the form of smaller animals and/or seagrass shoots, and filtration of pollutants/diseases that might affect fish.

4. What can we, as humans, to increase the thermal resilience of seagrass meadows?

   Common examples include: find and breed organisms that have higher thermal resilience, engage in climate change-fighting actions (e.g., reduce reliance on fossil fuels, increase use of renewable energy sources, recycle plastics, regulate corporate heat waste disposal), assisted migration (this is controversial), increase environmental regulations, increase awareness of loss

5. Record the following weights for your group, then copy it to the class table. Percent cover is already provided. To determine the density (# of shoots counted in ring), place the ring within the tote and count the number of shoots within the ring's area.

The following data was fabricated for the purposes of this answer key. Results will vary.

Habitat Type	Scooped gravel weight (g)	Total gravel weight (g)	Percent gravel moved (= scooped/total x 100)	Percent Cover	Density
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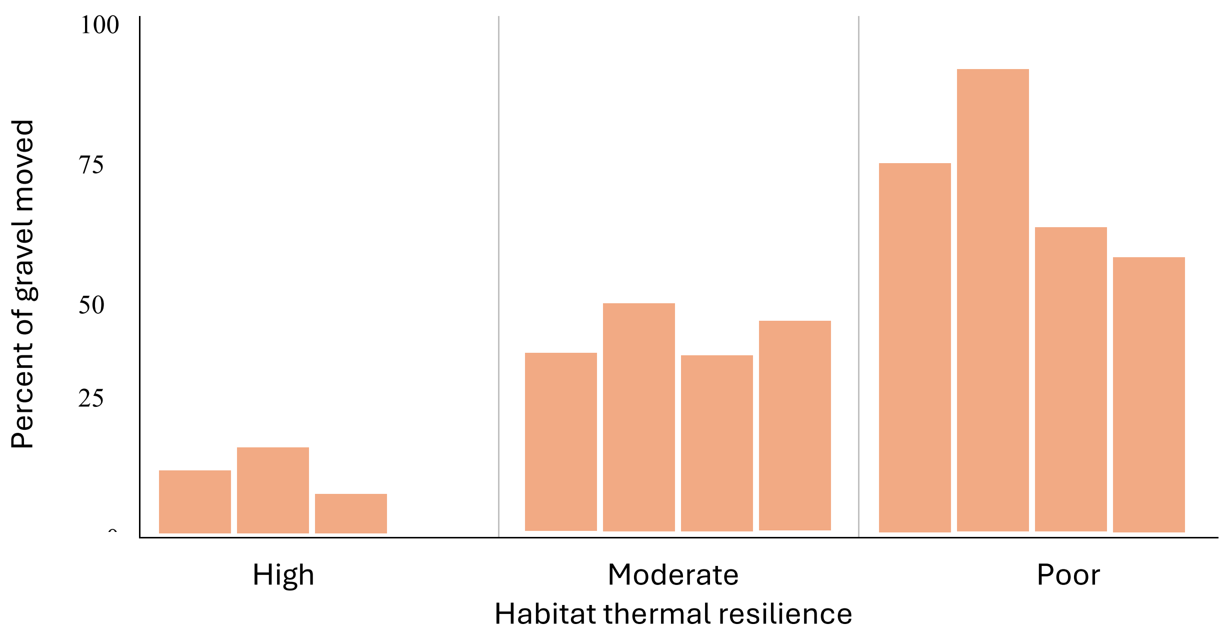
6. Using the class table, fill-in the bar graph provided. Don't forget titles and scales.



Imagine a class of students, each with their own bag of colored candy, who were asked to split the candy up by color. The class was then asked to count the number of each candy to create a histogram. Each time a student had a number of red candies that fell within a certain range, called a bin, the class added 1 to the frequency column. The bins for this class were split into groups of 10, such that a student with 6 red candies in their bag would add 1 to the 0-10 bin but a student with 38 red candies would add 1 to the 30-40 bin. As a result, their class data looked like the following, with the table on the left and its corresponding histogram on the right:

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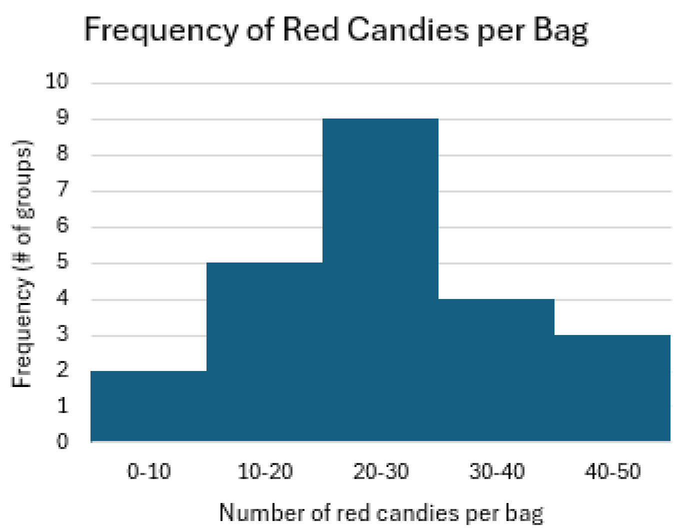

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7. Create a table similar to the one on the last page using the class data. Note that the bins for density are split into groups of 5.

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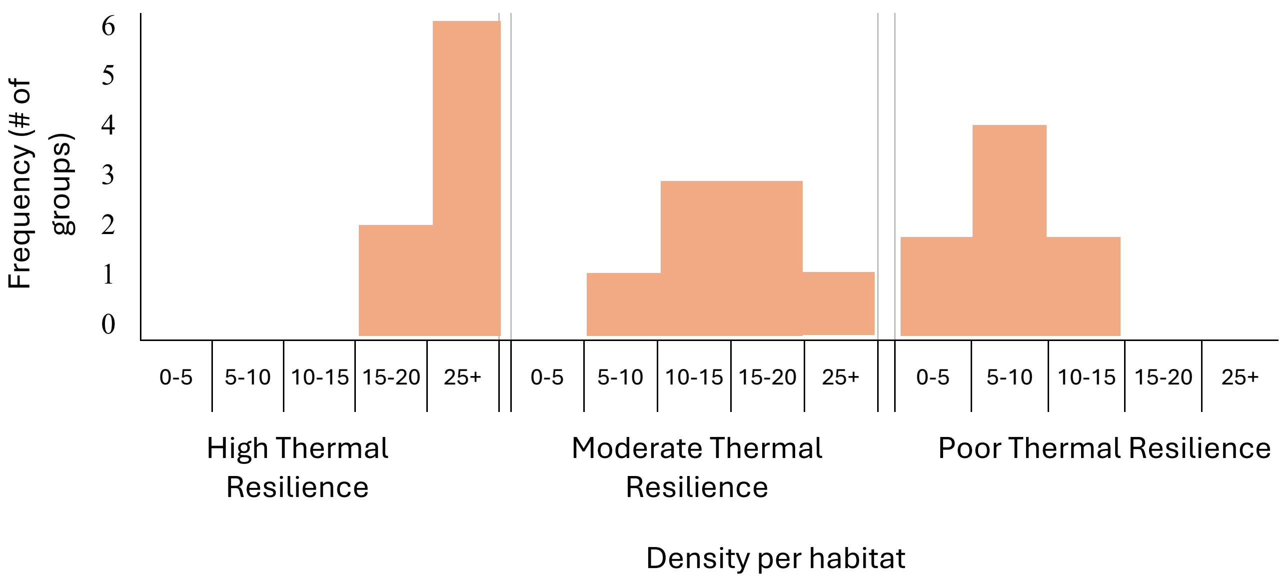
15-20	2	3	0
25+	6	1	0

8. Using the table you created above, fill in the histogram below. Before you begin, make notes of its axes. The Y axis is frequency (# of groups). The X axis is density per habitat (the number of shoots counted within that habitat's density ring), split into bins of 5. Each time a group has a density that fits within a bin, +1 is added to frequency's bin. Use the example of the class counting red candies from problem #1 to guide you.



10. Was your original hypothesis supported or unsupported? Provide evidence.

    Our original hypothesis was supported. As the thermal resilience decreased, the amount of gravel moved during wave action increased because the eelgrass could not retain the soil.

11. Percent cover and density often work together to indicate the overall health of a habitat – when the values of both are higher, this typically indicates higher health. Which habitat tote appears healthier? Use evidence from the table and your histogram.

    The high thermal resilience habitat appears to be the healthiest. It has the highest percent cover and density.

12. Why do you think seagrass prevents soil movement during wave action? Hint: there are 2 common answers. Provide at least 1 with consideration for physics and/or plant structure.

    The shoots floating in the water column break up wave energy as the wave passes by, reducing wave intensity overall. The roots also physically hold soil in place.

13. What does this mean for the fish that live in seagrass meadows, especially those that use seagrass as nursery habitat?

    Fish will be less likely to live in seagrass meadows because there will be less oxygen available in the water. There will be less refuge/area to hide from predators.

14. What will this mean for fishermen, either commercially or recreationally?

    There will be less fishing opportunities in seagrass habitats because there will be less fish available.