Gulf of Maine Research Institute

Teacher Guide

A Warming Gulf of Maine: Investigating Impacts on Predators and Prey

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Introduction

Module Overview

Essential Questions:

- What strategies can we use to understand predator/prey relationships in an ecosystem?
- How are warming ocean temperatures impacting fish species in the region?

Estimated time: 9-11 class periods

Lesson 1: Analyzing Predator/Prey Relationships -Students learn about predator/prey relationships by simulating a stomach content dissection of a specific fish, analyzing what they find and comparing their findings with other fish species examined in the class. Based on their findings, students use SageModeler to make a model of the predator/prey relationships.

Lesson 2: Modeling Feeding Patterns in the Marine Food Web - Students play a modeling game demonstrating the feeding patterns of different fish species and compare their experiences to better understand dynamics in the marine food web.

Lesson 3: Analyzing Relationships in Fish Diets - Using stomach content graphs and SageModeler, students analyze data about fish diets and model relationships in the amount of predators and prey.

Lesson 4: Using Data to Understand Ecosystem Changes - Using stations, students analyze data about the relationship between warming temperatures and habitat in the Gulf of Maine, including shifting ranges for some fish species.

Lesson 5: Modeling Feeding Patterns in a Warming Marine Food Web - Students repeat the modeling game from Lesson 2, but with new game elements introduced to reflect the impacts of warming ocean temperatures on the marine food web.

Lesson 6: Putting the Pieces Together- Ocean Warming and the Marine Food Web - Using learning from the previous lessons, students analyze the experiences of different fish species in a warming Gulf of Maine, revise their model to include the impact of ocean warming, and write a Claim, Evidence, Reasoning Statement about ocean warming and the marine food web supported by their model.

Background:

This learning module builds on previous learning about food webs and focuses on how ocean warming affects the feeding patterns of different fish species, leading to disruptions in long-standing marine food webs. Climate change is affecting oceans around the world in a variety of ways, particularly through widespread warming. The world's oceans have shown a warming trend since 1970, with the rate of warming doubling since 1993, pushing temperatures to unprecedented levels. This warming is triggering biological responses in species that affect their behavior, productivity, habitat and spatial distribution. As species respond in different ways and at different rates, there are impacts to predator/prey relationships. Using many decades of data collected from analyzing the stomach contents of different species, researchers are investigating how feeding patterns are changing and how fish populations are being impacted by these changes. This module is based on current and ongoing research being conducted by researchers at The University of New Hampshire and the Gulf of Maine Research Institute.

SUGGESTED EXTENSIONS:

- Models, Food Webs and a Warming Gulf of Maine Module - GMRI
- NOAA Ocean Food Webs Module

A NOTE ABOUT CLIMATE ANXIETY:
Research is showing increasing anxiety among young people due to climate change. There are many resources out there with tips and suggestions about how to begin addressing this with students in the classroom. Suggestions include emphasizing with students that it is not all on them to solve the issues of climate change, providing opportunities for students to process their feelings through journaling, discussion groups, art work and more, fostering connections with nature, and promoting opportunities for students to feel empowered by working on age-appropriate solutions. Educators are encouraged to seek out resources that feel appropriate to your students and setting to compliment classroom activities that focus on the negative impacts of climate change. Check out this article from the Yale Climate Center: Young people are suffering from climate anxiety. Here's how to help. We have also started a list of resources here.

Standards and Alignment

MS-LS2 Ecosystems: Interactions, Energy, and Dynamics

- MS-LS2-1. Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem
- MS-LS2-2. Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems
- MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

Cross Cutting Concepts:

- Cause and Effect - Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-LS2-1)
- Stability and Change - Small changes in one part of a system might cause large changes in another part. (MS-LS2-4),(MS-LS2-5)

Science and Engineering Practices:

- Developing and Using Models
- Analyzing and Interpreting Data
- Constructing Explanations and Designing Solutions

Lesson 1: Analyzing Predator/Prey Relationships

Lesson Overview:

Students will learn about predator/prey relationships by simulating a stomach content dissection of a specific fish, analyzing what they find and comparing their findings with other fish species examined in the class. Based on their findings, students use SageModeler to make a model of the predator/prey relationships.

Estimated time: 1-2 classes (75-100 minutes)

Lesson Objectives:

Students will be able to…

- Explore predator/prey relationships by analyzing stomach content data

Teacher Prep:

Lab Prep:

1. Review the Teacher Lab Prep Directions and decide if you will do the clean or messy version of the lab.
2. Set up the lab following the Teacher Lab Prep Directions
3. Print and laminate the Stomach Content Analysis Key for each group
4. Print the Analyzing Stomach Content Data Lab Notes for each student
5. Decide whether or not to include the extension: Stomach Content by Season Graph. Print or link for students to access if it is being used.

SageModeler Prep

1. Watch the SageModeler student tutorial to learn about how to use the tool. For more background see the SageModeler Teacher Tutorial and Getting Started link.
2. Play around with the predator/prey template to become familiar with the program interface. Make a link to this template available to students.

Materials

- Lesson Slides
- Analyzing Stomach Content Data Lab Notes
- Fish Species Images
- Stomach Content Analysis Key, laminated
- Colored beads: Blue, Orange, Red, Green, Yellow, Black and White
- Clean Version: Large and small envelopes
- Messy Version: Boxes and cups of goo (for example jello, pudding, oobleck, slime, etc), tweezers
- SAGE Modeler predator/prey template
- Extension: Stomach Content by Season Graph printed for each group

Lesson Steps:

Introduction: Food Webs (15 min)

1. Share the Gulf of Maine food web slide with students
    a. Ask students to share prior learning: What do food webs show? How do we read them?
    b. What is something you notice in this food web?

   c. Why is it important to know what something eats? How can information like this help us protect an ecosystem?
   d. Definite predator and prey.

2. Explore with students ideas about how researchers know what they know about relationships in a food web:
   a. What are some ways researchers could find out what eats what in an ecosystem? For example, how do we know that cod eat herring? How do we know that herring eat krill?
3. Introduce the research technique of stomach content analysis using the slides and video. In this method, fish are dissected and the contents in their stomach are analyzed to identify what the fish ate and can help identify specific predator/prey relationships.
4. Explain that scientists have been researching dozens of species in the Gulf of Maine for decades, allowing them to study relationships with the ecosystem as well as the health of specific species overtime.

Lab - Analyzing Stomach Content Data (20-30 min)

5. Explain to students that they will be simulating a stomach content analysis. They will be working in groups and "dissecting" the stomachs of a specific fish. Each bead represents a different species found in the stomach of the fish. These are based on real predator/prey relationships identified by researchers.
6. Review the key and lab notes paper with students so they are prepared for the investigation.
7. Students dissect their fish and complete their lab notes
8. Provide time for students to clean-up and/or reset the materials for the next class.

Lab Debrief (10-15 min)

9. Group students that dissected different fish together. Ask students to share their findings and complete the questions on the back of their Analyzing Stomach Content Data Lab Notes:
   a. What did your species eat?
   b. Did all species eat the same thing or the same amount of things?
10. Come together as a class and discuss:
   a. Did all species eat the same thing or the same amount of things?
   b. What are some reasons in the real world that one fish might eat more or less of something than another?

SageModeler Activity (20 min)

11. Remind students that NOAA has been collecting information through trawls about the species found in the Gulf of Maine and their stomach contents over many decades to monitor the health of the ecosystem, understand patterns in the predator/prey relationships, and notice when the patterns or health of the ecosystem changes. Researchers then use this information to make models which are simplified representatives that can help them see patterns and relationships. Explain that over the coming lessons, students will be using a program called SageModeler to make their own models based on what they learn.
12. Open the SageModeler predator/prey template and demonstrate how to use it using a volunteer student's lab findings as the basis:

a. Select the fish species
b. Using the arrow in the upper right corner of the fish, drag a line from the fish to one type of prey found in its stomach. Do not add any more information at this time about this relationship.
c. Repeat this process until all forms of prey found in the stomach contents for this species have been included.
d. Encourage students to move the icons around to make the model easy to understand (for example, species that were not found in the stomach can be moved to the bottom, etc).
e. Demonstrate how students should save the file
    i. Select the three lines on the left
    ii. Select "Create a Copy"and show students how you would like them to name it and where you want them to save it
    iii. Select "Share…" and enable sharing

13. Give students time to complete their own model based on their species and what they found in its stomach.
14. Students with extra time or interested in the exceeds option should then add the stomach contents for the remaining three species by checking in with their classmates or consulting the Stomach Content by Season Graph.
15. Before the class period ends, have all students save their work.

Debrief (10-15 min)

16. Come together as a class and discuss, while looking at student examples of the SageModeler diagram:
    a. What tips and tricks did you figure out as you made your model?
    b. What can the model made in SageModeler tell us about an ecosystem? Why do researchers want to know this information?
    c. What new things can we learn if we diagram the stomach contents of all four species?
    d. What are the limitations of this data? In other words, does this analysis tell us everything that a fish species eats or all of the relationships in this ecosystem? Why or why not?

Formative Assessment:

Below is a rubric you can use to assess student responses on the activity. You can invite students to self-assess if that is part of your practice. These are designed to be additive so that each step builds on the one before. If the work does not meet Level 1, it is not considered to have met any of the higher levels.

Level 1 Beginning	Level 2 Approaching	Level 3 Meets	Level 4 Exceeds
I can identify one or more methods researchers use to understand predator/prey relationships in an ecosystem.	I can compare and contrast the diets of different fish species using stomach content data.	I can use a model to show predator/prey relationships based on the findings from the species in my lab investigation. I can identify ways this model is useful to researchers and identify its limitations.	I can use a model to show predator/prey relationships for all of the fish species investigated in the lab. I can compare and contrast the usefulness of the single-species model and multispecies model and identify ways the multispecies model is useful to researchers as well as its limitations.

Lesson 2: Modeling Feeding Patterns in the Marine Food Web

Lesson Overview:

Students will play a modeling game demonstrating the feeding patterns of different fish species and compare their experiences to better understand dynamics in the marine food web.

Estimated time: 1 class (50 minutes)

Lesson Objectives:

Students will be able to…

- Use a model to test and analyze patterns in a marine food web
- Analyze and interpret data to understand the effects of feeding patterns and resource availability on specific species

Teacher Prep:

1. Fill 4 bowls with random groupings of beads and mixture material. Do not include all 4 colors of beads in every bowl, have some that only have two colors of beads, while others could have 3 or 4 colors. Put at least two cups of bead mixture in each bowl.
2. Place the bowls apart from each other and at least 15 feet away from where the groups are starting from.
3. Set up 4 starting stations, one for each group. Each station should have a spoon, one collection container and a print out of the fish species feeding rules.

Printable Set-Up Directions and Rules

Materials

- Lesson Slides
- Print out of the Fish Species Feeding Rules
- 4 bowls/containers
- Colored beads: yellow, red, green, black (~50 total of each color)
- 8+ cups of something to mix the beads into such as puffed rice, oats, dried beans, other beads, etc
- 4 plastic spoons
- 4 collection containers
- Chart paper, white board or digital program to graph results after each round
- Timer
- Modeling Feeding Patterns in the Marine Food Web Notes, one for each student

NOTE: Some teachers may choose to wait to do this lesson and combine it with Lesson 5. Look over the lessons and choose what you think works best for you and your setting.

Lesson Steps:

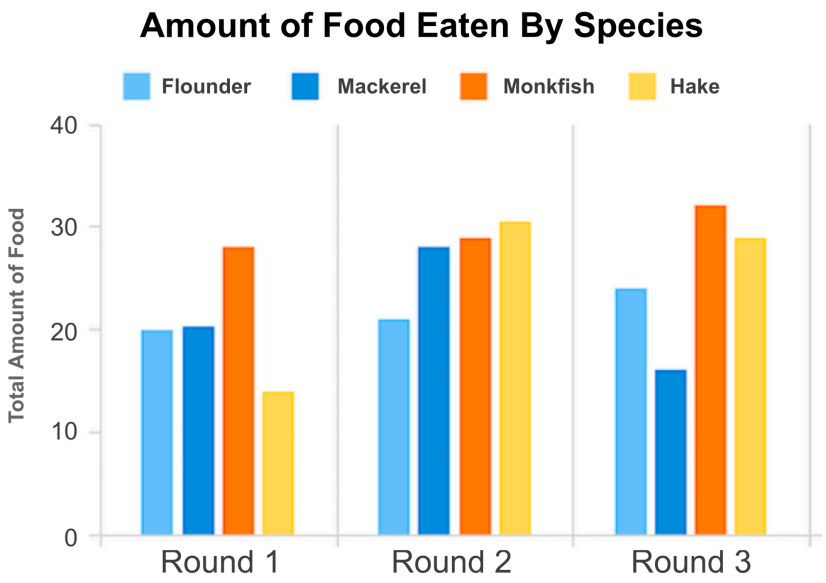
Introduction (5-10 min)

1. Ask students to reflect on their stomach content analysis lab from the previous class. Discuss the following:

- Think back to your lab from last class. What were some of the things you found in the stomach of your fish? (It may be helpful to have students look at their lab notes from the previous lesson to answer this question)
- Do you think the stomach contents for this type of fish will always be the same?
- What are some reasons fish might have different stomach contents at different times?
- Do all types of fish have the same things in their stomach? Why or why not?

Activity - Food Web Modeling Game - 20th Century (30 min)

2. Explain that today students will be modeling the feeding patterns of some fish species in the Gulf of Maine. Give each student a copy of the Modeling Feeding Patterns in the Marine Food Web Notes.
3. Review the basics of the modeling game:
   - Students will be in 4 teams representing different fish species
   - Similar to a relay race, students on a team will take turns collecting food in the ecosystem.
   - Each species has specific rules about what it can eat, represented by different colored beads. Students must go to the bowls to find the beads they can collect/eat.
   - Fish can go to any of the feeding bowls and as many bowls as they want as long as no one else is there when they go to it.
   - Once a member of the team has collected 5 beads, they return to their group, put the beads in the fish's "stomach" and tag the next person in.
   - As students move among the bowls, beads are collected in a plastic spoon representing the fish. If the beads get dropped, they cannot be counted.
   - Time is limited. When the timer sounds, only beads that have been returned to the group or are currently in the spoon can be counted. Each round is 90 seconds long.
   - At the end of each round, groups will record and share their data. The beads will be returned to the bowls, but not necessarily where they were before (the teacher can do this - don't let the students see which bowls have specific beads before the start of the round).
   - Students will play 3 rounds as their fish species.
4. Break students into 4 groups and send them to their starting stations. Allow student time to fill out the top of their Modeling Feeding Patterns in the Marine Food Web Notes.
5. Following the directions laid out above, play the first round.
6. At the end of the round, ask students to record the Round 1 notes based on their group's data.
7. As a whole class, discuss how much food each species was able to collect this round. Make a graph of the class's data showing results by species for the first round (this can be one graph the teacher or student volunteers make for the whole class to see). Here is an example of what the graph might look like after all three rounds:



8. After graphing the data for Round 1, have students repeat the game for Round 2 and Round 3. Graph the class data from each round as you go.
9. At the end of the three rounds, ask students to work in their groups to answer the analysis questions on the back on their notes sheet.

Debrief (10-15 min)

10. Discuss:
    - Which species were the most successful during this game? Was the most successful species different in different rounds?
    - What do you think allowed some species to be more successful than others?
    - How does this game compare to what happens in a real ecosystem?
    - What is an idea you have to make this game more like what happens in a real ecosystem?

Optional Extension in SageModeler (20 - 30 min)

11. Ask students to return to their SageModeler diagram from the previous lesson. Brainstorm with students what changes or additions they would make on the model based on the experiences in the modeling game.
12. Give students time to make these changes.
13. In small groups have students share and discuss the changes they made:
    - What changes did you make and why?
    - In what ways do you think these changes improved your model?
    - How accurate do you think your model is after these changes? Explain.

Formative Assessment:

Below is a rubric you can use to assess student responses on the activity. You can invite students to self-assess if that is part of your practice. These are designed to be additive so that each step builds on the one before. If the work does not meet Level 1, it is not considered to have met any of the higher levels.

Level 1 Beginning	Level 2 Approaching	Level 3 Meets	Level 4 Exceeds
I can make observations about the diets of different predators.	I can explain the experience of a specific species working to obtain the food it needs to survive using data generated by a model.	I can identify and explain the relationship between the feeding habits of a species and its overall success obtaining food and compare this to the success of other species. I can compare the model with what happens in the real world.	I can make specific suggestions about how to improve the model based on real-world phenomena affecting marine ecosystems and explain how these improvements could change the data generated by the model.

Lesson 3: Analyzing Relationships in Fish Diets

Lesson Overview:

Using stomach content graphs and SageModeler, students analyze data about fish diets and model relationships in the amount of predators and prey.

Estimated time: 2 class periods (80-100 minutes)

Lesson Objectives:

Students will be able to…

- Analyze the diets of different fish species using stomach content data
- Explain simple relationships between quantities of predators and their prey

Teacher Prep:

1. Print a copy of the Analysis Notes: Stomach Content Data by Season for each student
2. Share with students a digital link to Stomach Content Data by Season

Materials

- Lesson Slides
- Analysis Notes: Stomach Content Data by Season
- Link to Stomach Content Data by Season
- Access to the SageModeler diagrams students generated in Lesson 1

Lesson Steps:

Introduction (5-10 min)

1. Using a think/pair/share protocol, have students discuss the following questions:
    - Think back to the modeling game from last class. Did all fish species eat the same things? Why could there be differences in what different species eat?
    - Do you think a specific fish species eats the same thing all year long? Why might a fish's diet change in the fall compared to the spring?
    - Do you think temperatures in the ocean could impact what a fish eats? In what ways?

Investigation: Stomach Content Data by Season (25-30 min)

2. Give each student a copy of the Analysis Notes: Stomach Content Data by Season.
    a. Click on the link for Stomach Content Data by Season. Choose one species as a class and take some time to discuss with students how to "read" the stomach content graph for the species.
3. Give students time to complete the Analysis Notes on their own.
4. Using a think/pair/share protocol, have students discuss the following questions:
    - What sort of changes did you observe in the stomach contents of your fish in spring compared to fall?
    - What are some ideas you have about why there might be differences depending on the time of year?
    - Which species had the most similarities in stomach contents compared to your species?

- Which species had the most difference in stomach contents compared to your species?

5. As a class, look at the Seasonal Stomach Content Graph. Discuss:
    - What is this graph showing? How do we "read" it?
        - *Note that this graph is the **proportion** of diet by weight, not the total weight.*
    - Look at the stomach contents for all 4 species. What are some things you notice or wonder about?
        - *For example, Mackerel and Flounder ate more fish in the fall and less in the spring but Monkfish and Hake ate less fish in the fall and more in the spring. Why might we see different patterns depending on the species?*
    - Do all 4 species eat the same things or the same amount of things? How do you think this affects the ecosystem?

Activity: SageModeler (25-35 min)

6. Have students return to their SageModeler diagram from Lesson 1 (it is helpful to use a student-diagram to explain this part of the activity). Show students how to add relationships between predators and prey to the diagram:
    a. Select the settings wheel on the left and make sure "Expanded set of relationships" is selected.
    b. Then select the arrow sign above the settings wheel.
    c. Discuss with students which option to select for the statement "An increase in Atlantic Mackerel causes Worms to _____?" (Hint: they should select "decrease" for each of the prey found in the specie's stomach).
    d. Students will need to decide if the decrease is "a lot", "a little" or a different option based on the information from the Seasonal Stomach Content Graph. Model how to decide this knowing that the answer is somewhat imprecise.
    e. Model for students how to complete the "Why do you think so?" question for each choice.
    f. Click on the "Simulate" arrow, then select a predator and show what happens when the slider is moved up and down. What is this showing in the ecosystem?
7. Give students time to add these relationships to their own diagram for each of the prey their species eats. Students with extra time or interested in the exceeds option should then add in the relationships for the other predator species.

Debrief (10-15 min):

8. Using a student example or this example of the diagram, select the "Simulate" arrow and move the slider up, then down. It may be helpful to look at two different diagrams - one showing the relationships for just one predator, the other showing the relationships for all of the predators.
    a. What do you notice happens in this diagram as the population of this predator species increases?
    b. In what ways is this model helpful for understanding relationships in the ecosystem?
    c. What information is missing from this model?
    d. What would you like to change about this model? Why?

Formative Assessment:

Below is a rubric you can use to assess student responses on the activity. You can invite students to self-assess if that is part of your practice. These are designed to be additive so that each step builds on the one before. If the work does not meet Level 1, it is not considered to have met any of the higher levels.

Level 1 Beginning	Level 2 Approaching	Level 3 Meets	Level 4 Exceeds
I can compare the stomach contents of fish by season and/or species	I can make a model that shows the relationships between the amount of predators and the amount of prey	I can use a model to explain how changes in the amount of a specific predator impacts the amount of its prey I can identify ways to improve the model	I can use a model to explain how changes in the amount of predators in the ecosystem impact the amount of other species in the ecosystem I can identify ways to improve the model

Lesson 4: Using Data to Understand Ecosystem Changes

Lesson Overview:

Using stations, students analyze data about the relationship between warming temperatures and habitat in the Gulf of Maine, including shifting ranges for some fish species.

Estimated time: 1 class period (50 minutes)

Lesson Objectives:

Students will be able to…

- Analyze warming trends in the Gulf of Maine and explain what this could mean for where specific species are found
- Use scientific reasoning to make a hypothesis about how changes in ocean temperatures and habitat will impact fish diets.

Teacher Prep:

3. Print a copy of the Analysis Notes: Using Data to Understand Ecosystem Changes for each student
4. Share with students a digital link to Digital Stations - Using Data to Understand Ecosystem Changes

Materials

- Lesson Slides
- Analysis Notes: Using Data to Understand Ecosystem Changes
- Link to Digital Stations - Using Data to Understand Ecosystem Changes
- Access to the SageModeler diagrams students generated in Lesson 3

Lesson Steps:

Introduction (10 min)

1. Begin by showing an example of the SageModeler diagram from the previous class. Select "Simulate" and increase the amount of a specific species. Discuss as a class:
    a. What are some reasons there might be an increase of a specific predator in the ecosystem? How could that impact other species?
    b. What are some reasons there might be a decrease of a specific predator in the ecosystem? How could that impact other species?
2. Explain that today, students will be investigating how researchers track the amount of specific species in the Gulf of Maine through trawl surveys and some reasons the amounts of specific species found here may be changing.

Digital Stations - Using Data to Understand Ecosystem Changes (30 minutes)

3. Give each student a copy of the Analysis Notes: Using Data to Understand Ecosystem Changes and give an overview of the two digital stations. Students will work on their own or in pairs to complete the stations in order.

Debrief (10-15 min)

4. Using a think/pair/share protocol, have students discuss the following questions:
    - In Station 1, what did you learn about how changes in ocean temperature are impacting where we find Black Sea Bass?
    - What changes do you think researchers working with NOAA might see when they do fish surveys off the coast of Maine 20 years from now? Why?
    - How could warmer ocean waters change what is found in the stomach contents of your fish 20 years from now? Why?
    - Do you think all fish will be impacted the same amount by changes in the ecosystem that are caused by ocean warming?

SUGGESTED EXTENSION:

- Science Friday - Winners And Losers In Warming Northeast Waters

Formative Assessment:

Below is a rubric you can use to assess student responses on the activity. You can invite students to self-assess if that is part of your practice. These are designed to be additive so that each step builds on the one before. If the work does not meet Level 1, it is not considered to have met any of the higher levels.

Level 1 Beginning	Level 2 Approaching	Level 3 Meets	Level 4 Exceeds
I can compare the stomach contents of fish by season and/or species	I can explain how changes in ocean temperatures can change fish habitats	I can use scientific reasoning to make a hypothesis about how changes in ocean temperatures and habitat will impact fish diets and fish populations.	I can make a hypothesis about how changes in ocean temperatures and habitat will impact the diets of fish species differently, using reasoning based on the specific feeding behavior and/or habitat features for each species.

Lesson 5: Modeling Feeding Patterns in a Warming Marine Food Web

Lesson Overview:

Students will repeat the modeling game from Lesson 2, but with new game elements introduced to reflect the impacts of warming ocean temperatures on the marine food web.

Estimated time: 1 class (50 minutes)

Lesson Objectives:

Students will be able to…

- Use a model to test and analyze the impact of warming oceans on the marine food web.

Teacher Prep:

Set up materials similar to the 20th Century Version, except:

- For all three rounds, limit most of the red beads to two bowls and place these bowls significantly farther away than the other bowls and also far away from each other (these bowls can also include some of the other colored beads).
- In the second and third round, do not return any of the yellow colored beads to the bowls.
- In the third round, add a new colored bead and distribute it throughout the bowls. Allow only monkfish and hake to eat them.

Materials

- Lesson Slides
- Print out of the Fish Species Feeding Rules
- 4 bowls/containers
- Colored beads: yellow, red, green, black, and on additional color (~50 total of each color)
- 8+ cups of something to mix the beads into such as puffed rice, oats, dried beans, other beads, etc
- 4 plastic spoons
- 4 collection containers
- Chart paper, white board or digital program to graph results after each round
- Timer
- Copies of the Modeling Feeding Patterns in a WARMING Marine Food Web Notes.

Lesson Steps:

Introduction (15 min)

1. Ask students to discuss:
    - What might you wonder if we start to see a new type of food show up in the stomach contents of a fish? What might cause this?
2. Look at the data on this slide. Explain that the colors show the sea surface temperature of the water. The white line shows the area where a type of fish called a Black Sea Bass likes to live.
    a. Compare the data from 1986 with 2016. What do you notice?
    b. What do you think could be causing these changes in the water temperature? What could be causing changes in where this fish is found?
    c. How could changes to where this fish is found impact the food web?

   i. How might it impact the prey that it eats?
   ii. How might it impact the predators that eat it?
3. Introduce some ways warming temperatures may impact food webs using this slide.

Activity - Food Web Modeling Game - 21st Century (25 min)

4. Explain that today students will be repeating the modeling game from Lesson 2, but with some changes to reflect the impacts of a warming ocean. Give each student a copy of the Modeling Feeding Patterns in a WARMING Marine Food Web Notes.
5. Review the game rules using the lesson slides.
6. Break students into 4 groups and send them to their starting stations. Allow students time to fill out the top of their notes.
7. At the beginning of Round 1, share with students the first change to the game.
8. Play the first round.
9. At the end of the round, ask students to record the Round 1 notes based on their group's data.
10. As a whole class, discuss how much food each species was able to collect this round. Make a graph of the class's data showing results by species for the first round.
11. At the beginning of Round 2, share with students the second change to the game.
12. Play the second round.
13. At the end of the round, ask students to record their notes based on their group's data and then as a class, graph the data from the round.
14. At the beginning of Round 3, share with students the third change to the game.
15. Play the third round.
16. At the end of the round, ask students to record their notes based on their group's data and then as a class, graph the data from the round.
17. At the end of the three rounds, ask students to work in their groups to answer the analysis questions on the back on their notes sheet.

Debrief (10-15 min)

18. Discuss:
    a. How was this model different from the 20th Century Version we played?
    b. Which species were the most successful during this game? Why? Did it change between rounds?
    c. Describe any challenges your species faced getting food during this game.
    d. What would you say the most important takeaway from this game was?

SUGGESTED EXTENSIONS:

- Lesson: Interpret The Impacts Of Rising Ocean Temperatures On Ecosystems - Designed for students in grades 7-12, this lesson combines climate change data with the presence of new species in the Gulf of Maine such as Black Sea Bass.
- Article: As Cod Head for Cooler Waters, New England's Fisheries Face Upheaval

Formative Assessment:

Below is a rubric you can use to assess student responses on the activity. You can invite students to self-assess if that is part of your practice. These are designed to be additive so that each step builds on the one before. If the work does not meet Level 1, it is not considered to have met any of the higher levels.

Level 1 Beginning	Level 2 Approaching	Level 3 Meets	Level 4 Exceeds
I can give examples of how this model is different from the 20th Century version.	I can compare similarities and differences of the data generated by this model with the data from the 20th Century version.	I can explain how warming ocean temperatures impact species in the model and compare it to what happens in the real-world.	I can make specific suggestions about how to improve the model to better reflect climate-driven impacts on marine ecosystems and explain how these improvements could change the data generated by the model.

Lesson 6: Putting the Pieces Together- Ocean Warming and the Marine Food Web

Lesson Overview:

Using learning from the previous lessons, students will analyze the experiences of different fish species in a warming Gulf of Maine, revise their model to include the impact of ocean warming, and write a Claim, Evidence, Reasoning Statement about ocean warming and the marine food web supported by their model.

Estimated time: 2-4 class periods

Lesson Objectives:

Students will be able to…

- Use data to identify impacts of warming ocean temperatures on different species in the Gulf of Maine
- Make a Claim, Evidence, Reasoning Statement about ocean warming and the marine food web supported by a model.

Teacher Prep:

1. Print copies of Sea Surface Temperature Map Analysis, one for each student
2. Print out and cut sets of the Fish Biomass Over Time Graphs for each group
3. Watch: Video: Why is the Gulf of Maine warming so fast? | Maine Explained and decide if it should be included in this lesson.
4. Provide print or digital copies of Analysis: Understanding Changes in the Amounts of Different Fish Species for each student
5. Review the Assessment: Claim, Evidence, Reasoning Statement and modify as needed to align with class norms around CER statements. Provide print or digital copies for each student.

Materials

- Lesson Slides
- Sea Surface Temperature Map Analysis (one for each student)
- Red and Blue colored pencils or markers
- Printouts of Fish Biomass Over Time Graphs, one set per group
- Analysis: Understanding Changes in the Amounts of Different Fish Species, one for each student
- Access to the SageModeler diagrams students generated in previous lessons
- Assessment: Claim, Evidence, Reasoning Statement

Lesson Steps:

DAY 1:

Introduction (5-10 min)

1. Ask students to discuss:
    a. What changes are happening in the Gulf of Maine?
    b. How do we know these changes are happening?
    c. Why does it matter?
2. Explain that today students will be investigating these questions further and thinking about how we can respond to help support the ecosystem as species respond to warming ocean waters.

Investigation 1: Gulf of Maine Sea Surface Temperature Graph Analysis (20-35 min)
Note: This activity comes from the Models, Food Webs and a Warming Gulf of Maine curriculum module. Students that have already done this can reference their previous work rather than do this activity for a second time.

3. Project the Gulf of Maine Sea Surface Temperature Graph from the lesson slides. Ask students to discuss:
    a. What is this graph showing?
    b. What are some things you notice in the data?
4. Next, help students identify the following:
    - Title, being sure to highlight this is an average
    - X and Y Axis
    - Units of measurement
    - What each point means
    - Where the data comes from
    - Why is looking at the average helpful?
    - Why could it be a problem to only see the average?
5. Working individually or with partners, have students complete the Sea Surface Temperature Map Analysis questions.
6. After students have had time to complete the activity, discuss what students found. Ask them to share observations about when the coldest temperatures were and when the warmest temperatures were. The discuss the last question:
    a. Based on what you see in the graph, do you think there has been a lot of change in temperatures over time in the Gulf of Maine, little change in temperatures or no change at all?
7. Optional Extension: For classrooms ready to engage with a deeper understanding about warming in the Gulf of Maine, watch: Video: Why is the Gulf of Maine warming so fast? | Maine Explained
    - What is different about ocean warming in the Gulf of Maine compared to warming in other parts of the world?
    - What is causing more warming in the Gulf of Maine?
    - Why do you think studying the impacts of warming in the Gulf of Maine could help people who live in other places?

Investigation 2: Analyzing Changes to Fish Populations (20-25 min)

8. Ask students to discuss:
    a. How do you think species that live in the Gulf of Maine are being impacted by warmer ocean temperatures?
9. Hand out the Fish Biomass Over Time Graphs to groups of students.
    a. Using the example of Silver Hake and Monkfish, help students "read" the graphs. Point out the trend line (the blue dashed line). This shows the trend over time.
    b. Biomass - the total estimated weight of a particular species caught in a given area. These graphs show fish caught in the Gulf of Maine by scientists to understand what is available for fishermen to catch.

10. Ask groups to sort the graphs from decreasing amounts to increasing amounts of fish. Then, as a group or working individually, students complete the Analysis: Understanding Changes in the Amounts of Different Fish Species notes.

Debrief (5-10 min):

11. As a class, discuss:
    a. What are some observations you have looking at the fish biomass graphs?
    b. Was anything surprising? Is there anything you are wondering about?
    c. How do you think these graphs could help us plan for the future?

DAY 2+:

Introduction (10-15 min):

12. Return the Fish Biomass Over Time Graphs to student groups and project the Sea Surface Temperature Graph Slide.
13. Ask students to discuss their thoughts on these questions:
    a. As ocean temperatures increase, what is happening to the biomass of these different species?
    b. Why could this be happening?
    c. How might this affect the other species in the food web?

Activity: SageModeler (20-30 min)

14. Open the SageModeler Diagram from the previous lessons (some students will have a model for just one predator while others may have a model for all of the predators).
    a. Ask: How could we add ocean warming to this model? (Hint: There is a thermometer image pre-loaded in the image library)
15. Demonstrate how to add in ocean warming to the model by adding an image for ocean warming and then connecting an arrow from this image to each of the predators. Here is an example.
16. Next, model how to add relationships between ocean temperature and specific predators:
    a. Select the settings wheel on the left and make sure "Expanded set of relationships" is selected.
    b. Then select the arrow sign above the settings wheel.
    c. Using the Fish Biomass Over Time Graphs, students will need to determine how to complete the statement for each predator: "An increase in Ocean Temp in the Gulf of Maine causes Winter Flounder to _____"
    d. Students will need to decide if the increase or decrease is "a lot", "a little" or a different option based on the information from the graphs. Model how to decide this knowing that the answer is somewhat imprecise.
    e. Model for students how to complete the "Why do you think so?" question for each choice.
17. Give students time to add in ocean temperature and relationships to their diagrams. Here is an example of a complete diagram.
18. When students are done, they should compare with another student.
    a. How are your diagrams similar?

b. How are your diagrams different?

c. Is anything inaccurate or needs to be revised?

Activity: Simulating Ocean Warming (20 min)

19. Once students have had an opportunity to add ocean warming to their diagrams and compare with a partner, it is time to simulate increased warming on the ecosystem.
    a. Will all species be impacted the same way? Why or why not?
    b. How do you think the species that they eat will be impacted?
20. Click on the "Simulate" arrow, then select ocean warming and show what happens when the slider is moved up.
21. Have partners investigate the model to see what happens as temperatures change. Students can do this on their own model, or you can provide the example of a complete diagram for them to work from.

Assessment: Claim, Evidence, Reasoning Statement (30-60 min)

22. Using their own model or the example of a complete diagram, ask students to make a claim related to ocean warming that is supported by evidence in this model. Brainstorm as a class examples of claims that are supported by evidence in the model.
23. Provide print or digital copies of the Assessment: Claim, Evidence, Reasoning Statement to each student. Review the assignment together and then provide students time to complete the assessment.

Formative Assessment:

Below is a rubric you can use to assess student responses on the activity. You can invite students to self-assess if that is part of your practice. These are designed to be additive so that each step builds on the one before. If the work does not meet Level 1, it is not considered to have met any of the higher levels.

Level 1 Beginning	Level 2 Approaching	Level 3 Meets	Level 4 Exceeds
I can explain how temperatures have changed in the Gulf of Maine over the past 50 years.	I can use a model to show the relationship between ocean temperature and the amounts of different fish in the Gulf of Maine.	I can make a claim about ocean warming and the species in the Gulf of Maine supported by evidence in my ecosystem model and I can explain what is happening in the ecosystem that is leading to changes and why these changes matter.	I can make predictions about the impacts of future ocean warming for each species of predator modeled in the ecosystem. I can explain why each prediction makes sense given the data and trends observed.

Resource Library

Resource	Description	Curricular Fit	Audience
Models, Food Webs and a Warming Gulf of Maine Module - GMRI	GMRI Middle School curriculum that serves as a foundation for the lessons in this curriculum	Extension/ Pre-Lessons	Middle School
NOAA Ocean Food Webs Module	Data visualization tool that uses virtual reality to display simulations of ocean environments to learn about food webs, trophic level, and the relationships between populations of species that eat each other.	Extension/ Pre-Lesson	Middle School
LabVenture Express: How do changing ocean temperatures affect species habitats?	Interactive website investigating how the ideal habitat for Black Sea bass has changed over time	Lesson 3	Middle School
Northeast Surveys: The Fisheries We Count On	Video about the Northeast Fisheries Science Center's multiple yearly surveys at sea to understand how fish stocks and the marine ecosystem are changing over time	Lesson 3	Middle School
Lesson: Interpret The Impacts Of Rising Ocean Temperatures On Ecosystems	Designed for students in grades 7-12, this lesson combines climate change data with the presence of new species in the Gulf of Maine such as Black Sea Bass.	Extension	Grades 7-12
Article: As Cod Head for Cooler Waters, New England's Fisheries Face Upheaval	Dr. Rebecca Selden talks about her new study which looks at the impact of climate change on predator/prey relationships and how the migration of a keystone species can roil local economies.	Extension	Grades 7-12
Video: Why is the Gulf of Maine warming so fast? | Maine Explained	From Maine Public Broadcasting - Why is the Gulf of Maine warming so fast and how does that impact Mainers?	Lesson 5	Middle School
Science Friday - Winners And Losers In Warming Northeast Waters	Kristin Kleisner, a senior scientist at the Environmental Defense Fund's Fisheries Solutions Center, explains advantages and disadvantages for species as ocean temperatures change off the Northeast Coast.	Extension	Grades 7-12