Disrupted Food Webs: Exploring the Relationship between Overfishing and Dead Zones in the Chesapeake Bay

Lesson Overview:

Time: The lessons are organized in six parts and are designed to occur over four forty-minute class periods.

1) An introduction to the problem of dead zones in the Chesapeake Bay (20 minutes)

2) An analysis of the Chesapeake Bay food web before the arrival of European settlers and large- scale fishing (worksheet 1, 20 minutes).

3) An analysis of today's Chesapeake Bay food web with large-scale fishing – pulling out the role of oysters in filtering the Bay and keeping the water clean (20 minutes).

4) A graphing analysis of historic and present day nutrient pollution levels in the Bay in comparison to historic and present day numbers of oysters in the Bay (worksheet 3, 30-40 minutes).

5) Summary of conclusions and results (worksheet 4, 20 minutes with discussion)

6) Watch two short videos (*Rediagnosing the Oceans* about Chesapeake Bay pollution and other examples of the unexpected consequences of human disruptions of food webs in ocean ecosystems and *Jellyfish and Bacteria,* a humorous animation about the future of ocean ecosystems. [Both available from http://www.shiftingbaselines.org/videos/index.html, (20 minutes with discussion)]

7) Distribution of seafood cards [Available from http://www.blueocean.org/home, (20 minutes)]

Students Will Be Able To Understand That:

1) Food webs are all the feeding relationships in an ecosystem.
2) Food webs are made up of many different food chains.
3) Ecosystem stability is dependent on all ecosystem components including the importance of balance between primary consumers (filter feeders) and decomposers.
4) Excess nutrients lead to eutrophication and dead zones.
5) Filter feeders limit excess nutrients in estuary ecosystems
6) Overfishing destabilizes ocean ecosystems making them vulnerable to eutrophication.
7) Shifting baselines is a reason that society fails to notice the decline of many ocean ecosystems. Ecosystem decline occurs slowly over time causing us to mistakenly view severely degraded and poorly functioning ecosystems as "normal" and relatively healthy.
8) Graphs are important tools for comparing and seeing patterns in data.

Part 1: Introduction to the Problem: Why are there dead zones in the Chesapeake Bay? (20 minutes)

Use a short slideshow to engage students with the Chesapeake Bay. Begin with a map of the Bay and close up images of the rivers from six states and the District of Columbia that feed into the Bay. Share that the Bay is the largest estuary in the United States and that no other American estuary has a higher yield of fish and seafood (including blue crab, oysters, clams, and striped bass).

Next use photos of algal blooms and pictures of dead fish to introduce the problem of pollution, eutrophication, and dead zones in the Bay. Photos of nutrients and suspended sediment entering the Bay from places like farms (fertilizer and manure runoff) and cities (sewage) are used to discuss the factors leading to high nutrient levels in the Bay. Particular language and concepts to include in the discussion of eutrophication is the relationship between *detritus* (rotting material) and *microbes* (the microscopic organisms that eat the detritus) since these terms will appear when students analyze their food webs. Follow a step by step process of how dead zones are made. The steps to follow are below:

1. Sewage runoff and fertilizers contribute excess *nutrients* into the water leading to an explosion of algae (algal blooms), since the availability of nitrogen is no longer a limiting factor holding their growth in check.
2. Like all living things, algae die and become *detritus* that is decomposed by *microbes*.
3. The population of *microbes* explodes because of the large amounts of *detritus* available to eat.
4. Like us, *microbes use oxygen* to make energy. The large amounts of microbes use up the oxygen in the water.
5. The water now has *low dissolved oxygen*, killing fish and other organisms that need the oxygen to live.
6. This is a *dead zone*.

After the discussion of the causes of dead zones, the class will be able to summarize what appears to be obvious, that the excess nutrients that people are contributing to the Bay are causing the dead zone problem in the Bay. However, in an effort to learn more about the dead zone problem, ask the students to analyze the feeding relationships of all organisms that comprise the Bay ecosystem. But, in order to understand the feeding relationships amongst organisms in today's ecosystem, they need to understand what organisms lived there in the past. What did the Chesapeake Bay ecosystem look like 300 years ago, before the arrival of European settlers and large-scale fishing?

Part 2: The Chesapeake Bay Before European Settlers and Large-scale Fishing (worksheet 1, 10 -20 minutes – depending upon student group)

Hand each group of two students a food web of the Chesapeake Bay before large-scale fishing and a worksheet (worksheet 1). Ask the students to use the worksheet to analyze the food web. Before students begin analysis, we review the important terms in the food web and the food web key. This step is very important because some of the language in the food web is difficult to understand without discussion and because the first food web is very full of information (This complexity is one of the points of the exercise. The food web before fishing is very hard to read because it is so complex. The food web with fishing is easy to read by comparison because most of the complexity has been removed!) .

The worksheet prepares the students to compare this historic food web of the Chesapeake Bay to the food web of the present-day Chesapeake Bay ecosystem that they will receive next. Students must use the food web to determine abundant and rare species in the ecosystem and to predict the consequences of removing certain species from the ecosystem. Students also practice important basic skills like determining producers, consumers, and decomposers in an ecosystem and pulling out food chains from food webs. Importantly by contextualizing these terms into a dynamic and changing food web, students will begin to learn why these ecological terms are important for scientific understanding. An important point established in this worksheet is that historically, there was a 50-50 ratio of floating algae and sea floor plants. Students will revisit this ratio in later worksheets and the graphing exercise, as oyster harvesting changed this ratio dramatically.

When a group completes its worksheet, check over their answers and hand the group a new worksheet and a diagram of today's Chesapeake Bay food web with large-scale fishing (worksheet 2).

Part 3: The Chesapeake Bay Today With Large-scale Fishing (worksheet 2, 10 -20 minutes – depending upon student group)

This activity follows the same format as the previous food web and worksheet. Working in the same groups of two, students use the new worksheet to analyze the food web of today's Chesapeake Bay with large-scale fishing (worksheet 2). This food web is much less complex (and easier to read) than the food web that the students previously analyzed. Some species are now rare like whales, sharks, seals, predatory fish, grazing fish, predatory invertebrates, oysters, seafloor plants, sea grass, and sea turtles. Sea turtles used to be so abundant in the Caribbean that during the second voyage of Columbus a sailor described "that it seemed as if the ships would run aground on them, and their shells actually clattered" along the topsides. Scientists estimate that there were over 30 million sea turtles in the Caribbean alone before people started to harvest them. (http://www.flmnh.ufl.edu/sciencestories/2008/mother_sea_turtle.htm)]. Many feeding relationships that were once strong are now weak. Students are invited to think about why the food web is so different and how the changed food web might impact ecosystem health.

The worksheet moves the students through many important issues including asking students why jellyfish are abundant if historically they were rare and asking students why predatory fish are rare, even though their shark, seal, and whale predators are now rare. The worksheet then moves to the problem of pollution in the Bay. Students are asked to use what they know about eutrophication to explain why the algae are now abundant in the Bay. This is also a good point in the lesson to link the growth of algae to farming **and** the loss of filtering organisms, as the plankton (floating algae) levels start to rise in the mid-1700s with the introduction of farming, but hold steady while the oysters are still present in the Bay. The floating algae then rapidly spike after oyster harvesting removes most oysters from the Bay (this will be covered in more detail in worksheet 3). As a side note, they are also asked how the abundance of floating algae and phytoplankton might affect the abundance of plants that grow below them like seafloor plants and sea grass.

These questions begin to explain the state of the Bay today. Nutrients added to the Bay feed the growth of algae. The abundance of algae floating on the surface block the sunlight from reaching sea floor plants, causing them to become rare. Finally, students are asked to connect the high levels of nutrients, algae, and microbes to the loss of the oyster filters in the Bay. They develop a hypothesis about how the loss of oyster filters might contribute to the high algae levels in the Bay (*If people overharvested the oysters, then floating algae would increase*). After students develop their hypothesis and determine the type of data they would need to analyze to test their hypothesis, give students data on current and historic levels of oysters and algae in the Bay (worksheet 3).

Part 4: Graphing Analysis of Historic and Present-Day Floating Algae to Sea Floor Plant Ratios in the Bay in Comparison to Historic and Present Day Oyster Harvest Numbers in the Bay (worksheet 3, 30-40 minutes depending on student group).

The students must graph the oyster and floating algae to sea floor plant ratio levels and use the worksheet to analyze their results (worksheet 3).

This is a difficult graphing activity:
1) The graphs have two Y axes with different metrics.
   a. An axis for oyster catch with numbers going into the hundred of thousands of metric tons
   b. An axis for nutrient level with the highest number being 8 (as measured by the ratio of floating algae to sea floor plants found today and historically – This is a side note, but greater nutrient levels in the water lead to more floating algae and less sea floor algae because the sun is blocked by the floating algae.)
   c. However, the same scale can be used for both the oyster catch and the floating algae to seafloor plant ratio, since the range for the oyster catch is 1-7 hundred thousand metric tons, and the range for algae to floating plant ratio ranges from 1 to 8. This may be a good place to help students visualize how much a metric ton is: for example, a blue whale is 170 metric tons. So in a year when people harvested 500,000 metric tons of oysters, they removed the equivalent of 3000 blue whales from the Chesapeake.
2) The X axis includes data from 1700 onward, which is the earliest date for which we have much information about oyster harvesting. However, the floating algae to seafloor plant ratio data go back much further. To show this, we have added a benchmark to the graph.

After students complete their graph, ask students to complete the accompanying worksheet (worksheet 3).

One point emphasized in the worksheet is that floating algae begin to increase even before oyster harvesting begins. This is a record of the initial impact of farming by European settlers on the Bay due to the greater input of nutrients into the Bay from soil and cattle waste runoff into the Bay. Nutrient pollution from farming in the Chesapeake region began to affect floating algae early on, and then oyster harvesting made the problem substantially worse. When those tasks are complete, ask the students to complete a summary worksheet of the activity (worksheet 4).

Part 5: Summary Worksheet of the Activity (worksheet 4, 20 minutes)

This part of the activity asks students to summarize what they learned from analyzing historic and present-day food webs and data on historic and present-day oyster catch and nutrient levels. Students summarize how fishing has changed the Chesapeake Bay ecosystem. They cite the decline of most major ecosystem participants. They also recognize that although most species are fewer in number than they were before fishing, they are still present today, which gives us an opportunity to rehabilitate the ecosystem. Ask the students to to summarize the role of declining oysters in the Bay's dead zones. Without oysters cleaning the water of excess nutrients (fertilizer, manure, and sewage), the Bay is overrun with nutrients leading to algal blooms and dead zones.

The final question on the summary worksheet asks students about the importance of analyzing historic data and the role of historic baselines. Use the discussion of historic baselines to lead into the videos about the Chesapeake Bay.

Part 6: Watching Media about the Chesapeake Bay and Distribution of Seafood Cards (40 minutes with discussion)

Once the summaries are complete and you have discussed them, watch two videos, *Rediagnosing the Oceans* and *Jellyfish and Bacteria*. Both videos are available for download from http://www.shiftingbaselines.org/videos/index.html.

The first video, *Rediagnosing the Oceans* (11 minutes) uses the example the students just investigated, oyster fishing in the Chesapeake Bay, to explain why understanding historic baselines is important for understanding ocean ecosystems. (Note: This video has incredible pictures of mountains of oysters harvested from the Bay, which the students might not see if you do not point them out.) The video then introduces three other scientifically supported examples from other American ocean ecosystems to emphasize the importance of historic baselines. After watching this video, discuss other shifting baselines like climate (today vs 30 years ago), increased life expectancy (today vs 100 years ago), or even what is considered a normal level cell phone texting (adult viewpoints vs childrens').

The next video, *Jellyfish and Bacteria* (< 1 minute), is a humorous animation of ocean ecosystems that are overrun by jellyfish and bacteria. The video is set to the tune of "*Ebony and Ivory.*" The first verse is "Jellyfish and bacteria - that's what you get when the ocean is inferior. Side by side from the Black Sea to the Chesapeake Baaaaybeee." This video is a fun opportunity for the students to sing along and get excited about what they learned.

Finally, discuss seafood cards, a color-coded wallet sized list of healthy and overfished seafood species (Green for healthy. Red for overfished) to let students know that there

is something positive that they can do to help the oceans (Available from the Blue Ocean Institute, http://www.blueocean.org/home). Go over the list to discuss the best and worst seafood choices for our dinner plates. An ironic note is that oysters are considered a very good seafood choice today, since they are not wild caught (farm raised) and filter the water while they grow. (Not all farm raised seafood is a good choice though. Farm raised salmon and shrimp are major sources of pollution and habitat destruction).

Assessment

Ask students to apply what they learned from the ocean ecosystem to terrestrial ecosystems. Show students a food web of a historic local forest/pond ecosystem and asked them how people disrupt it. Students can relate it to historic overhunting, deforestation, or the introduction of invasive species.

References

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