The "Greening" of the Chesapeake: How Fishing and Farming Affect Estuarine Ecosystems

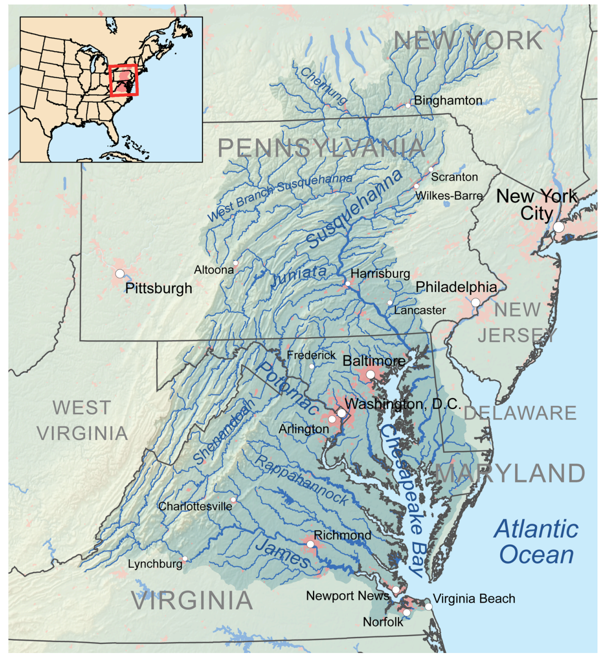
Background

Daily Life and The Chesapeake:
The Chesapeake Bay is the largest and most productive estuary in the United States. The watershed encompasses over 64,000 square miles of land in 6 states, and more than 17 million people live in the Chesapeake Bay watershed.

The Chesapeake Bay is also one of the most economically productive ecosystems in North America. In the 1700s, colonists who farmed the land around the bay and engaged in some small-scale fishing settled the bay. Later a commercial fishing industry grew up around the bay and people began to harvest blue crabs, clams, striped bass and oysters. In the 1950s, the harvesting peak, the fishing and shellfish industries employed over 9000 people.

The "Greening" of the Bay: The Chesapeake has experienced serious problems in recent years. Algal blooms caused by excess nitrogen have plagued the bay. They can be so extreme that the bay appears green in satellite images.

The Chesapeake Bay Watershed



The Chesapeake Bay Watershed encompasses six states and the District of Columbia

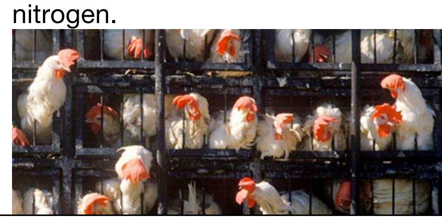
An image of the Chesapeake from space.
The green "halo" along the shoreline is an algal bloom.

The blooms are usually caused by nitrogen in run-off from fertilizer and large factory farms. Algal growth is normally limited by low nitrogen levels, but when nitrogen from land is added to aquatic ecosystems, algae populations can rapidly grow. However, these large algae populations soon die, and microbes begin break down the algae tissue in the water. Microbial respiration requires oxygen, and decomposing the excess algae can deplete oxygen from the water. These areas of deoxygenated water can kill fish and invertebrates causing "dead zones" in the water. For many years, scientists thought that the "greening" bay was due to pollution and run off alone. However, in recent years researchers began to examine the role of food webs in ecosystems in preventing algal blooms.

Box 2: Algal Blooms and Nutrient Pollution:

- In normal ecosystem low nutrient levels keep algae in check
- Adding nutrients causes algal blooms
- Algae die and become detritus (decaying matter)
- Detritus is decomposed by microbes, microbe populations boom.
- Microbes use the oxygen in the water
- Low dissolved oxygen in the water kills fish and other organisms
- Dead zones appear in the bay where nothing can live

The figure to the left shows how nutrient pollution (nitrogen rich run-off) can cause algal blooms. When large amounts of algae die microbes decompose them. Microbes use oxygen in decomposition, and when they decompose large amounts of algae they can deplete the oxygen in the water and cause "Dead Zones". Nitrogen can come from several sources on land: fertilizer from farms contains nitrogen. However, factory farms also produce large amounts of animal waste which also contains nitrogen.

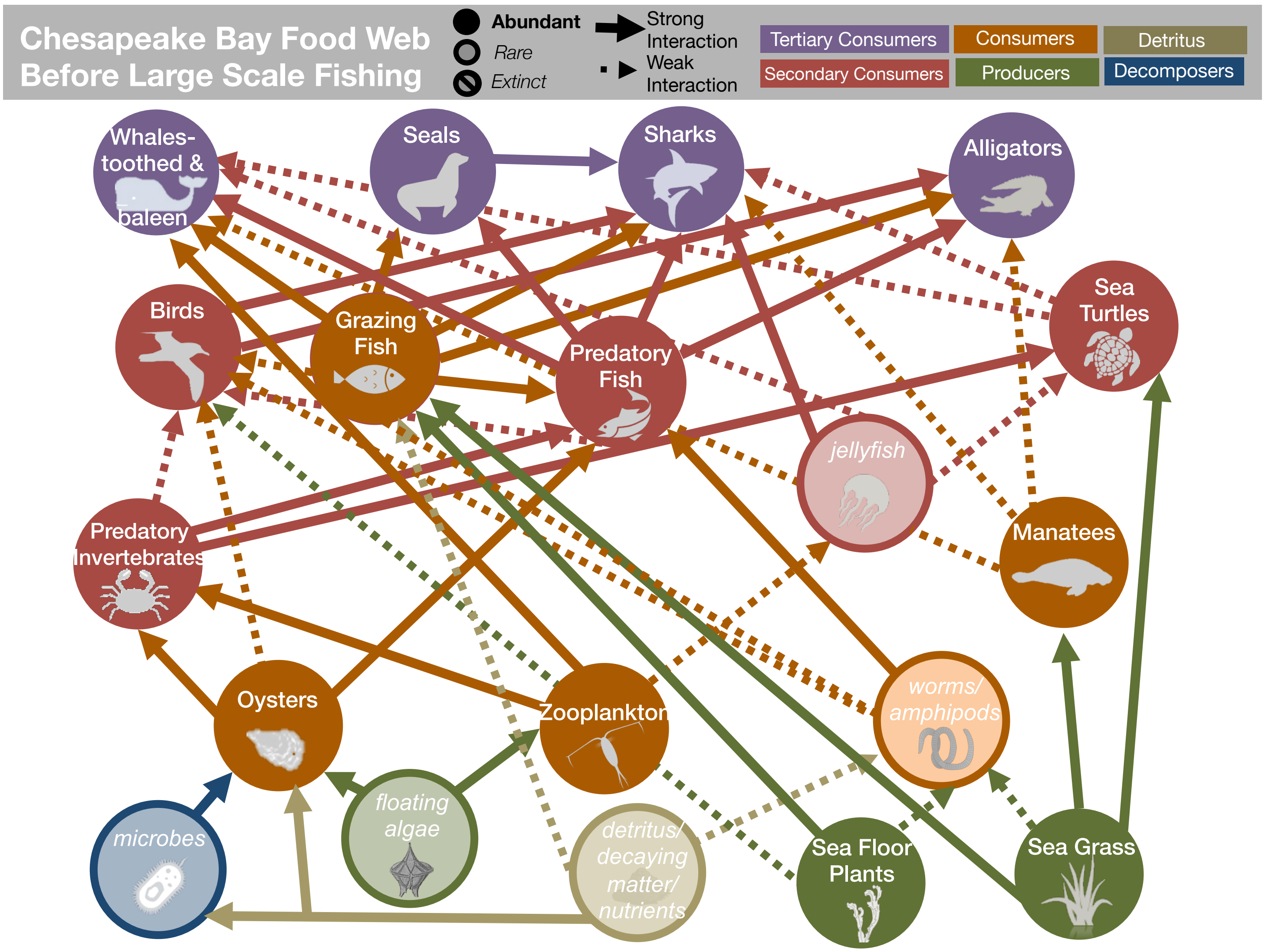


Investigating Food Webs Past and Present: Researcher Jeremy Jackson of the University of California at San Diego became interested in how food webs have changed over time and how this might affect the algae blooms. To determine how food webs were affecting algae blooms, he and his research team used from many sources to reconstruct a picture of the Chesapeake Bay ecosystem before large-scale fishing. First, they collected data from marine sediment to measure how algae levels had changed over time. To tie these algae levels to changes in the food web and human use, he and his team used information from a variety of sources. Jackson and his group used data from archaeological records to determine how people used the Chesapeake before large-scale fishing. They also used historical documents to determine what organisms were harvested and sold. Finally, they used modern scientific studies from the past 100 years to determine the structure of food webs in the Chesapeake Bay currently. In this case study, you will use the food webs reconstructed by Jackson and his research group, as well as data on algae levels and fisheries records to determine how humans have affected the Chesapeake Bay ecosystem.

Name________________ Class: _______________ Date: _____________

Part 1: The Chesapeake Before Fishing

In these activities you will be investigating how fishing and farming affected the Chesapeake Bay ecosystem Analyze the food web (re-visualized from Jackson et.al's paper) to answer the following questions about the Chesapeake Bay ecosystem prior to large-scale fishing.



1. Examine the food web before humans began fishing the Chesapeake (above). Notice which groups of species are abundant (dark circles) and which groups of species are rare (light circles). Color or check the squares on the chart below to indicate which species were rare or abundant.

	Whales	Sharks	Seals	Alligators	Birds	Predatory Fish	Sea Turtles	Predatory Invertebrates	Jellyfish	Grazing Fish	Oysters	Worms/Amphipods	Manatee	Zooplankton	Floating Algae	Sea Grass	Sea Floor Algae	Microbes	Worms/Amphipods	Detritus/Decaying Matter
Abundant																				
Rare																				
	A				B					C					D			E		F

2. Are most species groups abundant or rare? Which species groups are rare?

3. The species groups in the chart above and are organized by trophic level. Write the name of the trophic group (i.e. producer, consumer, etc.) for groups A, B, C, D, and E and include a brief explanation of how each group interacts with other trophic levels.

A.

B.

C.

D.

E.

4. How is it possible that the worms/amphipods are considered part of two groups?

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5. What is group F? What is the role of detritus in the food web?

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6. List the number of strong and weak interactions for each of the species groups listed at the top of this chart. Count the number of strong and weak connections (arrows going to or from a species group) to complete the chart below:

Connection	Sea Floor Plants	Predatory Fish	Grazing Fish	Floating Algae
Strong: → Weak: ⇢ Total:	Strong: Weak: Total:	Strong: Weak: Total:	Strong: Weak: Total:	Strong: Weak: Total:

7. The producers can be organized based on where they are found in the water. Some float and some grow from the seabed. Which producer's float and which producers grow from the sea bottom?

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8. In this ecosystem, which type of producers are more abundant, the producers that float or the producers that grow from the sea bottom?

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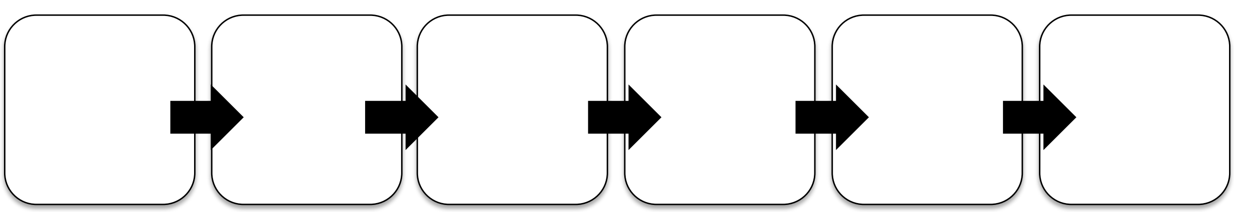
9. Find and write out a six -step food chain:



10. Compare this food chain to a food chain that you find on land. How do they compare in length? Why do estuary food chains appear to be a different length than food chains on land?

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11. If whales and turtles become rare in this ecosystem what would you expect to happen to the number of jellyfish?

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12. If whales, sharks, seals and alligators were removed from the ecosystem what would you expect to happen to the numbers of predatory fish?

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13. If the oyster population was reduced what would you expect to happen to the quantity of microbes, floating algae and detritus?

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14. If fertilizer and nutrients were added to the Chesapeake Ecosystem, how would that affect primary producers?

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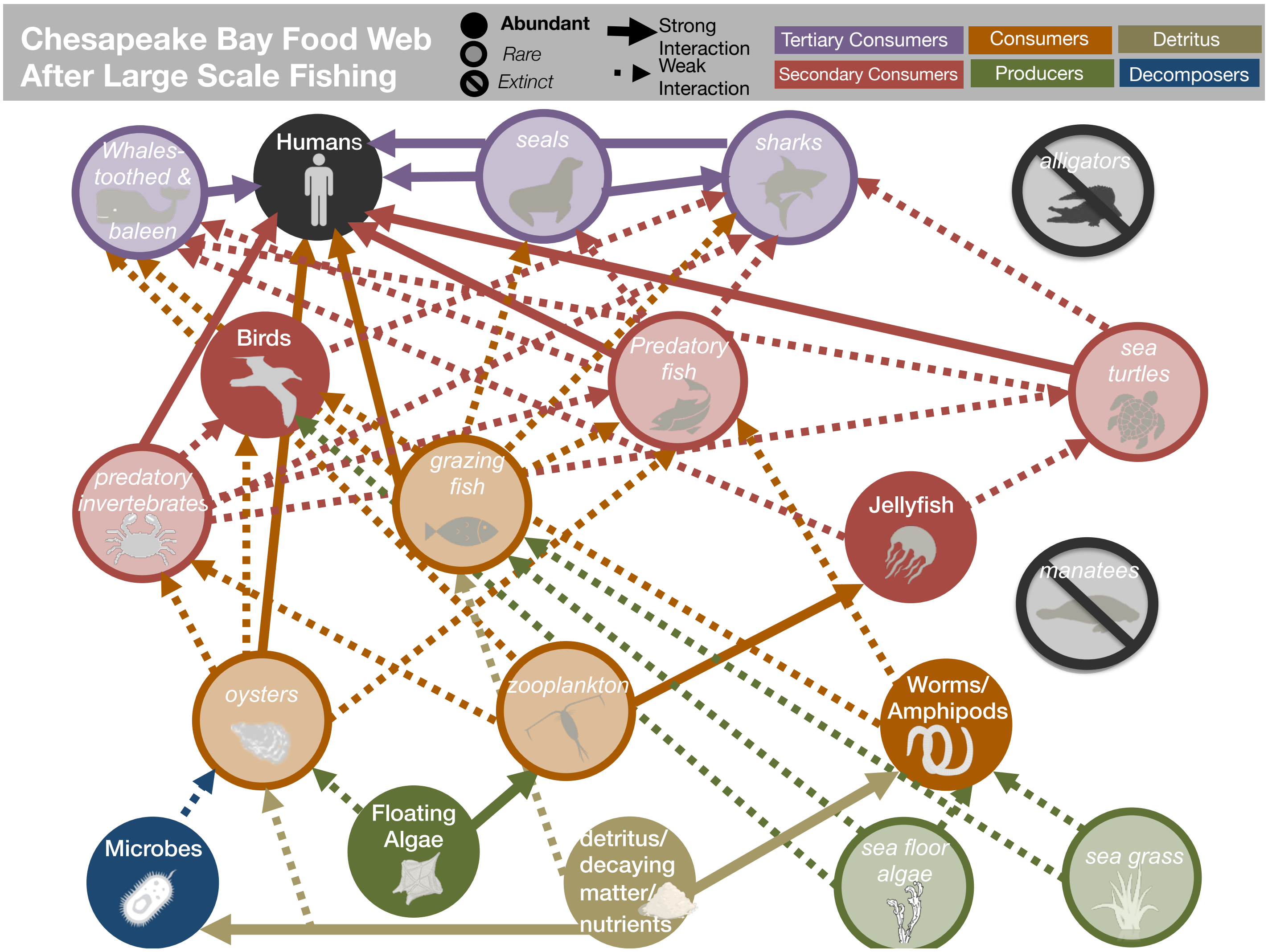
Part 2: The Chesapeake after Fishing and Farming

Analyze the food web (also re-visualized from Jackson et.al. 2010) to answer the following questions about the Chesapeake Bay ecosystem prior to large-scale fishing.



1. Now examine the food web *after* humans became part of the Chesapeake Bay ecosystem through fishing. Complete the same chart that you completed for the previous food web, and color or check which species groups are now rare or abundant. If a species has gone extinct, then cross out both boxes with an X.

	Whales	Sharks	Seals	Alligators	Birds	Predatory Fish	Sea Turtles	Predatory Invertebrates	Jellyfish	Grazing Fish	Oysters	Worms/Amphipods	Manatee	Zooplankton	Floating Algae	Sea Grass	Sea Floor Algae	Microbes	Worms/Amphipods	Detritus/Decaying Matter
Abundant																				
Rare																				
	A				B					C					D			E		F

2. Which organisms went locally extinct?

3. Are more species groups rare or abundant after large-scale fishing? Which organisms are abundant?

4. Are these the same organisms that were abundant in the pre-human food web?

5. What happened to the tertiary consumers? Were they more or less affected than other trophic groups?

6. List how many species groups depend on each of the species groups listed at the top of this table. Count the number of strong and weak connections (arrows going to or from a species group) to complete the table below:

Connection	Sea Floor Plants	Predatory Fish	Grazing Fish	Floating Algae
Strong: Weak: Total:	Strong: Weak: Total:	Strong: Weak: Total:	Strong: Weak: Total:	Strong: Weak: Total:

7. In general, do these species groups have more connections or less after fishing?

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8. How does the strength of the interactions compare between this food web and the one before fishing?

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9. What does it mean for the ecosystem when most of the interactions are weak?

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10. Redraw the food web including only the abundant species? What do you notice?

11. How is this food web similar/different to the food web without people?

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12. Why do you think jellyfish are now abundant?

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13. Why are there fewer predatory fish if there are fewer whales, sharks, seals and alligators?

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14. Which producers are now more common in this ecosystem, the floating algae or the sea floor algae and plants and sea grass?

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15. From what you know about the relationship between high levels of nutrients and algae growth, why have the floating algae increased?

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16. What happened to the sea floor algae and plants? If fewer organisms are eating them, shouldn't their numbers have increased? Why are they rare now? Hint: Like all plants, what do the sea floor algae and plants need to grow? How do more floating algae limit the resource that plants need? Explain.

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17. How does this food web connect to the present-day problem of high nutrient levels in the ocean? Use the food web to explain how harvesting oysters affected the levels of detritus and floating plankton.

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18. Based on your answer to question seventeen make a hypothesis for how catching oysters affects floating algae levels?

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19. What type of data would you need to collect in order to test your hypothesis? Hint: You would need to compare historic and present day data on two elements of the ocean. What are those elements?

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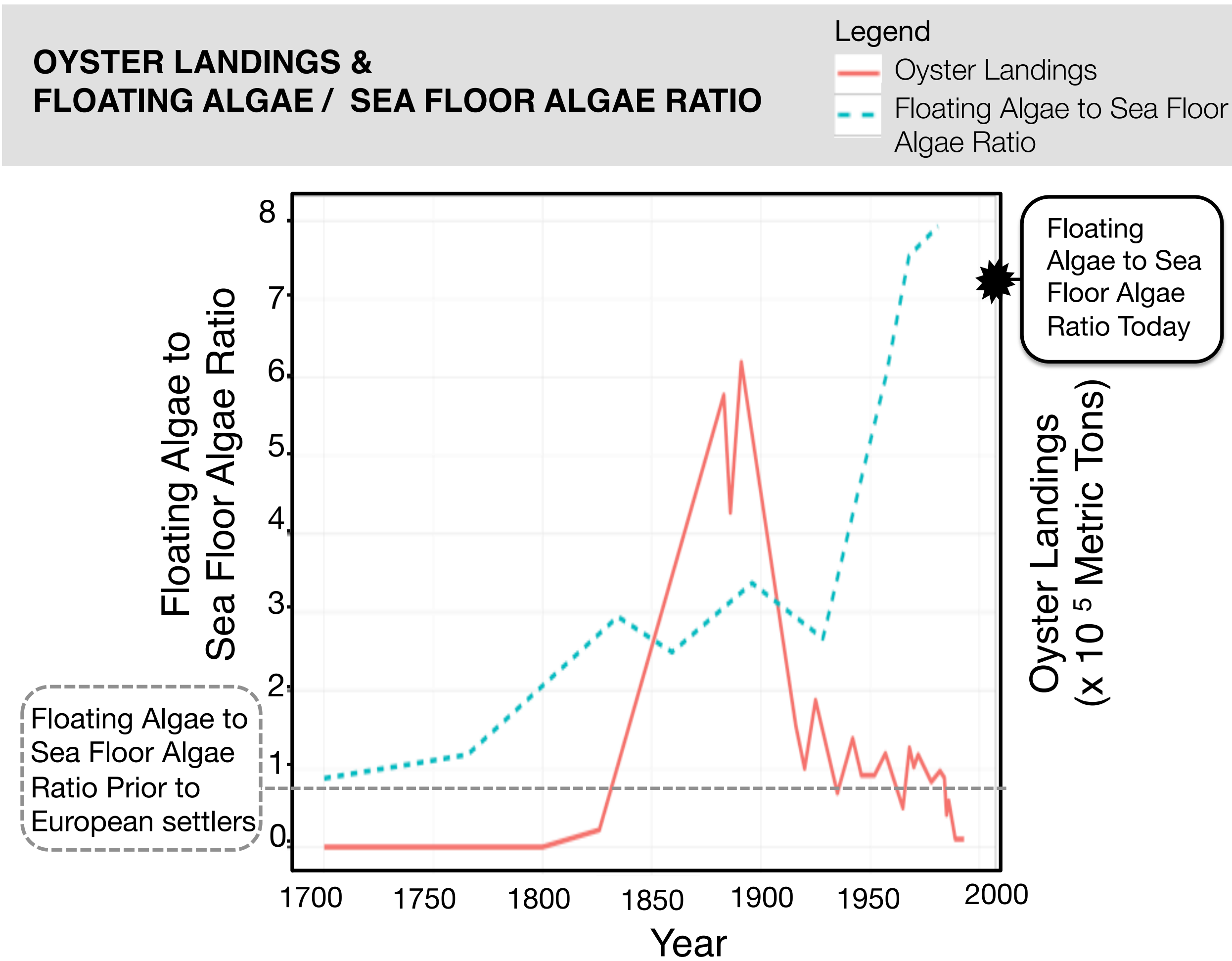
Part 3: Oyster Catch and Nutrient Levels in the Chesapeake Bay

Testing the hypothesis that oysters maintain healthy floating algae levels in the Chesapeake. This graph was made using the data on algae levels from marine sediment and historical records of oyster harvests collected by Jeremy Jackson's research group.



1. What was the ratio of floating algae to sea floor algae in 1700?

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2. How does it compare to the ratio today?

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3. What does the increase in floating algae indicate about today's level of nutrient pollution as opposed to the nutrient levels 300 years ago?

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4. Why do you think the ratio of floating algae to sea floor algae levels in the Bay began to increase around 1750 (before major oyster harvesting began)? (Hint: In the 1700s Europeans settlers began to establish farms in the Chesapeake region).

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5. Did the increase in the ratio of floating algae to sea floor algae in 1750 have anything to do with the oyster catch? Why or why not?

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6. The ratio of floating algae to sea floor algae held steady for a very long time at around three and then suddenly increased towards eight starting after 1930. Use your graph to determine what happened to the oyster catch over the same time period.

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7. How might the decline of oysters lead to the sudden increase in the ratio of floating algae to sea floor algae levels? Use what you know about the role of oysters in the Bay food web to answer this question.

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8. How does this graph help us to understand how oysters affect the ratio of floating algae to sea floor algae?

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9. Why are so few oysters being caught today as compared to the end of the 1800s?

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10. How would you propose to solve the problem of algae overgrowth and also help the oyster industry?

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Part 3: Synthesis and Solutions

1. How have humans affected the Chesapeake Bay food web?

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2. Explain the role that oysters play in keeping the ratio of floating algae to sea floor algae levels of the Bay healthy.

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3. Use your food webs, charts and data from part III to list at least five consequences of the altered food web of the Chesapeake Bay.

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B.____

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C.____

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D.____

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E.____

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4. How can understanding historic ecosystem food webs help us understand today's ecosystems?

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Creating Artificial Habitat to Restore Oysters

Oyster larvae spend their first few weeks of life as floating zooplankton but they need a hard substance to attach to in order to develop into adults. Dredging of the sea floor by the oyster fishery has removed many natural oyster reefs and oyster larvae cannot find an appropriate location to settle. Scientists can create artificial oyster reefs from concrete or from old oyster shells to help young oysters get established. Larvae settle on the surface of the artificial reef and can establish new oyster colonies

5. Imagine that you are a biologist in charge of restoring oysters to the Chesapeake. You and your colleagues will create artificial reefs made of oyster shells and then place oyster larvae on them. You must create a monitoring plan to ensure that the new oysters are improving the health of the bay.

A. List at least groups of species you can measure to see if restoration is helping?

1.____________________ **3.** ____________________

2.____________________ **4.** ____________________

B. Describe for groups of species what trends or changes in abundance would indicate that the bay is becoming healthier:

1.____

2.____

3.____

4.____