DATA Nugget

Urbanization and Estuary Eutrophication

Featured scientists: Charles Hopkinson from University of Georgia and Hap Garritt from the MBL Ecosystems Center

Research Background:

An estuary is a habitat formed where a freshwater river or stream meets a saltwater ocean. Many estuaries can be found along the Atlantic coast of North America. Reeds and grasses are the dominant type of plant in estuaries because they are able to tolerate and grow in the salty water. Where these reeds and grasses grow they form a special habitat called a **salt marsh**. Salt marshes are important because they filter polluted water and buffer the land from storms. Salt marshes are the habitat for many different kinds of plants, fish, shellfish, and birds.

Scientists are worried because some salt marshes are in trouble! Runoff from rain washes nutrients, usually from lawn fertilizers and agriculture, from land and carries them to estuaries. When excess nutrients**,** such as **nitrogen** or **phosphorus**, enter an ecosystem the natural balance is disrupted. The ecosystem becomes more productive, called **eutrophication**. Eutrophication can cause major problems for estuaries and other habitats.

With more nutrients in the ecosystem, the growth of plants and algae explodes. During the day, algae photosynthesize and release O_2 as a byproduct. However, excess nutrients cause these same algae grow densely near the surface of the water, decreasing the light available to plants growing below the water on the soil surface. Without light, the plants die and are broken down by decomposers. Decomposers, such as bacteria, use a lot of O_2 because they respire as they break down plant material. Because there is so much dead plant material for decomposers, they use up most of the O_2 dissolved in the water. Eventually there is not enough O_2 for aquatic animals, such as fish and shellfish, and they begin to die-off as well.

View of a salt marsh in Plum Island Estuary. Photo by Harriet Booth.

Two features can be used to identify whether eutrophication is occurring. The first feature is low levels of dissolved O_2 in the water. The second feature is when there are large changes in the amount of dissolved O_2 from dawn to dusk. Remember, during the day when it's sunny, photosynthesis converts CO_2, water, and light into glucose and O_2. Decomposition reverses the process, using glucose and O_2 and producing CO_2 and water. This means that when the sun is down at night, O_2 is not being added to the water from photosynthesis. However, O_2 is still being used for decomposition and respiration by animals and plants at night.

Scientists Charles and Hap have studied estuaries most of their careers. Over time they noticed a serious decline in estuary health worldwide. The health of their local estuary, Plum Island Estuary in Massachusetts, appeared to be declining over time as well. They noticed a loss of salt marsh habitats, and that the remaining salt marshes had fewer fish. They thought that urbanization nearby might be causing these losses. Charles and Hap set out to test if the loss of salt marshes in Plum Island Estuary was occurring because of eutrophication from large amounts of excess nutrients entering the estuary in runoff from the nearby urban areas.

The scientists focused on two locations in the Plum Island Estuary and measured **dissolved O_2 levels**, or the amount of O_2 in the water. They looked at how the levels of O_2 changed throughout the day and night. They predicted that the **upper** part of the estuary would show the two features of eutrophication because it is located near an urban area. They also predicted the **lower** part of the estuary would not be affected by eutrophication because it was farther from urban areas.

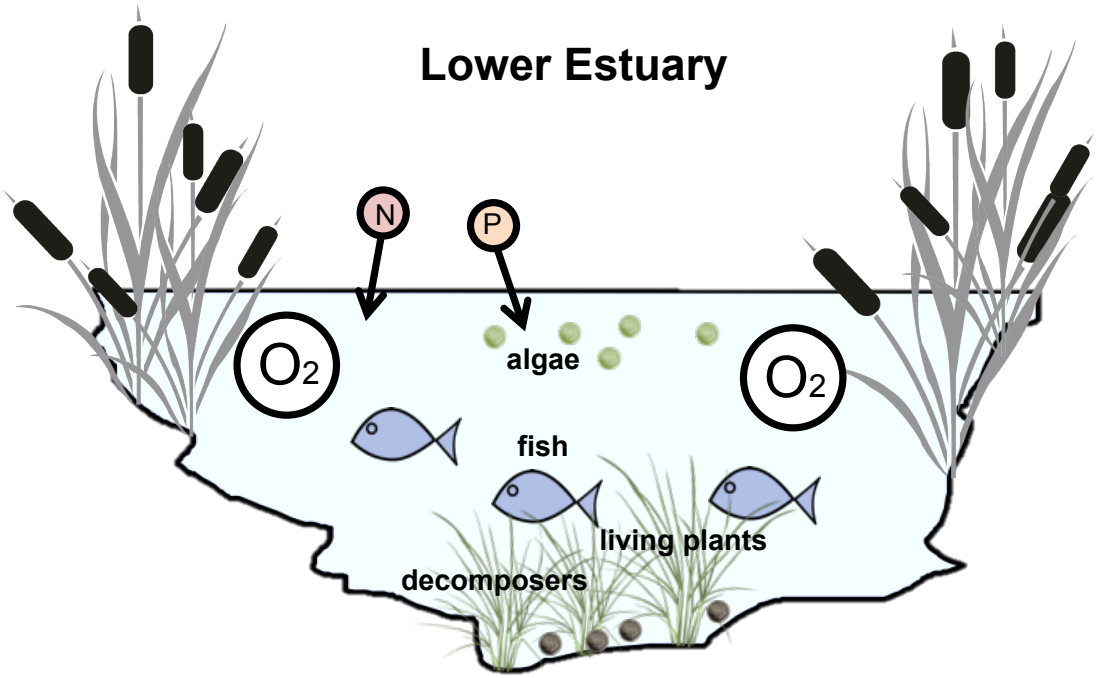
Hap Garritt removing an oxygen logger from Middle Road Bridge in winter.

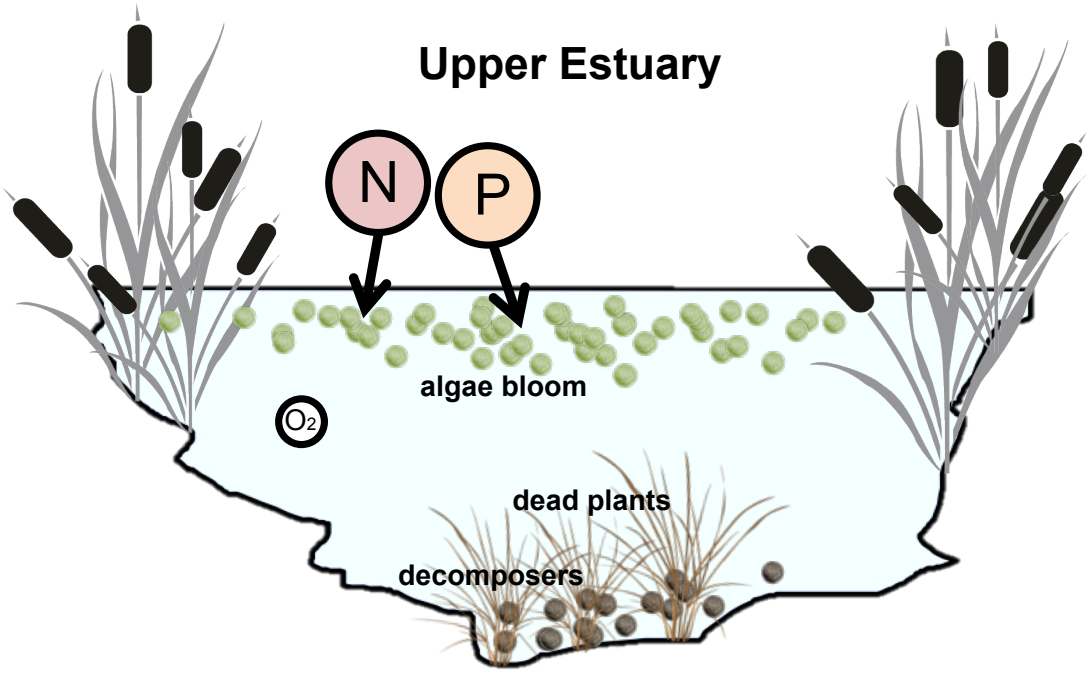
Scientific Question: What are the effects of urbanization on salt marshes in the Plum Island Estuary?

What is the hypothesis? Find the hypothesis in the Research Background and underline it. A hypothesis is a proposed explanation for an observation, which can then be tested with experimentation or other types of studies.

Charles Hopkinson out taking dissolved O_2 measurements.

Draw your predictions: Fill in the diagram to show your predictions for the upper and lower parts of the Plum Island Estuary. Be sure to include the following organisms: 1) algae, 2) plants, 3) decomposers, and 4) fish. Also include your predictions for levels of 1) nitrogen (N), 2) phosphorus (P), and 3) dissolved oxygen (O_2) in each location. Label each part of your diagram or create a legend.





Scientific Data

Use the data below to answer the scientific question: Teacher Hint: Students will have to complete the tables and make two graphs. For Graph 1, students must calculate Average Dissolved O_2 for the upper and lower estuary. For Graph 2, students will have to calculate the range of dissolved O_2 between dawn and dusk.

Part of Estuary	Sample number	Dawn O_2 (mg/l)	Dusk O_2 (mg/l)	Fluctuation in Dissolved O2 (dusk - dawn)
Upper Estuary	1	10	11	1
Upper Estuary	2	7	12	5
Upper Estuary	3	7.5	10	2.5
Lower Estuary	1	11.2	12.8	1.6
Lower Estuary	2	8.5	9.5	1
Lower Estuary	3	9	10	1

Dissolved O2				
Part of Estuary	Dawn Mean	Dawn SE	Dusk Mean	Dusk SE
Upper Estuary	8.2	0.9	11.0	0.6
Lower Estuary	9.6	0.8	10.8	1.0

Fluctuation in Dissolved O2		
Part of Estuary	Mean	SE
Upper Estuary	2.8	1.2
Lower Estuary	1.2	0.2

What data will you graph to answer the question?

Graph 1:

Independent variable: Part of Estuary (upper or lower)

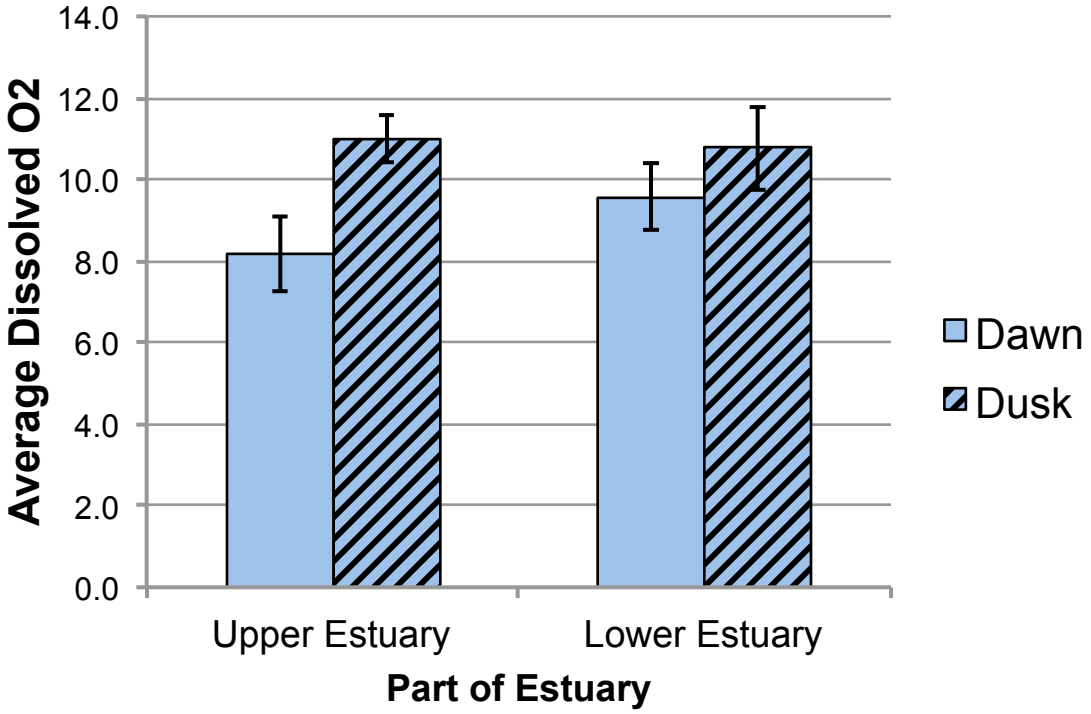
Dependent variable: Average Dissolved O_2 at dawn and dusk

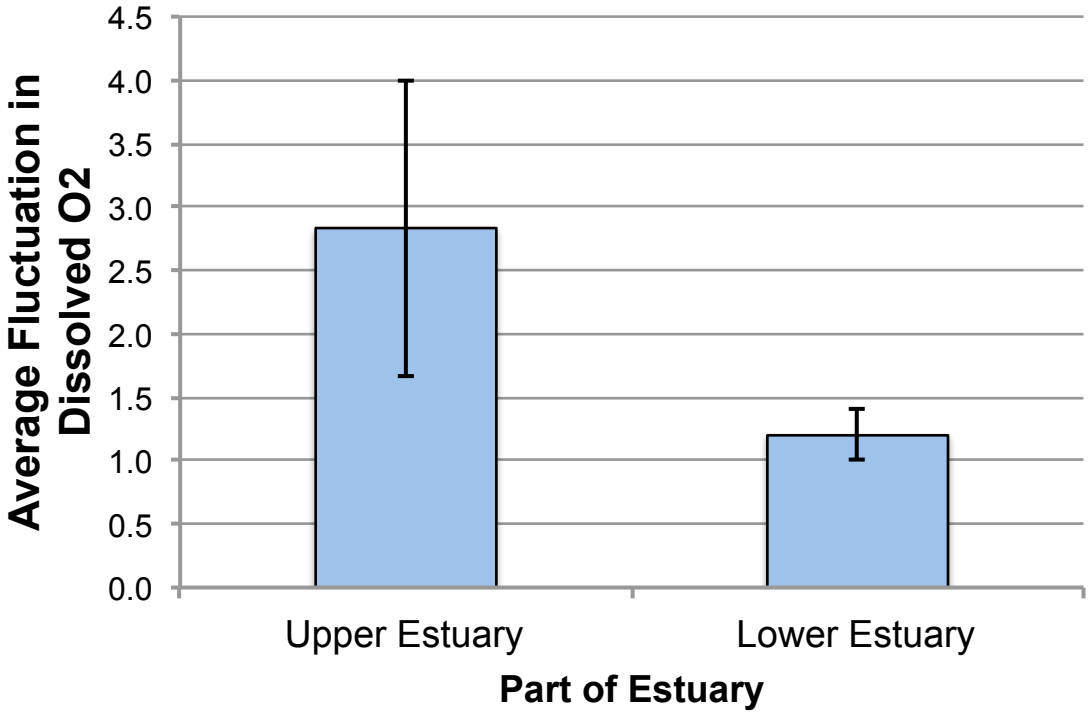
Graph 2:

Independent variable: Part of Estuary (upper or lower)

Dependent variable: Average Daily Fluctuation in Dissolved O_2 (difference between dusk and dawn measurements)

Draw your graphs below:





Interpret the data:

Make a claim that answers the scientific question.

Urbanization appears to be causing some signs of eutrophication in the Plum Island Estuary, but more data is needed.

Support your claim using data as evidence. Describe the relationship between the dependent and independent variables. Refer to specific parts of the table or graph.

There are no signs of the first feature of eutrophication. At the upper location in the estuary, dawn dissolved O_2 is 8.2 mg/l and dusk is 11.0 mg/l. This is very similar to the 9.6 mg/l and 10.8 mg/l dissolved O_2 levels in the lower part of the estuary, far from urban areas.

There is evidence that the second feature of eutrophication is occurring in the upper part of the marsh near urban areas. The upper part experienced large daily swings in dissolved oxygen levels. On average, dissolved O_2 fluctuated by 2.8 mg/l per day. The lower part experienced low daily swings in dissolved oxygen levels compared to the upper part. On average, dissolved O_2 fluctuated by only 1.2 mg/l per day.

Describe your scientific reasoning and explain how the evidence supports your claim.

The upper part in Plum Island Estuary shows just 1 of the 2 features of eutrophication. Dawn and dusk levels of dissolved O_2 are similar in both the upper and lower estuary. This means that the upper part near the urban area is not showing the first feature of eutrophication. The dissolved O_2 fluctuation data tells a different story. Fluctuations in the upper part were more than twice that of the lower part, meaning that the upper part of the estuary is showing the first feature of eutrophication

What do the data from this study tell us about the scientist's hypothesis?

The data partially supports the hypothesis that the loss of salt marshes in Plum Island Estuary is driven by eutrophication, caused by large amounts of excess nutrients entering the estuary from urban areas. While the upper part near the urban area has a greater fluctuation in dissolved O_2 it does not show a lower level of dawn or dusk dissolved O_2. Evidence for the hypothesis is mixed.

Your next steps as a scientist: Science is an ongoing process. What new question do you think should be investigated? What future data should be collected to answer this question?

One important feature of this dataset to bring up to students is the lack of replication in the experimental design. In this experiment, 1 replicate = 1 site near urbanization paired with 1 site far from urbanization. The scientists only measured data for 1 location near urbanization and 1 location lower in the estuary. Even though students averaged data from three samples, this does not count as replication, just more thorough sampling of each location.

Because there is no replication, it is impossible to tell from this dataset if proximity to an urban area is responsible for increased eutrophication, or if some other feature that differs between the two sites is driving the pattern. Have a discussion with students about how future data collection could remedy this issue. If there are multiple estuaries like Plum Island, data could be combined across 3+ estuaries, each with a site near urbanization and away. If all three showed the same patterns of increased eutrophication near urban areas, we would have much better evidence that urbanization was driving these patterns.

Future research could include:

- Measuring differences in nitrogen/phosphorous levels at the upper and lower parts of the estuary to see if there is evidence that nutrients are entering the system from urban areas.
- Determining whether there are any additional indicators that eutrophication is occurring at the upper location. Indicators could include decreased plant, fish and shellfish productivity or reduced water clarity.
- Are there any other human/environmental factors that differ between the upper and lower parts? For example boating, swimming, noise pollution, or other features of urbanization could cause the lack of fish and other wildlife in the upper part of the estuary. These serve as alternative hypotheses to eutrophication.
- How can we attempt to minimize eutrophication within susceptible parts of the estuary? Scientists and students could investigate suburban lawn management and agricultural practices within the watershed.