

Name \_\_\_\_\_

Date \_\_\_\_\_

## Effects of Zebra Mussels on the Hudson River

How has the zebra mussel invasion changed the Hudson River ecosystem? In this activity, you will discover some of these changes using data collected by scientists.

### **Part 1: How did we get this data?**

Read the following paragraphs, written by the researchers, about how they collected the zebra mussel data over a long period of time. Then answer the questions that follow.

These data are annual means of several important ecological variables for the growing season (May 1-September 30) for the freshwater tidal Hudson River in eastern New York State. They were collected as part of a long-term study of the Hudson River ecosystem by researchers at the Cary Institute of Ecosystem Studies, started in 1991 and continuing today. This work was supported by grants from the Hudson River Foundation, the National Science Foundation, New York Sea Grant, and the Hudson River Estuary program of the New York State Department of Environmental Conservation (we note that none of these funding agencies endorses or guarantees these data or the conclusions we reach from the data).

Zebra mussel populations are sampled using divers and grabs. Populations living on hard bottoms are sampled by a diver, who collects 10 rocks at each of 7 sampling sites in June and again in August. These rocks are put into coolers and returned to the lab, where zebra mussels are counted and the projected area of the rock estimated by tracing its outline. A subset of zebra mussels are measured for shell length ( $n=300/\text{site}$ ) and to develop length-dry mass regressions ( $n=50/\text{site}$ ), and samples are archived in ethyl alcohol and in the freezer. Populations living on soft bottoms are sampled in July using a standard PONAR grab ( $0.05 \text{ m}^2$ ) at 48 sites deployed in a stratified random design throughout the freshwater estuary. We identify, count, measure, and weigh all native unionid bivalves, continuing our long-term study of these animals and their response to the zebra mussel invasion (Strayer et al. 1994, Strayer and Smith 1994, 1996).

Phytoplankton are sampled weekly at our long-term station near Kingston throughout the year and in 2 sets of spatially distributed samples. We sample phytoplankton and many other variables (see below) at 6 "cardinal stations" arrayed over 120 km of the Hudson 4-6 times per year. In addition, 4-6 times a year, we sample phytoplankton and basic water chemistry and clarity every 2-4 km along the entire freshwater tidal Hudson River. Zooplankton are sampled every 2 weeks during the ice-free season at our long-term study site near Kingston. All plankton samples are taken in triplicate.

In addition to these key variables, we measure water temperature, light penetration, pH, dissolved oxygen, suspended sediments, dissolved and particulate organic matter, dissolved inorganic carbon, dissolved inorganic and total nitrogen and phosphorus, and bacterioplankton abundance and productivity in our weekly samples at Kingston and at the 6 cardinal stations (Caraco et al. 1997, 2000, 2004, Raymond et al. 1997, Findlay et al. 1991, 1998, Lampman et al. 1999, Findlay 2004).

1. How did the scientists collect the zebra mussel data? For how long have they been collecting it?
2. How do the scientists collect phytoplankton and water chemistry data?
3. Why do you think long-term monitoring of ecosystems is important?
4. What are the variables in this research project?
5. In order to have an idea of how many zebra mussels exist in the Hudson River, what would be better: to collect 10 rocks at 7 sites, 70 rocks at one site, or 2 rocks at 35 sites? Why? Why do you think the scientists involved in this study decided to collect 10 rocks at 7 sites?

## **Part 2: Organism Changes**

In the Excel datasheet, open the tab that says ‘organisms’ at the bottom. Create a graph showing the changes in the zebra mussel density and the unionid mussel density over time (unionids are native pearly mussels, often called freshwater clams). You will have to create a secondary axis to show both of these mussels on the same graph, because there are so many more zebra mussels than unionids.

Next, create three graphs to show the relationship between zebra mussels and plankton in the river.

Graph A: Zebra mussels and phytoplankton (measured as chlorophyll a)

Graph B: Zebra mussel and rotifers

Graph C: Zebra mussels and cladocerans

Once you have completed your graphs, answer the following questions:

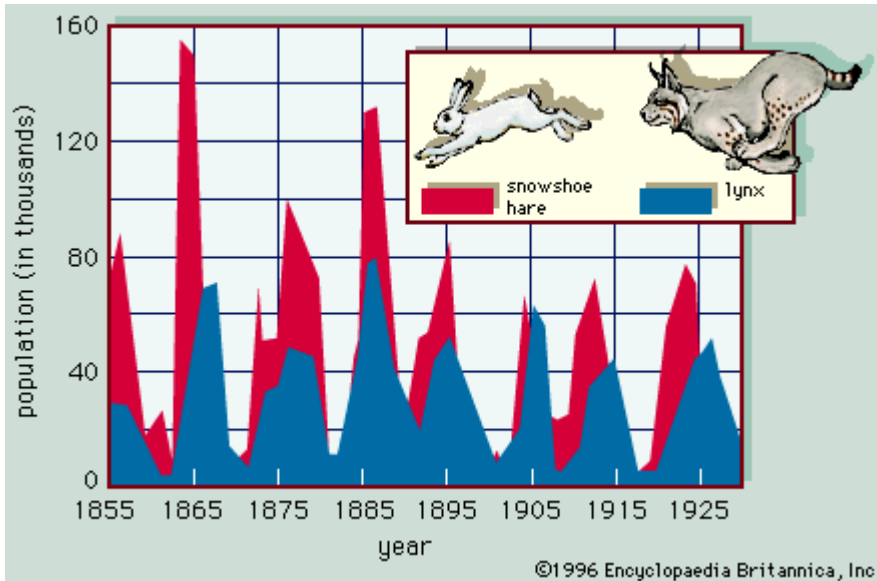
1. Why was the zebra mussel population at zero for the first part of the graph? When did the zebra mussel population increase? Describe the changes within the zebra mussel population since their arrival.
2. What happened to the native mussel population after the zebra mussels arrived?
3. Why do you think the zebra mussel population numbers go up and down over time?
4. Do you think there is a trend in the unionid population, or is it just by chance that the native population is decreasing? You, just like scientists, can use statistics to prove this trend actually exists, and isn't just something you *think* you observe.

Add a trendline to the unionid data of your graph, and ask Excel to display the r-squared ( $r^2$ ) value. To do this, click somewhere on the line of the unionid data, and right click for the option “Add trendline.” In the “add trendline” box that pops up, mark that you want to display the r-squared value on the chart. If the  $r^2$  value equals “1.0,” it means that the mathematical model (i.e. the linear mathematical relationship you are suggesting exists between the unionid and zebra mussels) is explaining all of the data points. If the  $r^2$  value is “0.0,” it means that there is no linear relationship. Nearly all  $r^2$  values are somewhere in between; the higher the value, the more confidence you can have that the mathematical relationship you are suggesting is real.

Describe the trendline on the graph. What is the  $r^2$  value of the unionid population?

5. Create a trendline for the zebra mussel population, along with an  $r^2$  value. Explain what you see in the trendline, and give the  $r^2$  value. Why do you think this  $r^2$  is not as high as the unionid  $r^2$ ?
6. Based on Graph A, what can you say about the phytoplankton population based on the data you see? Is there a trend? What consequences might these changes have on other parts of the Hudson River food web?
7. Based on Graph B, what can you say about the rotifer population? What consequences might these changes have on other parts of the Hudson River food web?
8. Based on Graph C, what can you say about the cladoceran population? What consequences might these changes have on other parts of the Hudson River food web?

9. The following graph shows the population size of hare and lynx through time. What basic principle of population ecology does this data demonstrate? Explain the relationship between these two animals, demonstrated by their population curves in the graph. Do the zebra mussels have the same effect on the plankton populations? Why or why not?



### Part 3: Chemistry Changes

Now that you've discovered something about how the arrival of the zebra mussels changed zooplankton and phytoplankton communities in the Hudson River, create another graph to display the changes in water chemistry. In the same excel spreadsheet, open the sheet that says 'chemistry' at the bottom. Create a graph of the annual mean of water transparency (measured with a secchi disk; higher values indicate greater water clarity; y-axis) versus zebra mussel population density (x-axis). Next, choose one of the other variables, and create a graph showing how that variable changed as the zebra mussel population increased and decreased. Then, answer the questions that follow.

10. Based on your graph of the relationship between water transparency and zebra mussel population density, what can you conclude about the effects of the invasion?
11. Which factors regulate the transparency of the water? Which factors do the zebra mussels control? What else would you need to know before deciding if the invasion of the zebra mussels affected the transparency of the water?
12. If water transparency changes, how might that affect the other organisms in the Hudson River?
13. Using the second graph you created, explain how the chemistry of the Hudson River changed over time. Describe the relationship (if any) that you see between the changes in the chemistry and the zebra mussel population. What other factors might influence the changes in water chemistry?

**Part 4: Synthesis**

14. Do you think all of these changes are a direct result of the invasion of the zebra mussel? Is there anything else that could have caused some of these changes? If so, what?
15. There are statistical techniques that allow researchers to quantify the effects of different factors on the plankton communities. Because these are complex computations, we will not replicate them in the classroom, but scientists employed these techniques and found that the changes are indeed primarily caused by the zebra mussels.

Summarize the changes that have taken place in the Hudson since the arrival of the zebra mussel, referring specifically to graphs that you created to support your claims. Hypothesize how these observed changes might affect other parts of the food web.