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 local 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/site) and to develop length-dry mass regressions (n=50/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 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 live in the Hudson River, the scientists decided to collect 10 rocks at 7 sites. Why do you think this may be better than, say, collection 70 rocks at one site? What might be a problem with collecting only 2 rocks at 35 sites? Why?

Part 2: Organism Changes

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 may have to graph these on two separate graphs or use two y-axes with different scales, since the population numbers are very different and may be difficult to fit onto one graph.

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

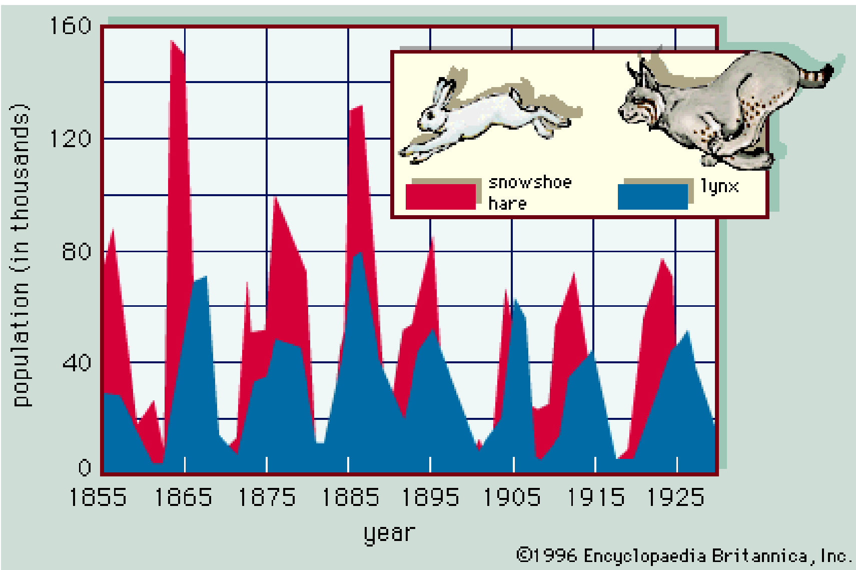
Graph A: Zebra mussels and phytoplankton (measured as chlorophyll a-- The amount of chlorophyll a in the water gives a good approximation of the amount of phytoplankton in the water.)

Graph B: Zebra mussel and rotifers

Graph C: Zebra mussels and cladocerans

Once you have completed your graphs, you should be able to 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. Based on Graph A, what can you say about the phytoplankton population from the data you see? Is there a trend? What consequences might these changes have on other parts of the Hudson River food web?
5. 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?
6. 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?
7. 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

Refer to **Table 2** to complete the activity and answer the following questions.

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. Graph the annual mean of water clarity (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.

1. a. In which year was the water at its clearest?
   b. In which year was it least clear?
   c. What relationship do you see, if any, between water clarity and the zebra mussel population?
2. Which factors regulate water clarity? Which factors do the zebra mussels control? What else would you need to know before deciding that the zebra mussel invasion affected water clarity?
3. If water transparency changes, how might that affect the other organisms in the Hudson River?
4. 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

1. 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?
2. 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.

Table 1. Hudson River **population data** pre- and post-zebra mussel invasion

YEAR	Zebra mussels (#/m^2)	Unionid mussels (#/m^2)	phytoplankton: Chlorophyll a (µg/l)	zooplankton: Rotifers (#/L)	zooplankton: Nauplii (young copepods; #/L)	zooplankton: Copepods (adults; #/L)	zooplankton: Cladocerans (#/L)
1987			17.45	440.40	61.65	7.04	34.03
1988			28.95	495.74	65.24	4.83	42.73
1989			17.25	401.38	56.01	4.72	13.73
1990			17.52	880.12	78.15	5.03	8.69
1991	4	7.95	25.48	1244.15	75.91	6.17	33.47
1992	1941	7.95	12.18	363.45	60.74	3.43	30.48
1993	2508	8.59	5.04	115.18	27.67	3.50	12.67
1994	1329	3.46	4.91	40.00	48.53	4.48	16.46
1995	790	3.55	5.34	60.98	36.77	5.43	12.76
1996	478	3.408	3.74	36.92	29.41	2.78	3.76
1997	3181	2.132	6.89	67.71	41.80	5.32	7.01
1998	1392	1.3	7.50	8.82	3.41	3.39	20.65
1999	1012	1.72	6.56	78.98	21.57	8.86	21.56
2000	797	1.616	4.40	25.68	16.79	4.85	1.86
2001	494	1.857	11.47	204.68	34.65	3.53	7.56
2002	2355	1.71	5.44	38.45	29.35	3.88	34.69
2003	607	2.409	4.81	21.83	41.36	3.55	3.66
2004	691	1.626	4.64	19.76	31.44	5.69	7.02
2005	460	2.106	8.84	563.18	104.21	7.20	7.63
2006	48	1.97	5.90	225.18	44.62	7.57	4.81
2007	3808	1.04	4.10	612.20	58.32	4.94	6.17
2008	273	2.87	4.96	391.70	67.30	7.05	17.70
2009	1844	1.936	6.71	61.67	85.94	7.26	31.36

Densities of zebra mussels and unionid mussels are given in number per square meter, averaged over the freshwater tidal Hudson (RKM 99-248); data collected in August for zebra mussels and July for unionids. Plankton and water chemistry are means for 1 May - 30 September from Kingston-Rhinecliff (RKM 144-149). One meter squared equals ten square feet.

**If a square is empty, that means no data were collected that year. These points are NOT the same as "0.0" and should therefore not be graphed as such. Leave these blank in Excel.

Table 2. Hudson River **chemistry data** pre- and post-zebra mussel invasion

YEAR	Zebra mussels (#/m^2)	Unionid mussels (#/m^2)	Water clarity: Secchi disk (cm)	Water chemistry: otal N (µM)	Water chemistry: ammonium (µM)	Water chemistry: itrate (µM)	Water chemistry: otal P (µM)	Water chemistry: Phosphate (µM)
1987			96.67				1.86	0.39
1988			97.73				2.12	0.40
1989			88.18					
1990			97.73	51.93				
1991	4	7.95	90.00					
1992	1941	7.95	109.33		2.68	30.88	1.24	0.67
1993	2508	8.59	114.62		2.08	38.70	2.25	0.88
1994	1329	3.46	151.00	44.26	1.94	27.17	1.64	0.49
1995	790	3.55	131.07	46.72	4.69	38.90	1.34	0.94
1996	478	3.408	60.00	59.94	1.62	37.54	1.95	0.95
1997	3181	2.132	102.27	49.25	4.22	29.46	1.05	0.48
1998	1392	1.3	86.33	52.36	2.58	27.40	1.32	0.60
1999	1012	1.72	115.00	62.86	3.21	29.79	1.31	0.60
2000	797	1.616	64.55	51.73	3.24	38.46	1.91	0.90
2001	494	1.857	85.91	45.19	2.50	24.82	1.73	0.48
2002	2355	1.71	121.55	43.67	2.49	32.65	1.51	0.86
2003	607	2.409	115.45	44.08	3.82	29.55	1.52	0.41
2004	691	1.626	90.00	54.35	4.62	33.13	1.42	0.74
2005	460	2.106	91.82	42.65	3.39	26.06	1.63	0.70
2006	48	1.97	63.64	42.89	2.90	20.48	1.94	0.62
2007	3808	1.04	90.91	50.02	2.25	29.18	1.79	
2008	273	2.87	101.82	38.82	3.77	22.42	1.30	0.21
2009	1844	1.936	80.45	32.24	1.40	18.41	0.87	0.04

Densities of zebra mussels and unionid mussels are given in number per square meter, averaged over the freshwater tidal Hudson (RKM 99-248); data collected in August for zebra mussels and July for unionids. Plankton and water chemistry are means for 1 May - 30 September from Kingston-Rhinecliff (RKM 144-149). One meter squared equals ten square feet.

**If a square is empty, that means no data were collected that year. These points are NOT the same as "0.0" and should therefore <u>not</u> be graphed as such. Leave these <u>blank</u> in Excel.