Name ________________________ Class _______ Date _______

Zebra Mussel Graphing

How has the zebra mussel invasion changed the Hudson River ecosystem? By completing the following graphing activity, you should be able to answer this question to some degree.

Part 1: Reading about the 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? How long have they been collecting this data?
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?

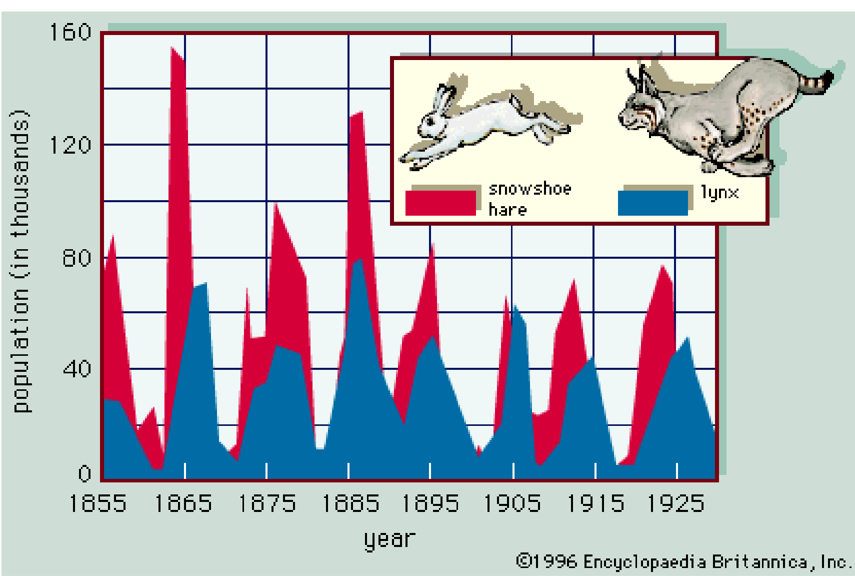
Part 2: Organism Changes

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, as the population numbers are very different and may be difficult to get onto one piece of graph paper. Next, create three graphs to show the relationship between zebra mussels and the 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, 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 goes 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. What principle of population ecology is demonstrated in the following graph, which shows the population levels of hare and lynx? Explain the relationship in the graph. Do the zebra mussels have the same effect on the plankton populations? Why or why not?



8. Do you think all of these changes are a direct result of the invasion of the zebra mussel? Is there anything else could have caused some of these changes? If so, what?

9. Scientists have used statistics to eliminate the possibility of other factors causing the large changes in phytoplankton and microzooplankton (rotifers and immature copepods). We cannot replicate their statistical analyses, however, because they use special computer programs that are not available in the classroom. Based on scientists' understanding of the situation, they are confident that the changes that have taken place are a result of the zebra mussel invasion. Summarize the changes that have taken place in the Hudson since the arrival of the zebra mussel. Hypothesize how these observed changes might affect other parts of the food web.

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 says "nd", that means no data was collected during that year.

year	zebra mussel density #/m2	unionid mussel density #/m2	phytoplankton biomass chlorophyll a (mg/m^3)	zooplankton: cladocerans (number/L)	zooplankton: copepods (number/L)	zooplankton: immature copepods (number/L)	zooplankton: rotifers (number/L)
1987	0.00	nd	nd	33.74	5.89	61.65	440.40
1988	0.00	nd	28.95	45.29	4.04	65.24	495.74
1989	0.00	nd	17.25	13.70	4.72	56.01	401.38
1990	0.00	nd	16.65	8.65	5.03	78.15	880.12
1991	7.00	nd	27.06	33.41	6.17	75.91	1244.15
1992	3929.00	8.03	17.20	42.60	2.14	60.74	505.67
1993	2571.00	8.61	4.18	12.67	3.50	27.67	115.18
1994	1357.00	3.46	4.83	15.20	4.40	48.53	40.00
1995	627.00	3.56	6.11	12.74	5.43	36.77	60.98
1996	2091.00	3.41	2.94	3.69	2.78	29.41	36.92
1997	2475.00	2.14	2.76	7.00	5.32	41.80	67.71
1998	902.00	1.3	5.29	20.63	3.39	3.41	8.82
1999	1066.00	1.72	6.35	21.53	8.86	21.57	79.25
2000	674.00	1.62	2.74	1.81	4.85	16.79	25.68
2001	674.00	1.86	12.07	7.49	3.53	34.65	204.68
2002	2354.00	1.71	5.78	34.61	3.88	29.35	38.45
2003	607.00	2.41	3.96	3.76	3.47	41.36	21.83
2004	698.00	1.64	5.83	7.00	5.69	46.90	19.76
2005	nd	2.11	nd	7.59	7.20	104.21	563.18

Part 3: Chemistry Changes

Now that you've discovered something about the changes in zooplankton and phytoplankton after the arrival of the zebra mussels, make another graph to understand the changes in water chemistry. Create a graph of zebra mussel population density and the annual mean of water transparency, which was measured with a secchi disk. Next, choose one of the other variables, and create a graph showing the change in that variable along with the change in the zebra mussel population. Then, answer the questions that follow.

1. Based on your graph of water transparency and zebra mussel population, what can you conclude about the effects of the invasion?
2. What factors regulate the transparency of the water? What 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?
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. Do you see a relationship between the changes in the chemistry and the zebra mussel population? Why or why not? What other factors might influence the change in water chemistry?

Densities of zebra mussels and unionid mussels are given in number per square meter, averaged over the freshwater tidal Hudson. Data was collected in August for zebra mussels and July for unionids. Plankton and water chemistry data are means for May 1-September 30 from the Kingston-Rhinecliff sampling station. ND means "no data",

year	zebra mussel density #/m2	Water transparency (m) Secchi disk	Water chemistry (µM) phosphate	Water chemistry (µM) total P	Water chemistry (µM) nitrate	Water chemistry (µM) ammonium	Water chemistry total N	Water chemistry pH	Water chemistry (mg/L) suspended solids
1987	0.00	nd	0.34	2.23	nd	nd	nd	7.88	nd
1988	0.00	0.97	0.39	1.86	nd	nd	nd	7.81	nd
1989	0.00	0.98	0.40	2.12	nd	nd	nd	nd	12.44
1990	0.00	0.88	nd	nd	nd	nd	nd	nd	14.23
1991	7.00	0.98	nd	nd	nd	nd	55.81	nd	13.34
1992	3929.00	0.90	nd	nd	nd	nd	nd	nd	11.80
1993	2571.00	1.06	0.48	1.56	23.92	2.59	nd	7.80	10.28
1994	1357.00	1.09	0.87	2.32	35.34	1.97	nd	7.79	9.54
1995	627.00	1.36	0.53	1.65	24.79	2.85	44.13	7.78	7.20
1996	2091.00	1.31	0.94	1.28	37.69	3.51	46.63	7.77	7.61
1997	2475.00	0.62	1.01	2.03	37.85	1.41	59.33	7.67	25.75
1998	902.00	0.99	0.57	1.07	30.53	5.22	53.34	7.74	14.01
1999	1066.00	0.85	0.55	1.84	26.51	2.80	51.35	7.66	20.64
2000	674.00	1.04	0.60	1.19	28.77	2.06	57.76	7.76	13.44
2001	674.00	0.55	0.74	1.73	36.26	2.52	50.24	7.63	18.09
2002	2354.00	0.81	0.46	1.90	22.00	2.15	42.81	7.90	17.10
2003	607.00	1.14	0.86	1.57	30.30	2.32	42.03	7.89	15.58