FINAL PROBLEM SET – INTEGRATIVE LIMNOLOGY – FALL 2006

Due by 5 PM on Monday, December 4th (at 456 Illick)

50 points total

Most of this problem set is much more interpretation and integration than actual computations. With luck, it will begin to help you put all of these physical, chemical and biological concepts together into a coherent picture, and help you to begin reviewing for the exam. If you can either print out your answers or write clearly, it will help Cynthia a lot. Also, be sure to write out your answers fully and describe your ideas thoroughly.

1. Stable isotope techniques have revolutionized the fields of community ecology and food web dynamics over the past decade; this problem addresses two possible ways that stable isotope information can inform conservation and management decisions.

You are interested in conserving a (mythical) fish-eating bird, *Volarepiscivorous wetlandus*, that lives in marsh areas. You have two major areas of concern. (1) **First**, there are limited funds available to protect a bird sanctuary that is home to large populations of the bird. You can either choose first to protect and rehabilitate the marsh itself, or to concentrate on protecting upland habitat around the marsh. Eventually you want to do both, but you need to allocate available resources for the first stage of the plan to either the marsh or the wetlands. You wonder whether production in the marsh or in the uplands is most important in supporting the portion of the food web that includes *Volarepiscovorous.* You collect the following information on the stable isotope composition of several key food web components:

Table 1.

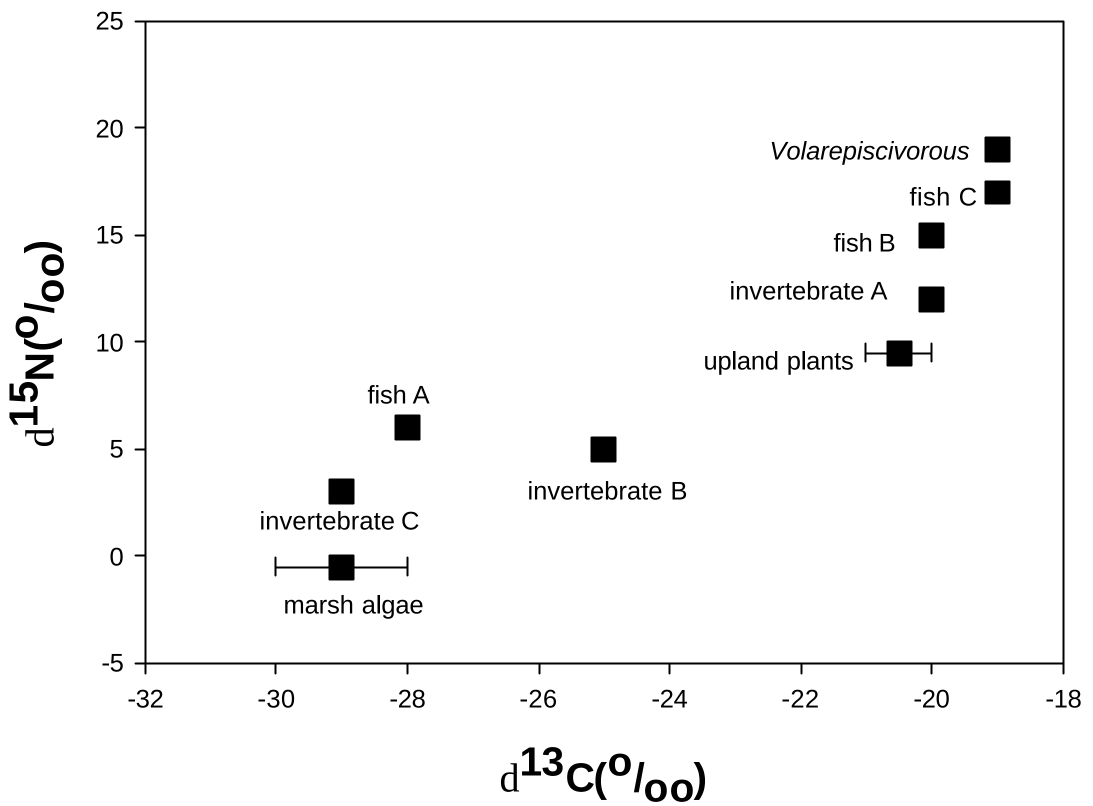
Organisms	**$d^{15}N$ ($^o/_{oo}$)**	**$d^{13}C$ ($^o/_{oo}$)**
Marsh algae	-1 to 0	-30 to -28
Upland plants	9 to 10	-21 to -20
Invertebrate species A	12	-20
Invertebrate species B	5	-25
Invertebrate species C	3	-29
Fish species A	6	-28
Fish species B	15	-20
Fish species C	17	-19
Volarepiscivorous	19	-19

A.

(a) Plot $d^{15}N$ ($^o/_{oo}$) vs. $d^{13}C$ ($^o/_{oo}$) for all the species (on one graph), with $d^{13}C$ on the X axis and $d^{15}N$ on the Y axis.

3 points

Nitrogen and Carbon stable isotope values for marsh foodweb

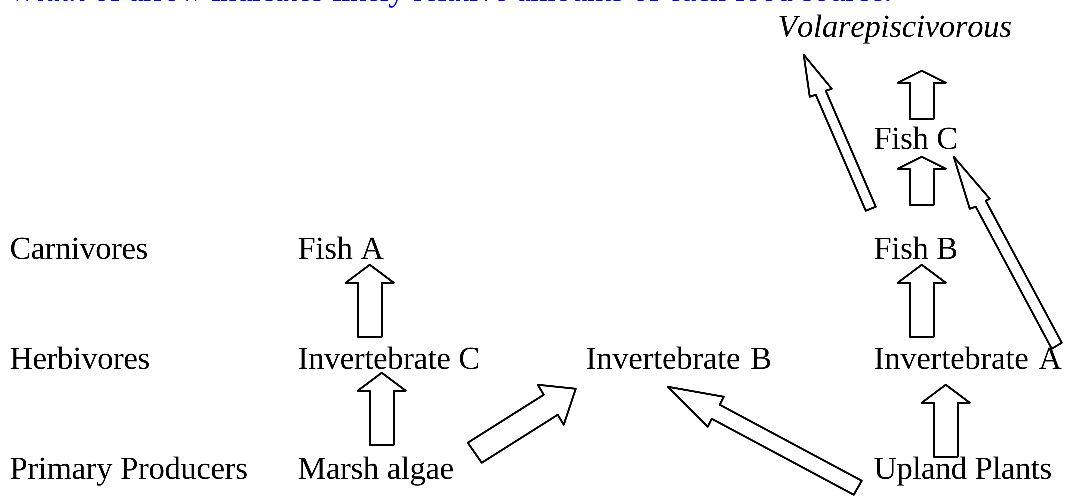


Full credit was given for something like above. No points were taken off if people didn't put error bars on the primary producers. If axes or points weren't labeled, points were removed.

(b) Sketch out the most likely food web for your bird sanctuary marsh.

4 points (0.5 points off per incorrect or missing link or incorrect trophic level)

Width of arrow indicates likely relative amounts of each food source.



(c) Does your bird rely more on production that originates with marsh algae or with upland plants? How did you know this?

3 points

Volarepiscivrous wetlandus (the bird) relies on a bit of the food web that seems to be almost entirely linked to upland plants. You can tell this from the carbon isotopic fractionation, which is very similar to that of upland plants and the organisms feeding on them (Invert A, Fish B and Fish C), but very different than the Carbon isotopic signal of marsh algae. Since you 'are what you eat' (plus or minus 1 per mil) for C, the bird is most dependent on production arising from upland plants.

(d) Which will you do first – rehabilitate and protect the marsh or protect surrounding upland areas? Why?

2 points

There is no one right answer here. If you are really interested in protecting the birds, you should probably first invest in protecting surrounding uplands, since that is the part of the marsh food web that the birds are utilizing. (You may also have the side benefit of improving marsh conditions indirectly by creating more of a good riparian zone around the marsh). However, since the birds are using the marsh habitat, too, some effort should be made to preserve the marsh. 1 point off if you didn't realize that the uplands are important.

B. Your **second** concern has to do with potentially harmful levels of toxaphene in your birds. Another study showed that *Volarepiscivorous wetlandus* has widely differing levels of PCB contaminants and Nitrogen stable isotope fractionation in different wetlands (Table 2), even when the loading of toxaphene to each of these systems is the same. You wonder why these differences might be occurring and if the birds in your wetland are in danger.

Table 2.

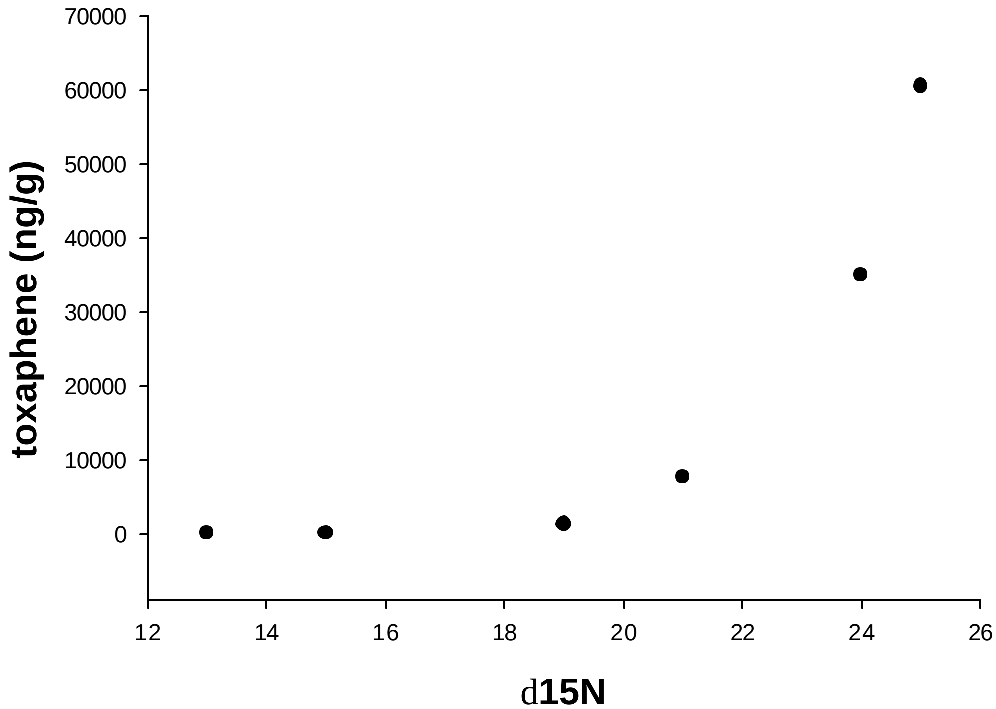
Wetland number	**$d^{15}N$ ($^{o}/_{oo}$)**	**Toxaphene (ng/g wet weight)**
1	15	105
2	13	25
3	21	7,500
4	19	1,255
5	24	35,000
6	25	60,550

(a) Plot the $d^{15}N$ and toxaphene values given above (you may want to plot log(toxaphene)).

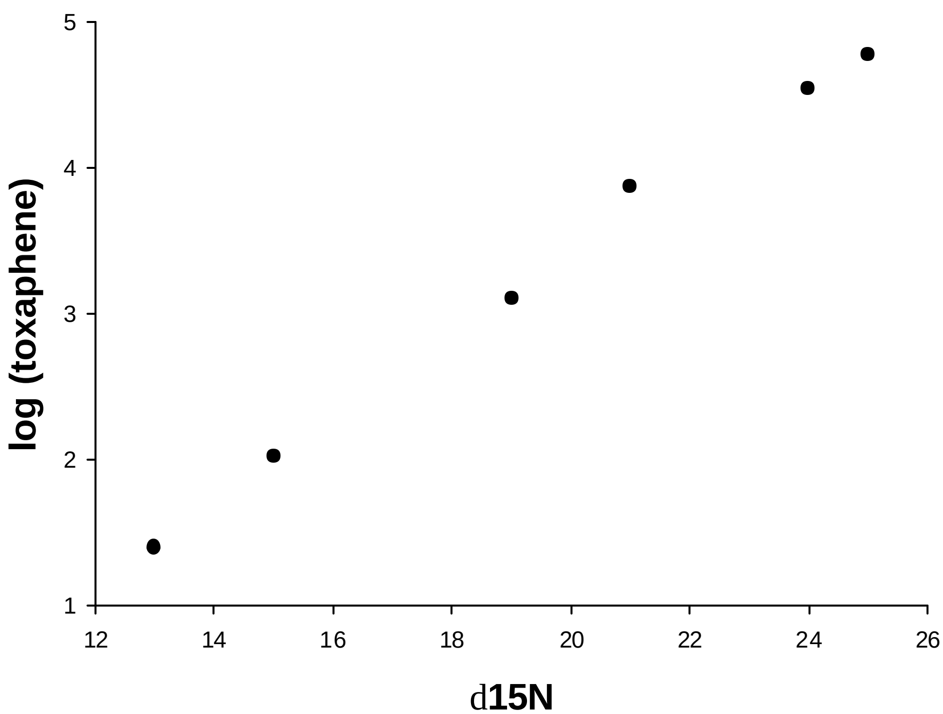
3 points

Either of the plots below would give you full credit. Points taken off if you didn't label axes correctly or if you didn't make the scales quantitative (not increasing linearly), so you couldn't easily see the trend.

Toxaphene and d15N content of *Volarepiscivorous*



Log Toxaphene and d15N content of *Volarepiscivorous*



You also could get credit for plotting wetland # on the X axis and the other parameters on the Y axis, although that would make it harder to see the overall trend.

(b) Upon examining this figure, you immediately think of a plausible hypothesis to explain this pattern. Describe this hypothesis (be sure your hypothesis explains the relationship between the PCB and stable isotope pattern).

2 points
Anything that is plausible and might explain the pattern shown is ok here.
One good hypothesis is that the birds may be at different trophic levels in the different wetlands; the higher their trophic level, the more the toxaphene has bioaccumulated in the birds. For example, in some wetlands the birds eat fish that are piscivorous, in some wetlands they may eat omnivorous fish (eating both fish and herbivorous invertebrates), and in some wetlands the birds may eat the fish that eat invertebrates. This is very similar to the example of lake trout given several times in class. In some lakes lake trout eat invertebrates and are at a lower trophic level and have a lower PCB load than in other lakes where lake trout are piscivores, have a higher tropic level and a higher biomagnification of PCBs.

(c) Describe one way that you could test this hypothesis.

3 points
There are a bunch of possible solutions here. For example, you could see if your predicted diets in the different wetlands are borne out when you look at what they eat (so the birds with the highest del ^{15}N levels should be feeding on fish that are higher on the food chain and more contaminated with toxaphene). You might even do something like feeding birds in one area with high contaminant loads fish at a lower trophic level and see if their contaminant and del ^{15}N levels both decrease.

(d) How might you be able to decrease the toxaphene values in your birds even if you aren't able to alter contaminant loading?

2 points
This could really be tough! You would basically need to alter the food web, which might be bad for the whole marsh (only ½ credit was given for the answer that you should manipulate the food web to favor fish at lower trophic levels, since this might result in other negative effects). Some other possibilities would be to feed the birds less contaminated food (might also be some negative side effects of this), or to concentrate on encouraging birds to nest and feed in areas where planktivorous or other invertivorous fish dominate rather than where piscivores dominate. In a few locations, people have actually had to chase birds away from highly contaminated areas with high fish populations to prevent them from accumulating deadly loads of toxicants. To get full credit you needed to have a feasible, well-explained possibility, or to have possibilities where the possible negative effects were fully discussed.

2. Many factors, such as basin morphometry, nutrient cycling, phytoplankton standing stock, and primary production, are important in understanding the concept of eutrophication. Often people confuse the concepts of natural and anthropogenic eutrophication. Write a short (< 1 page) essay describing the differences and similarities between anthropogenic and natural eutrophication that could be summarized with the following (long!) sentence:

> "Thus, one of the primary differences between 'natural eutrophication' and 'cultural eutrophication' lies in the fact that the former results from a change in basin morphometry, while the later results from a change in nutrient input, even though in both cases there is an increase in primary production."

(8 points) There are several key points that should have been included here including: (2 points per correct observation; a few points off if you said something incorrect.)

- Natural eutrophication
  - Is caused by a slow filling of the basin due to the gradual sinking of organic matter from the lake and sediments from the inflows. This results in a decrease in the hypolimnetic volume of the lake.
  - There is not an increase in the amount of nutrients that are entering a lake during natural eutrophication. However, because the lake is shallower, there is an increase in the nutrients per m^2 (on an aerial basis)
  - Even the same amount of production in the epilimnion of the naturally eutrophic lake must be decomposed in a smaller hypolimnion – thus there is less oxygen available
  - At some point, the hypolimnion becomes shallow enough that it will go anoxic during the summer. At this point the **iron trap** stops working and more phosphorus will be released from the sediments, increasing the rate of eutrophication – there will be more productivity due to an increase in internal phosphorus loading
  - Natural eutrophication may proceed to the point where the lake completely fills in and then becomes a marsh or dry land
- Cultural eutrophication
  - Is due to human increases in the nutrients (especially phosphorus) running into a lake (e.g., from sewage, agriculture, detergents…)
  - This increased nutrient input results in an increase in primary production
  - If production is increased sufficiently, decomposition in the hypolimnion may use up all of the oxygen, thus increasing the rate of eutrophication (as above)
- Cultural eutrophication can sometimes be reversed by reducing nutrient inputs, while reversing natural eutrophication would require dredging.
- A critical point in both types of eutrophication is when the hypolimnion becomes anoxic and internal phosphorus loading increases – (if you didn't mention the importance of oxic versus anoxic hypolimnia you got 3 points off)

3. In the past 25 years, the populations of a fish eating bird, the double-crested cormorant (*Phalacrocorax auritus*) have increased dramatically in Lake Ontario and some inland lakes of N.Y. State. The cormorant is a bird that is native to North America, but had not been reported in large numbers in the eastern Great Lake regions of the United States during recorded (post-European settlement) history.

Since the invasion of the cormorant, the populations of several fish species, for example small mouth bass, have declined precipitously. Many fishermen believed that predation by the cormorant was responsible for these declines, and this led to several incidents where cormorants nesting on islands in Eastern Lake Ontario were shot illegally. Correlations of increases in cormorant abundance with increased bass mortality (see figure below) have been confirmed by estimations of cormorant diet and predation pressure. The birds are indeed eating a substantial portion of the fish, and are responsible for the increase in fish mortality. The cormorant populations are now being controlled by the oiling (killing) of eggs at nesting sites.

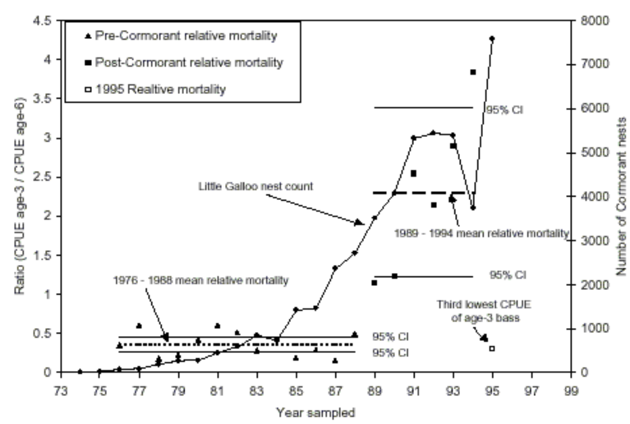


Figure 1. The relative mortality (between ages 3-6) of small mouth bass from the eastern basin of Lake Ontario and the number of cormorant nests on one of the main breeding islands in Lake Ontario. (CPUE = catch per unit effort); Figure from DEC special report.

To date, all of the scientists studying cormorant effects have been understandably interested in the direct effects of cormorants on fish. However, if the cormorants are indeed causing substantial declines in the fish populations, there may be repercussions for the rest of the food web, and, if you are a believer in 'top down control', even on water clarity.

a. Right now scientists are quantifying what types and ages of fish the cormorants consume. Based on the ideas of top-down control and biomanipulation, try to predict the effects of cormorants on the entire aquatic food web given two scenarios: (1) the cormorants eat mostly piscivorous fish; (2) the cormorants eat mostly planktivorous fish. Be sure to explain clearly why you are making these predictions.

6 points

If cormorants:

(1) Eat mostly piscivorous fish, then top-down control would predict that cormorant predation would decrease the number of piscivorous fish, this

would increase the number of planktivorous fish (because they aren't being eaten by the piscivores), decrease the number of large zooplankton (because they get eaten by more planktivorous fish), increase the amount of phytoplankton, and increase lake turbidity.
(2) Eat mostly planktivorous fish, then top-down control would predict that there would be an increase in the number of large zooplankton (because they are not being eaten by fish, and they are better able to avoid invertebrate predation), a decrease in the amount of phytoplankton (because large zooplankton are more effective grazers), and an increase in water clarity

b. Describe several other possible factors that may complicate or alter the simple predictions that you made above.

4 points – 2 per answer

Some complicating factors would include:

- Ontogenetic shifts (changes in diet between juveniles and adults) – if piscivorous fish are consumed, this would result in a decline in juvenile piscivorous fish, which are often planktivores. Thus, there might also be a decline in planktivores, and that would complicate matters. Also, juvenile cormorants might have different diets than do adults.
- Shifts in species – the species of algae might change to favor inedible forms, thus preventing zooplankton grazing from substantially influencing the algal standing stock.
- Patchiness in predator/prey interactions -- Cormorant predation might be localized to a few areas near islands, or to a time scale restricted to the nesting season, before migration. Also, natural increases and decreases in nesting success and population growth would alter the strength of the top-down interactions, just as recruitment factors other than cormorant predation might be important for the fish populations.
- Diet switching – cormorants and other predators might switch from one type of prey to another as prey densities change.

4. As we discussed in class, acid deposition can have many effects on aquatic systems. One possible remediation technique is liming – the addition of carbonates to buffer the added acid. Below are some graphs showing the chemistry and zooplankton composition for three acidified lakes (acidified due to atmospheric sulfur deposition). Three lakes (Middle, Hannah and Nelson Lakes) were limed for remediation beginning in 1975, and changes in their chemistry and plankton communities were followed for almost 15 years. The plankton communities were compared with those in non-acidified reference lakes (Red Chalk, Harp, and Blue Chalk Lakes).

Fig. 1. Long-term changes in pH, Ca, TP, and Cu in the experimental lakes. Data are ice-free season averages of weekly to twice-monthly samples prior to 1980 (Yan and Dillon 1984; Yan and Lafrance 1984) and monthly samples thereafter.

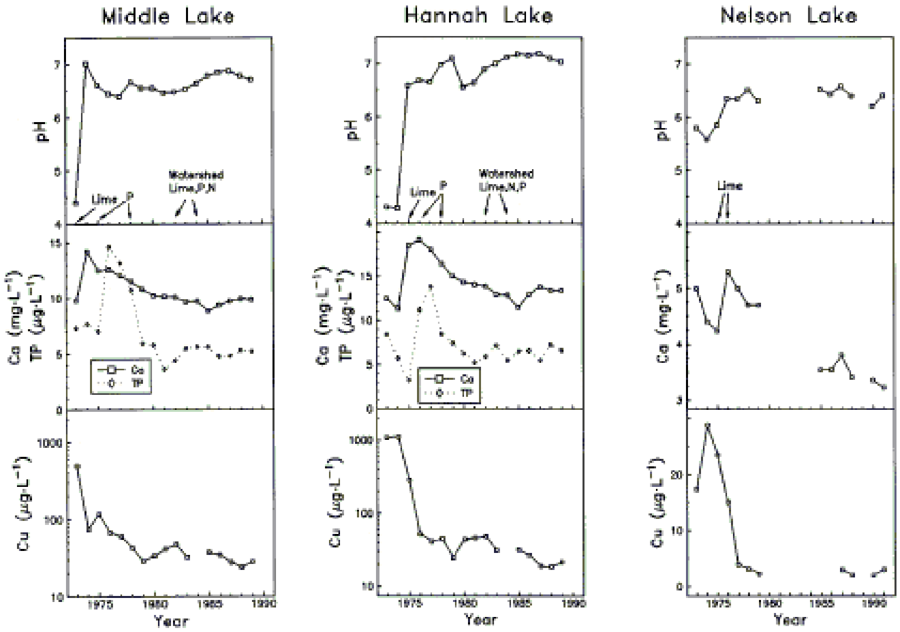


Fig. 4. Long-term changes in daily species richness averaged over the ice-free season of the crustacean zooplankton assemblages of the temporal reference and experimental lakes. A notched box plot of richness in the 22 spatial reference lakes with pH > 6.0 is provided. The whiskers of the box provide the 99% confidence interval on the mean; the box boundaries represent the quartiles; the notch provides an approximate test for deviations of independent estimates from the median.

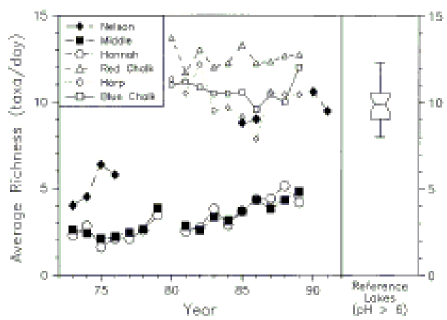


Fig. 6. Long-term changes in average diversity of the crustacean zooplankton assemblages of the temporal reference and experimental lakes. A notched box plot (see Fig. 4) of diversity in the 22 spatial reference lakes with pH > 6.0 is provided.

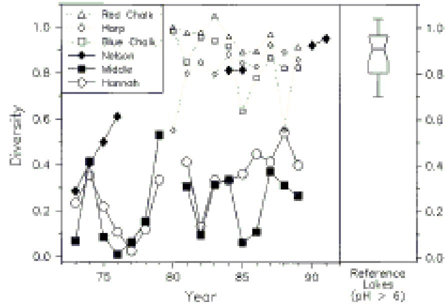


Fig. 7. Long-term changes in evenness of the crustacean zooplankton assemblages of the temporal reference and experimental lakes. A notched box plot (see Fig. 4) of evenness in the 22 spatial reference lakes with pH > 6.0 is provided.

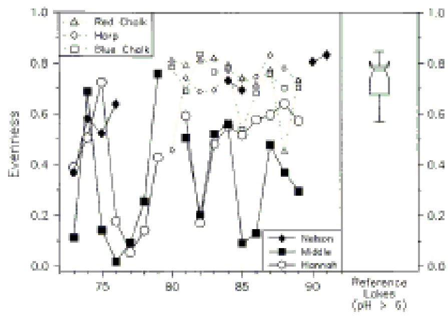
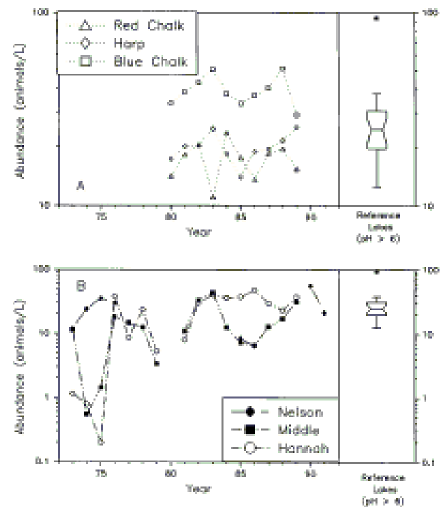


Fig. 8. Long-term changes in ice-free season abundance of the crustacean zooplankton assemblages in (A) the temporal reference lakes and (B) the experimental lakes. Each panel also provides a notched box plot (see Fig. 4) of abundance in the 22 spatial reference lakes with pH > 6.0.



a. Discuss the success of liming as remediation in these lakes – be sure to look at the rates of recovery of water chemistry and zooplankton in these limed lakes.

5 points – 2.5 for water chemistry; 2.5 for zooplankton

In terms of water chemistry, the pH of the lakes increased greatly after liming in all three lakes. Total phosphorus spiked after initial liming and then declined, and heavy metals such as cobalt and copper declined, although these reached very different levels in the 3 lakes.

Zooplankton community indices, such as evenness, richness, diversity and abundance, never reached the levels of the unacidified reference lakes. Over the 15 or more years of record, these parameters are all relatively variable (lots of interannual variation), and there is an increase in richness and abundance. Evenness and Diversity indices showed the least recovery.

b. How might the liming technique for assisting with the recovery of acidified lakes be improved?
   a. Describe one idea that you have to increase the recovery of these lakes.

2 points

Several possibilities here include:

-'Spiking' or adding natural phytoplankton and zooplankton to the lake to assist with recovery of the organisms in the lake

-The same thing with the fish
-Reducing the cost or liming more frequently

b. Discuss what types of parameters you might want to measure (including and in addition to those shown above) to assess recovery.

3 points – need – 1 point for each of two answers and 1 point for a description of how they would help recovery.

This really depended on what you put for the earlier answers. Any suggestion that actually would have sped recovery of some aspect of the lake ecosystem was ok (if it was totally impractical, points were subtracted). To get the one point credit for recovery, you needed to choose parameters that would actually have indicated whether your treatment was working to speed or assist recovery.