The effect of changing calcium concentration on crayfish, fish, macrophytes, and snails in freshwater littoral zones of UNDERC lakes

by
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Abstract

This report investigates the influence of dissolved calcium on macrophytes, snails, crayfish, and fish populations in ten freshwater lakes at the University of Notre Dame Environmental research Center (UNDERC) located in Vilas County, Wisconsin, and Gogebic County, Michigan. Conclusions were drawn from population collections in each lake during the summer of 1987.

I hypothesized that a direct correlation existed between calcium concentration and size and variety in aquatic communities. Results show that calcium is not a major controlling factor in littoral zone communities. Fish variety and numbers decreased as calcium increased. Calcium concentration did not affect macrophyte presence significantly. However, calcium did influence crayfish and snail communities. In addition, a threshold was evident, below which neither snails nor crayfish were found. No significant pattern emerged in snail or macrophyte species diversity when plotted against increasing calcium levels.

Introduction

Benthic communities vary between lakes. This basic observsation is the result of a complex interaction of myriad forces, which makes studying this region of lakes both difficult and fascinating. Both physical and biological factors influence benthic diversity.

In ths paper, I am focusing on calcium concentration as the significant physical limiting factor to the littoral zone. Calcium has been shown to influence various components of freshwater littoral zones. Pip (1979) showed that certain macrophyte species were selective for certain levels of calcium, as was the overall abundance of macrophytes in the central Canadian lakes that he sampled. Capelli and Magnuson (1983) noticed the presence of a calcium threshold below which crayfish could not survive. Fish and snails would also seem to be controlled to some extent by calcium, since this mineral is critical to their development.

Ten lakes were selected on the UNDERC property with calcium levels ranging from 3.7 mg/l to 57.5 mg/l, to test the influence of calcium concentration on fish, macrophyte, snail, and crayfish populations. I hypothesized that all of these communities would increase in diversity of species and abundance as calcium concentration increased. Results varied between tthe communities, showing both negative and positive correlations between community size and calcium concentration, as well as instances when no significant pattern emerged. These results should be treated suspiciously, for flaws existed in some of the collection techniques, and the amount of data is too little to be significant.

Materials and Methods

Ten lakes were sampled during the summer of 1987, using consistent collection methods. The ten lakes, with corresponding calcium concentrations are : Raspberry (3.7), Roach (6.3), Long (8.0), Bergner (10.6), Plum (25.0), Kickapoo (30.0), Tenderfoot (32.0), Mullahy (33.0), Morris (35.0), Ward (57.5). These lakes are located on the UNDERC property.

fish

Fish were trapped using South Dakota trap nets, which were set perpendicular to the shore, so as to channel fish into the holding sack while swimming in the shallow water. Fish were collected daily (twenty-four hour period, plus or minus two hours). They were sorted by species, counted and returned to the lake away from the net, so as to minimize the number of recaptures. The data collected were the number of each species present in one twenty-four hour set. The number of sets varied between lakes. Fish were not sampled in Plum, Roach, Tenderfoot, or Mullahy Lakes.

macrophytes and snails

Macrophytes and snails were collected using a rectangular net on a two meter long wooden handle. The netting was finely woven and supported by a rectangular metal frame. Samples were taken in one to two meters of water by moving the net along the substrate. Each sample . was rinsed in the net, placed in a plastic bag, and brought to the lab. In the lab, the macrophytes were further rinsed, sorted by species, spin dried in a lettuce spinner, and weighed damp. Snails were collected in the strainer used to rinse the macrophytes and in the muck collected in the net. Once sorted, the snails were preserved and identified at Notre Dame in the fall of 1987. The macrophyte key used was by Fassett. The snail key used was by Harman and Berg.

crayfish

Crayfish traps were made by enlarging the opening of wire mesh minnow traps. 120 grams of beef liver was used to bait each trap. These traps are selective for male crayfish, and have shown to give an accurate account of the crayfish population in a lake (Capelli and Magnuson, 1983). Traps were placed randomly along the perimeter of eah lake in one to two meters of water for a twenty-four hour periods, and only males were counted in each trap, because of the traps have shown to be gender selective. Thirteen traps were placed in each of the following lakes: Ward, Mullahy, Raspberry, Long, and Morris. Five traps were placed in each of the following: Kickapoo, Bergner, Roach, and Tenderfoot. Crayfish were not sampled in Plum Lake. Crayfish were identified using the appendix by Girard in Distribution, Life History, and Ecology of Crayfish in Northern Wisconsin (Capelli, 1975).

Results

Fish

Fish populations were negatively affected by calcium. Regression analysis in Figure 1 (top) shows a slightly negative relationship between the number of fish species and calcium concentration. This, however, may be deceiving because four out of the six lakes had four fish species in them. In Kickapoo, six were collected, and in Ward Lake, with the highest concentration of calcium, only three species were trapped.

Figure 1 (bottom) shows a negative correlation between the total number of fish in the lake and calcium concentration, under regression analysis. Again, Ward Lake, with a calcium Concentration of 57.5 mg/l, had the smallest population of fish, with an average of 26 fish caught in a net per day. Both Bergner and Morris had an average of 48 fish per net per day, even though their calcium concentrations differed by 24.4 mg/l.

Macrophytes

No significant relationship was apparent between calcium concentration and macrophyte populations in these lakes. A regression line with a slope near zero and an r value of 6% indicates that the number of species found in a lake is not related to the calcium concentration (Fig. 2 top). Kickapoo Lake, with a median calcium concentration, contained the most macrophyte species. Both Raspberry and Ward, which had extreme high and low calcium levels, contained only six macrophyte species.

Macrophyte biomass did show an overall increase as calcium increased (Fig. 2 bottom). As above, Kickapoo Lake had the largest macrophyte presence. However, Tenderfoot, Mullahy, and Morris, with calcium concentrations similar to that of Kickapoo, showed a significantly lower biomass average. Raspberry, Roach, and Long, with low calcium concentrations, supported a sparse community of macrophytes. These results show that calcium does affect macrophyte presence to some extent, although other factors undoubtedly play a major role.

Figure 6 is consistent with Figure 2 (top), in showing that no strong correlation exists between calcium concentration and species numbers. Individual species did seem to be selective for certain calcium concentrations. *Drepanoclatus sp., M. falwelli, M. tenellum, Sparganium sp., and Isoetes sp.* were only present in lakes with calcium concentration of 10.6mg/l and below. *Najas flexilis* and *Chara sp.* showed selectivity for lakes with calcium concentrations above 30 mg/l.

crayfish

Calcium did not prove to be a good indicator of crayfish population size. However, data shows a threshold between 10 and 30 mg/l of calcium, below which crayfish were not present (Fig. 3). The fact that no crayfish were found in Ward indicates that calcium was not the only factor limiting crayfish presence in lakes. That so few crayfish were caught in any of the lakes takes away from the confidence in this data. This topic will be covered more extensively in the discussion.

snails

A strong correlation existed between snail population and calcium concentration. The number of snail species present in a lake showed an overall increase with increased calcium concentration (Fig. 4 top). An r value of 73% confirms this direct relationship. Ward and Tenderfoot were noticable exceptions to this pattern.

Figure 4 (bottom) shows a trend of increasing numbers of snails with increasing Ca^{+}. The data also shows a threshold between 10 and 25 mg/l of Ca^{+}. Plum Lake was the lake with the lowest calcium concentration that contains a snail community.

Figure 5, however, shows something different. Species composition studies of the snail populations showed declining species variety with increasing calcium, once a threshold had been reached. Plum and Kickapoo Lakes had the highest calcium concentrations of snail-containing lakes; in both of these lakes, eight species of snails were identified, which is more than were collected in any of Mullahy, Morris or Ward lakes, all of which had higher calcium concentrations than the first two.

In all of the lakes, *Amnicola sp.* comprised the majority of the population. *Physa sp.* were present only at intermediate calcium concentrations (25 and 30 mg/l).

Discussion

My results show that although calcium seems to have a minor impact on littoral zone communities and that more influencial factors exist that work on this ecosystem. Variety in aquatic life does tend to follow increasing calcium concentrations, yet this pattern is not without exception. Physical factors such as lake size, and ecological factors such as habitat and food web relationships should also be considered.

In addition, these results should be considered with a degree of skepticism. Only ten lakes were sampled, which does not allow for much confidence. Many characteristics vary between the lakes, and this factor could have had great influence on my results. Collection methods could have been made more accurate by using SCUBA to do much of the sampling. Discussion of the various specific collections follows.

fish

The fact that the fish community did not respond to varied calcium concentrations indicates that other factors are much more important in determining fish community composition. Ward is the smallest lake sampled, with a surface area of 1.1 ha (Greene). Both the variety in numbers and the total number of fish collected is the lowest in Ward Lake. Bergner Lake is the largest lake sampled for fish, and the total fish population was highest in this lake. The fact that both

Kickapoo and Morris Lakes, both with moderate calcium levels, held large fish populations begs further study. Both of these lakes sustain a thick macrophyte population. This factor will be analyzed in a future paper.

Setting of the nets was random. However, based on results from extensive netting of Morris Lake, inconsistencies do occur in the number of fish caught from day to day or from net sight to net sight. I have no numbers to support this observation, yet Schlais' UNDERC report may discuss this factor.

macrophytes

That total macrophyte biomass showed a tendency to increase as calcium concentration increased does support my original hypothesis. This trend was also noticed by Pip (1979). That there was little fluctuation in the number of species present with varying calcium concentration becomes more meaningful when Figure 6 is considered.

Pip (1984) showed that macrophyte species were selective for certain water chemistry compositions. His results showed that *Chara sp.* and *Najas flexilis* were present in high pH and TDS lakes. I found these species to be present in lakes only with high calcium concentrations. Based on his results, Pip suggested that water chemistry plays an important role in macrophyte species composition of freshwater lakes. My data confirm this hypothesis, and also suggest that water chemistry does not play a major role in the total number of macrophyte species in a lake.

Poor sampling technique may account for inconsistencies particularly in Tenderfoot and Kickapoo macrophyte data. Samples collected in Kickapoo probably covered a larger area than samples taken from other lakes. Based on visual observations, Tenderfoot appeared to have greater abundance and variety of macrophytes than was collected. Because Tenderfoot is a large lake with diverse substrates, incomplete collecting could have given these results. Substrate make-up could be a very important factor in determining the make-up of the macrophyte community in a given lake.

crayfish

Three crayfish species were found in the UNDERC lakes: *O. propinquis, O. immunis,* and *C. diogenes.* Typically, lakes are one-species dominated (Capelli and Magnuson,1983). Crayfish were absent from lakes with calcium levels below 30 mg/l. Once this threshold has been crossed, calcium is not a good determinant for crayfish numbers in a lake. Other factors, mainly habitat, seem to be more important.

Although crayfish were not caught in traps set in , several were found clinging to the fish nets used to sample the lake. This contradicts the data collected that led me to believe that crayfish did not inhabit Kickapoo Lake. In addition, it is contrary to earlier cited material (Capelli and Magnuson 1983), which suggested that the sampling technique used gives an accurate account of the crayfish community in the lake being sampled. In addition, the low number of crayfish found in any of the lakes indicates that the data may not accurately reflect the crayfish population of a lake.

The evidence of a calcium threshold indicates that the presence of crayfish in a lake can be used to place a minimum level on calcium concentration of that lake. Because of the gap between 10.6 mg/l in Bergner, where no crayfish were present, and 30.0 mg/l in Kickapoo, the lowest calcium level sampled to support crayfish, these data do not indicate what that minimum value would be. Further investigation could reveal this result.

snails

The snail community best supported the hypothesis that littoral zone communities are larger and more various in lakes with higher calcium concentrations.

Regression analysis of Figure 4 confirms this pattern. However, Figure 5 shows that species variety does not increase consistently with calcium level increase. Once the threshold has been reached (between 10 and 25 mg/l), there is no pattern to the varying number of snail species.

Bronmark (1985) showed that snail diversity increased with lake size. This would explain why eight species were found in Plum Lake, and only six species were found in Ward Lake.

In Tenderfoot,the largest lake sampled, the snail community was abnormally small and comprised only two species. This can be explained by considering the sampling method. Snails were collected from the macrophyte samples, and the Tenderfoot macrophyte samples were small and complete. It would probably be best to disregard the snail data from Tenderfoot.

For the same reason, the fact that Kickapoo's macrophyte samples were abnormally large would suggest that the snail numbers would also be high. Thus, 174 snails per sample is should be considered in this light.

Figure 5 shows that *Amnicola sp.* made up the majority of the snails collected in each of the lakes containing snails. That it was abundant in all calcium concentrations, shows that this species has a tolerence for a variety of water types. *Physa sp.* were found only in lakes with intermediate calcium levels (25 and 30 mg/l). Physa seems to be calcium-limited.

Because of patterns and a threshold that showed up in the data, it seems that snails are a good indicator of the condition of a lake with regard to calcium.

A survey of the littoral zone shows that calcium is a factor in controlling the biota present. Snails and crayfish are calcium-limited. Macrophyte abundance and species composition also react to changes in calcium changes. Only fish seemed not to vary with differing calcium concentrations in the lakes sampled. It is also evident that other factors influence this aquatic ecosystem significantly. I will explore certain ecological interactions in a paper soon to be written.

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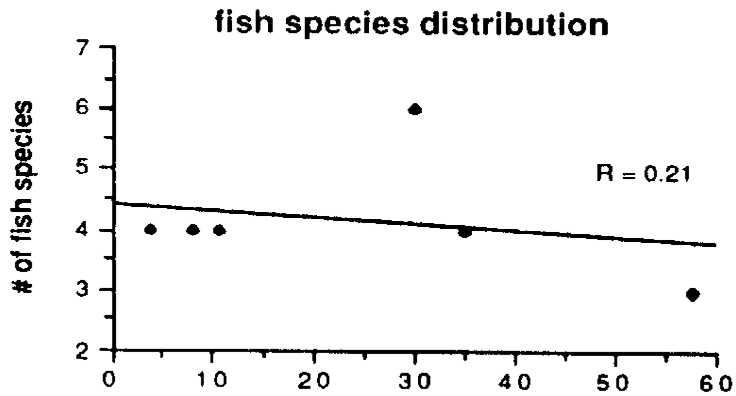
Fish



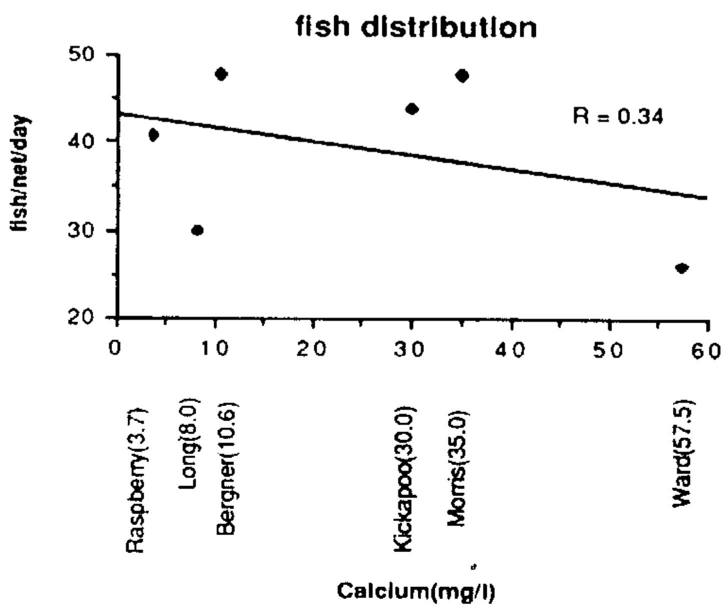
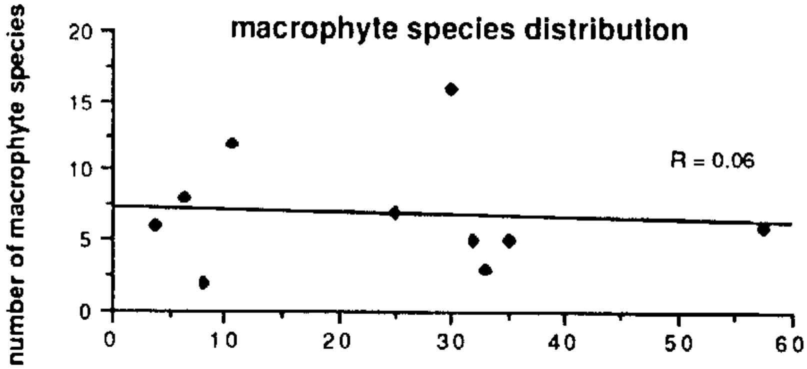


Figure 1. *top:* Number of fish species in each lake according to calcium concentration in each lake. *bottom:* Number of fish caught in one net in one day according to calcium concentration in each lake. In both graphs, points corrospond to lakes as listed along the x-axis of the bottom graph.

Macrophytes



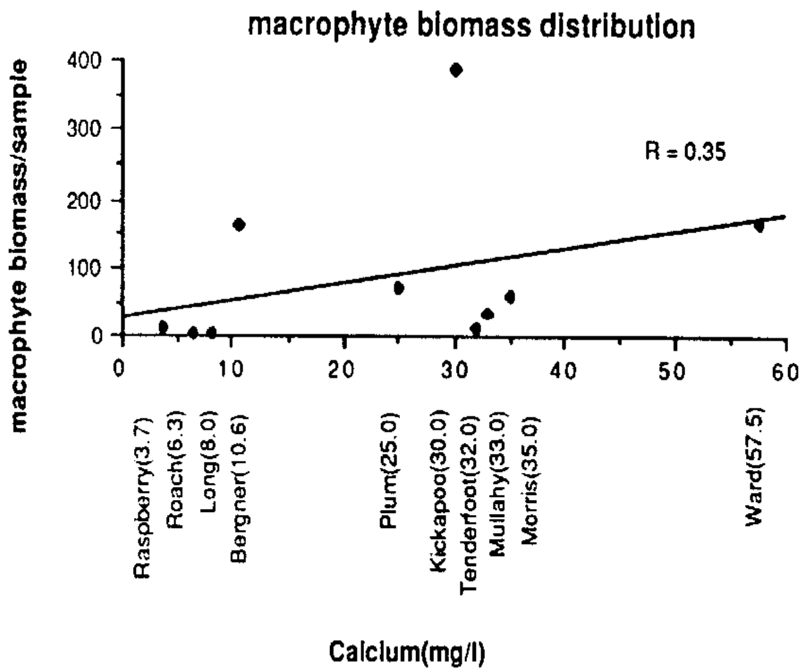


Figure 2. *top:* Number of macrophyte species present in each lake according to calcium concentration in each lake. *bottom:* Mean macrophyte biomass per sample in each lake according to calcium concentration in each lake. In both graphs, points corrospond to lakes as listed along the x-axis of the bottom graph.

Crayfish

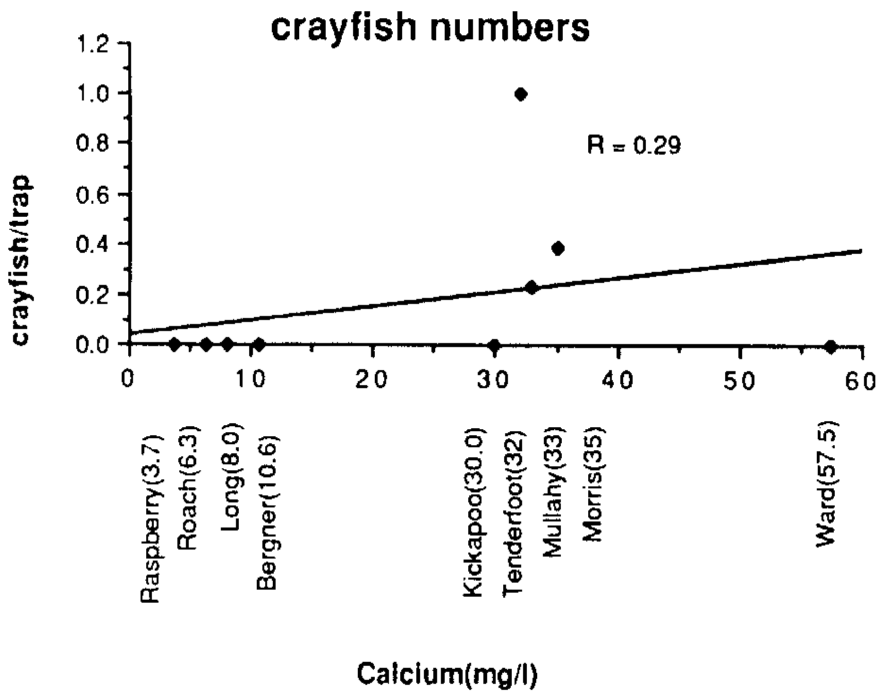
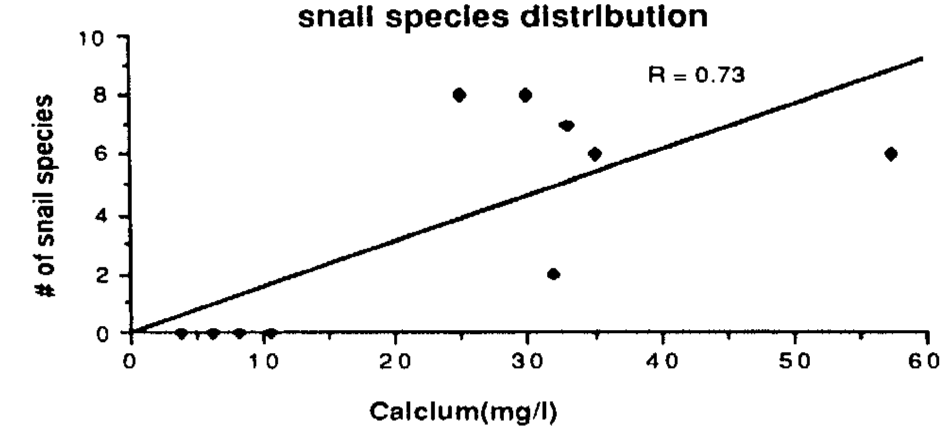


Figure 3. Average number of male crayfish caught in a trap against increasing calcium concentration. Females were disregarded. Each point represents crayfish abundance in that lake corrosponding to its calcium concentration.

Snails



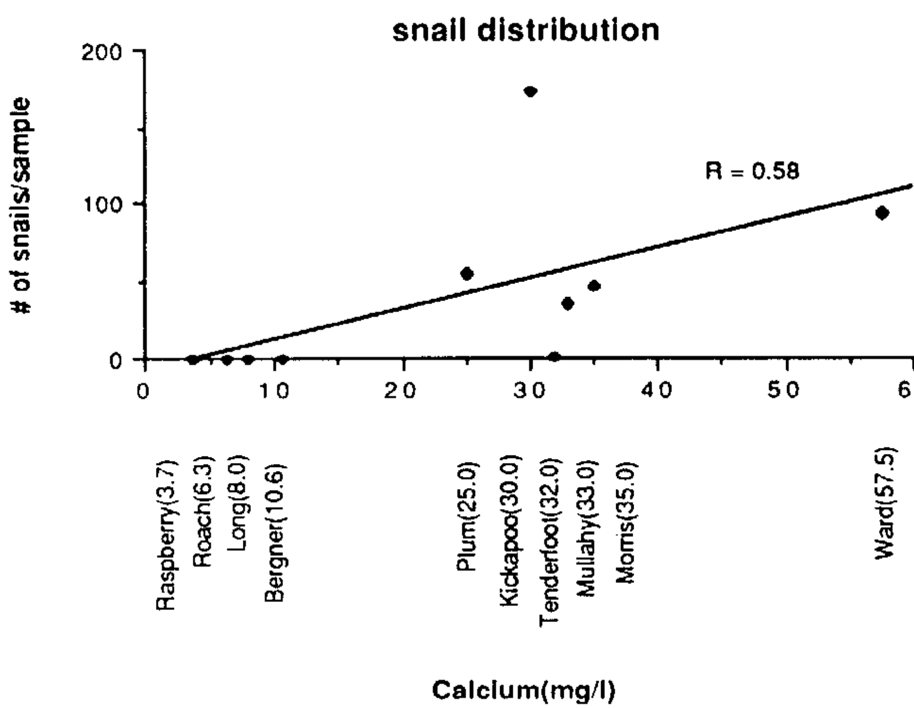
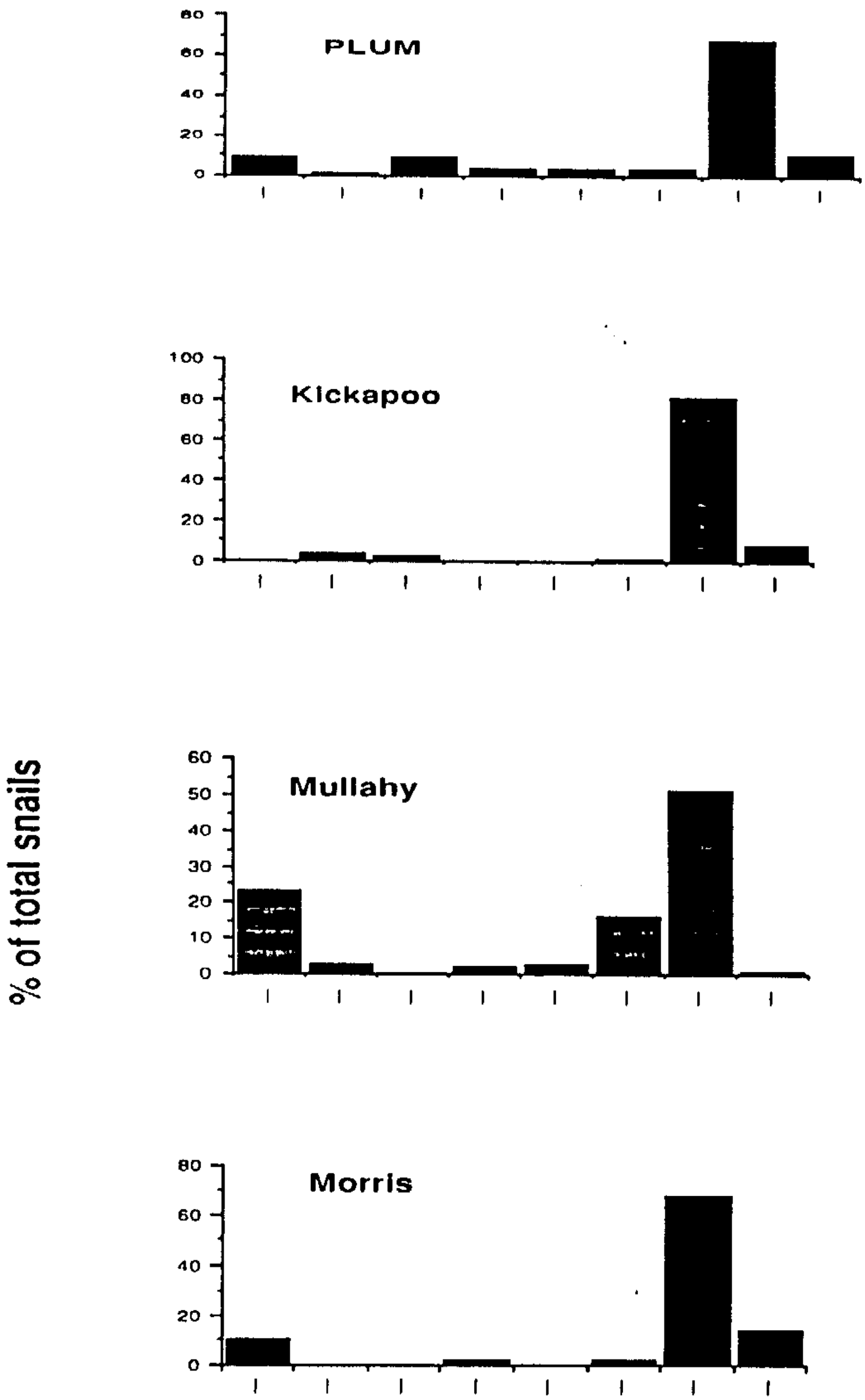


Figure 4. *top:* NUmber of snail species found in each lake according to calcium concentration in each lake. *bottom:* Average number of snails per sample for each lake. In both graphs, points corrospond to lakes as listed along the x-axis of the bottom graph.


PLUM
80
60
40
20
0
Kickapoo
100
80
60
40
20
0
Mullahy
60
50
40
30
20
10
0
Morris
80
60
40
20
0
% of total snails

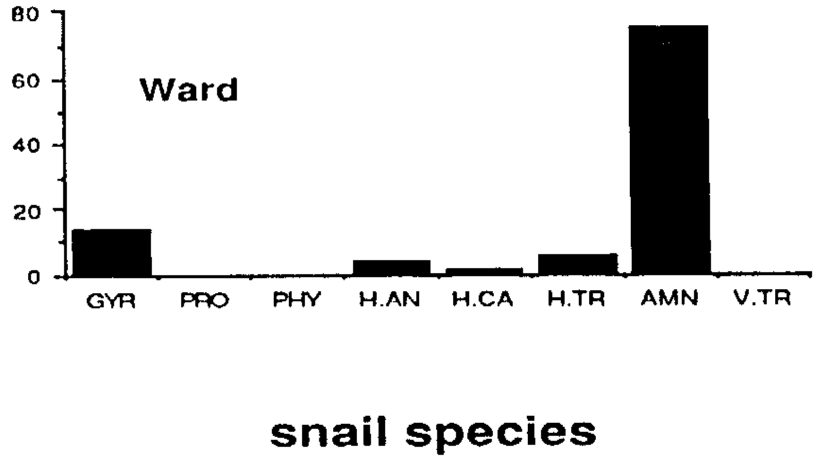
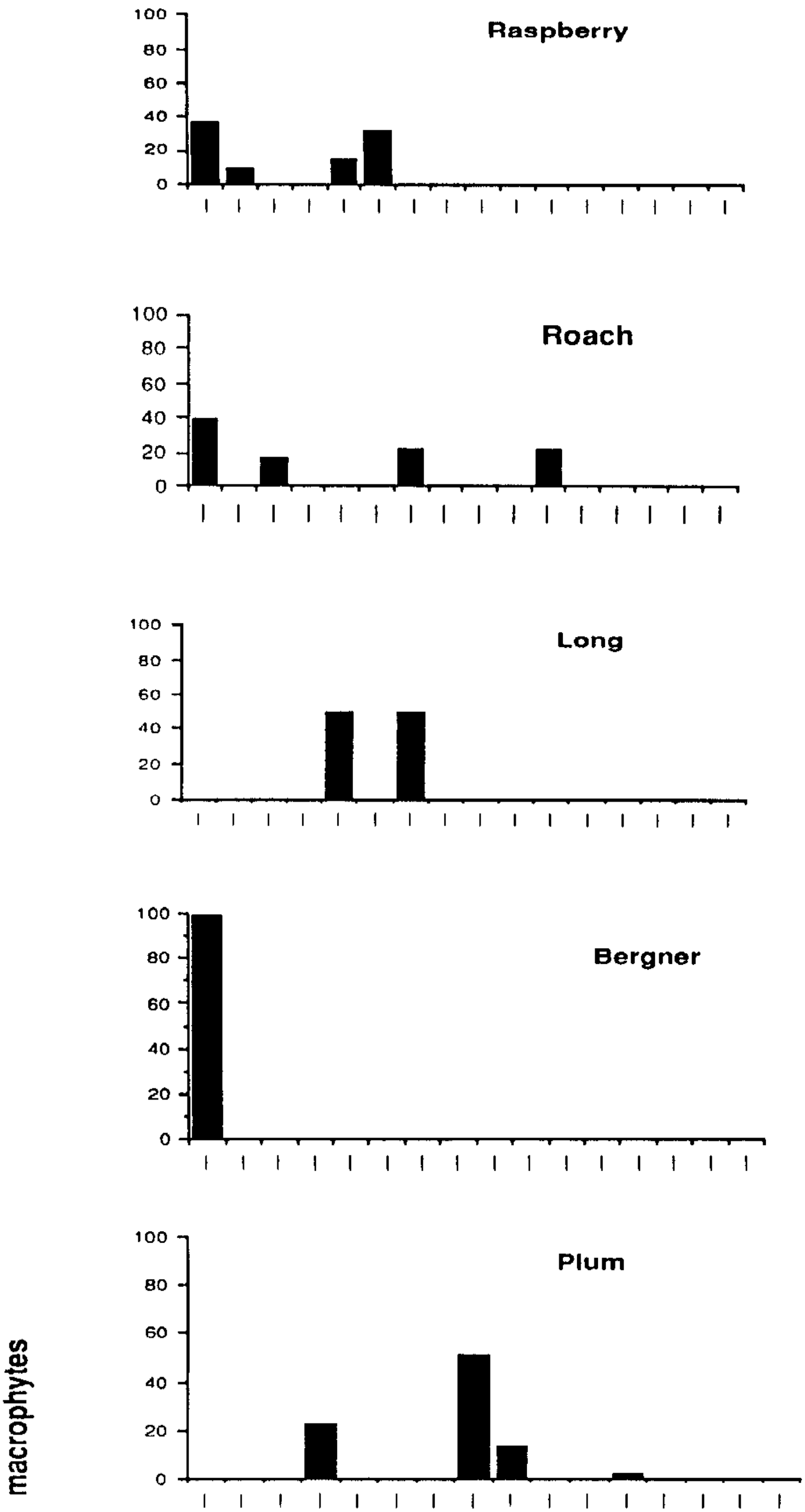
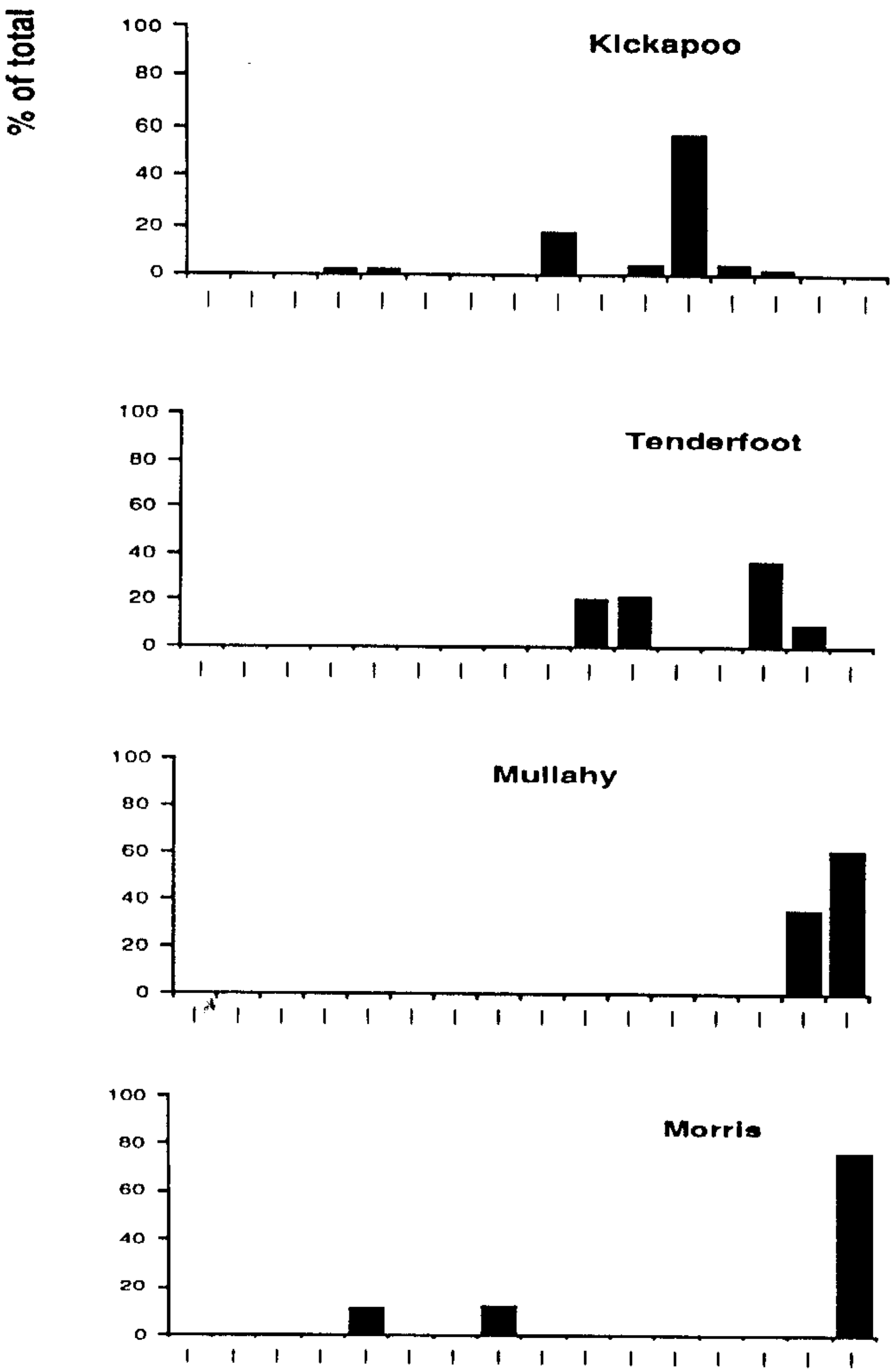


Figure 5. Breakdown of percentage each snail species comprised of the total sample for each lake. GYR = *Gyraulus sp.*; PRO = *Prometus sp.*; PHY = *Physa sp.*; H.AN = *Helisoma anceps* ; H.CA = *Helisoma campanulata* ; H.TR = *Helisoma trivolvus* ; AMN = *Amnicola sp.*; V.TR = *Valvata tricarinata.*


Raspberry
Roach
Long
Bergner
Plum
0
20
40
60
80
100
macrophytes



% of total
Kickapoo
Tenderfoot
Mullahy
Morris
100
80
60
40
20
0

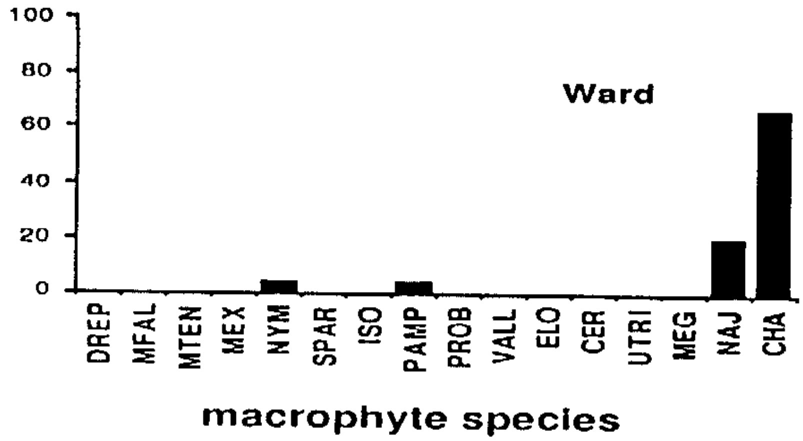


Figure 6. Breakdown of percentage each macrophyte species comprised of the total sample for each lake. DREP =*Drepanoclatus sp.*; MFAL = *Myriophyllum falwelli* ; MTEN = *Myriophyllum tenellum* ; MEX = *Myriophyllum exalbescens* ; NYM = Nymphaceae; SPAR = *Sparganium sp.*; ISO = *Isoetes sp.*; PAMP = *Potamogeton amplifolius* ; PROB = *Potamogeton robinsii* ; VALL = *Vallisnaria sp.*; ELO = *Elodea sp.*; CER = *Ceratophyllum sp.*; UTRI = *Utricularia sp.*; MEG = *Megaladonta beckii* ; NAJ = *Najas flexilis* ; CHA = *Chara sp.*

Appendix I

Table 1: data used for figures 1-4.

Table 1

lake	crayfish/trap	#ofmac.spec.	mac.biomass	#snailspecies	snails/sample	# fish species	fish/net/day	Calcium(mg/l)
Raspberry	0	6	10	0	0	4	41	3.7
Roach	0	8	2	0	0			6.3
Long	0	2	4	0	0	4	30	8.0
Bergner	0	12	160	0	0	4	48	10.6
Plum		7	71	8	55			25
Kickapoo	0	16	389	8	174	6	44	30
Tenderfoot	1	5	12.8	2	2			32
Mullahy	.23	3	36	7	36			33
Morris	.38	5	60	6	47	4	48	35
Ward	0	6	163	6	94	3	26	57.5

Appendix II

Table 2: data used for figure 5.

Table 2

snail spp	Plum	Kickapoo	Tenderfoot	Mullahy	Morris	Ward
GYR	9	0	0	23	10	14
PRO	1	4		3	1	0
PHY	9	2		0	0	0
H.AN	4	0		2	3	4
H.CA	4	0		3	1	1
H.TR	3	1		16	3	6
AMN	67	82		52	68	74
V.TR	10	8		1	14	0

Table 3

SPECIES	RASPBERRY	ROACH	LONG	BERGNER	PLUM	KICKAPOO	TENDERFOOT	MULLAHY	MORRIS	WARD
DREP	37	39	0	99	0	0	0	0	0	0
MFAL	10	0	0	0	0	0	0	0	0	0
MTEN	0	17	0	0	0	0	0	0	0	0
MEX	0	0	0	0	22	2	0	0	0	0
NYM	14	0	50	0	0	2	0	0	11	4
SPAR	31	0	0	0	0	0	0	0	0	0
ISO	0	22	50	0	0	0	0	0	0	0
PAMP	0	0	0	0	51	0	0	0	0	0
PROB	0	0	0	0	13	17	0	0	12	4
VALL	0	0	0	0	0	0	20	0	0	0
ELO	0	22	0	0	0	5	22	0	0	0
CER	0	0	0	0	2	57	0	0	0	0
UTRI	0	0	0	0	0	4	0	0	0	0
MEG	0	0	0	0	0	2	37	0	0	0
NAJ	0	0	0	0	0	0	10	36	0	20
CHA	0	0	0	0	0	0	0	61	76	67

Appendix III

Table 3: data used for frigure 6.