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INFLUENCE OF pH ON THE DISTRIBUTION AND ABUNDANCE OF FRESHWATER SNAILS

ABSTRACT

We compared snail populations with pH as a limiting factor in two acidic and two alkaline lakes in Northern Michigan. We estimated populations by the depletion method to determine whether the snails differed in abundance and diversity. The two acidic lakes contained no snails as opposed to the basic lakes which had relatively large snail populations. No species overlap existed between these alkaline lakes. We concluded that pH was a limiting factor in snail distribution.

INTRODUCTION

The niche of a freshwater organism has many dimensions which include abiotic and biotic factors. "In freshwater environments, abiotic factors tend to overshadow biotic ones, especially in temperate climates (Aldridge1983)." The pH of surrounding freshwater can be one of these abiotic factors. "The pH of soil in terrestrial environments or of water in aquatic ones is a condition which can exert a powerful influence on the distribution abundance of organisms (Jewell 1929)." Freshwater snails need specific pH levels for the formation and development of the shell. The mantle of the snail, which is the skin that lies next to and underneath the shell, is responsible for making the shell. The mantle takes up fluids containing Ca^{++} and HCO_3^- from the body and external medium. The mantle's cells excrete Ca and H_3CO_3 to the extrapallial fluid. This fluid separates into two phases, one of which is the $CaCO_3$ shell (Figure 3), (Wilbur and Yonge 1964). "Under the conditions leading to acid accumulation...the $CaCO_3$ of the shell will act as a buffer. The result is an etching or erosion of the inner shell surface (Wilbur and Yonge 1964)." Based on the premise that pH levels will influence the development of snails, we propose to find different snail fauna and abundance when comparing acidic and basic lakes.

DESCRIPTION OF AREAS SAMPLED

We sampled four lakes in the Upper Penninsula that were known to have varying pH levels (N. Tuchman, pers. comm.). In this study we incorporated two acidic lakes, Johnson Lake (pH 4.46) and McNearny Lake (pH 3.86), and two basic lakes, Piatt Lake (pH 7.08) and Carp Lake (pH 8.09), (Table 1). All of the lakes sampled had sandy bottoms and vegetation around the shoreline. Johnson Lake (T43N, R6W, Sec. 26) was a small lake (16 hectares) with few houses. There was quite a bit of vegetation around the shore and the sandy bottom included some black soil. McNearny Lake (T47, R5W, Sec. 32) was surrounded by homes and activity was apparent by the presence of the residents' boats. McNearny Lake was also one of the smaller lakes we sampled (50 hectares). The shoreline was surrounded by shrubs and soil deposits also existed on this lake bottom. Piatt Lake (T46N, R6W, Sec. 35) was relatively larger (102 hectares). Human activity at this lake was evident from the presence of houses and boats. Piatt Lake had sandy beaches and a unique feature in that it had adjoining ponds which flowed into the lake and were rich in lillies and weeds. Carp Lake (T44N, R6W, Sec.22) was surrounded by a sandy beach; this sandy substrate continued into the lake bottom. There were many rocks scattered across the bottom of this larger lake (137 hectares).

MATERIAL AND METHODS

We obtained a water sample from each lake in a 50 mL polyurethane bottle. These samples were analyzed for calcium and pH levels by Michael Grant at the UMBS chemical lab. Both of us collected snails in a 10 x 5 meter quadrat at the same time to ensure that we thoroughly covered the quadrat. We scanned the quadrat and collected all snails found underneath lily pads and on the lake bottom in 15 successive five minute samples. Glass bottom buckets were used to increase visibility. The samples from each of the five minute intervals were counted separately and recorded to observe the successive depletion of the population. We proceeded with this method twice at each lake. The above method describes the depletion estimate from which population estimates can be determined. This method consists of taking repeated sampling of a population so that a constant fraction of the remaining population will be taken in each sample. "This fraction can be estimated by regression of the number taken in ith sample (Y) against the total taken in all previous samples (X). The slope of the regression line is the estimate of the fraction of the remaining population taken with each sample. The X intercept of the line is the estimate of the total population size" (Zippin 1958). We estimated snail species populations for only the species in which we captured more than ten representatives were found. Also, we determined a snail population for the total number of snails found within the quadrats. From these population estimates we found the mean of the samples captured on the two separate sample days.

RESULTS

From the water samples of each lake we found the calcium levels to be proportionally related to the pH levels (Figure 2). Mean population estimates for snails in Piatt Lake (pH 7.08, Ca=10.4 mg/L) and Carp Lake (pH 8.09, Ca=72.3 mg/L) were 491.71 and 201.38, respectively (Table 1 and Table 3). We found no snail fauna in either Johnson (pH 4.46, Ca=1.3 mg/L) or McNearney Lake (pH 3.86, Ca=0.8 mg/L) after searching each for 90 minutes (Table 1). Figure 1 displays differences between mean population estimates of the lakes. In Piatt Lake, the two most abundant species had mean population estimates of 322.89 *Physella ancillaria* and 67.13 *Ferrissia paralleia*, (Table 2). *Amincola limosa*, population estimate=180.12, and *Valvata sincera,* population estimate=21.25, (Table 2) were the only two species for which population estimates were made at Carp Lake.

DISCUSSION

The effects of pH levels were most obviously seen in comparing Johnson Lake (ph 4.46) and McNearny Lake (pH 3.08) with the basic lakes, Piatt (pH 7.08) and Carp Lake (pH 8.09), (Figure 1). There was no snail species found in the acidic lakes while relatively large snail populations existed in the basic lakes. The trend of increasing snail fauna with increasing pH did not continue when comparing Piatt Lake with Carp Lake, (Table 1 and Table 3). Even though Carp Lake had a higher pH, it contained less snails than Piatt Lake. This may suggest that pH is determining the abundance or presence of snails when the lakes are highly acidic, but there may be no difference once a certain pH level is reached (Figure 1). Jewell (1929) found that "the most acid waters in which molluscs were found was pH 6.1 in case of snails and pH 5.7 for *Pisidium*. This approximates the point at which the deposition of lime shells would theoretically cease to be possible."

There was no species overlap in the quadrats or in the shells found on the beaches of Piatt Lake and Carp Lake . From the shells on the beach, we recovered and identified*Gyraulus Torquis circumstriatus* at Piatt Lake. At Carp Lake we found five other shells of species not already mentioned: *Stagnicola emarginata*, *Sphaerium simile*, *Sphaerium striatinum*, *Planorbella Campanulata campanulata* and *Planorbella Pleisoma trivolvis*. This suggests that species diversity varies proportionally with pH levels. "...the restriction of species to specific types of habitats is the general rule (Burch 1989)."

No snails were found in extremely acidic waters and snail species differed between the basic lakes; therefore, our data support the idea that pH levels do limit the abundance and distribution of freshwater snails. However, it is important to keep in mind the other dimensions of an organisms niche. As described earlier, calcium is important in the formation of a snail's shell. Calcium levels in the lakes will also have an effect on snail distribution and abundance. The calcium and pH levels rose proportionally in the lakes that we surveyed, (Figure 2). It would be difficult to exclude one factor in order to study the other. Calcium levels may have been the determining factor of snails presence instead of the pH level. Boycott (1934) also found in his survey that a number of molluscs do not live in freshwater below a specific calcium level.

Varying vegetation will also affect snail distribution. Piatt Lake contained more vegetation than Carp Lake. The ponds connected to Piatt

Lake also provided this lake with more algae slime which freshwater snails eat (Boycott 1919). Aldridge (1983) found that "...food availability is an important determinant of snail distribution patterns." Water lilies also provide favorable habitats for snails. Boycott (1919) observed that water lilies afford particularly favorable nurseries for the eggs and young.

Temperature could also alter the abundance and distribution of freshwater snails. "Many animals, including molluscs, migrate downshore or into the sublittoral during the autumn...(Wilbur and Yonge 1964)." The size of the lakes can help determine the temperature. For example a smaller, and shallower lake will provide a snail with a higher temperature. At the same time, a smaller lake could also provide a snail with less vegetation and possibly make food and shelter limiting resources. All of the factors mentioned above influence the niche of freshwater snails, but we conclude that pH levels do play a significant role in determining snail distribution and abundance.

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MEAN POP ESTIMATES IN FOUR LAKES AS RELATED TO pH

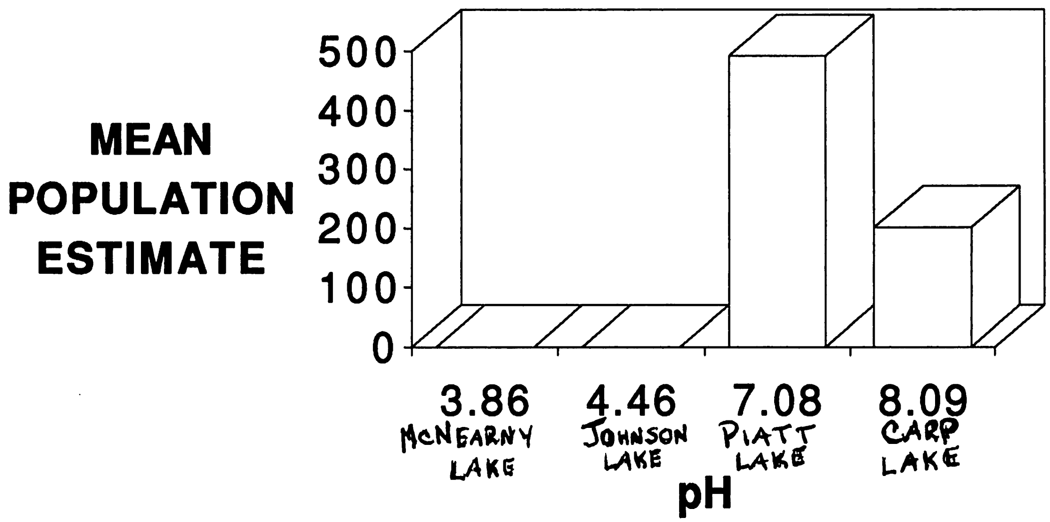

FIGURE 1

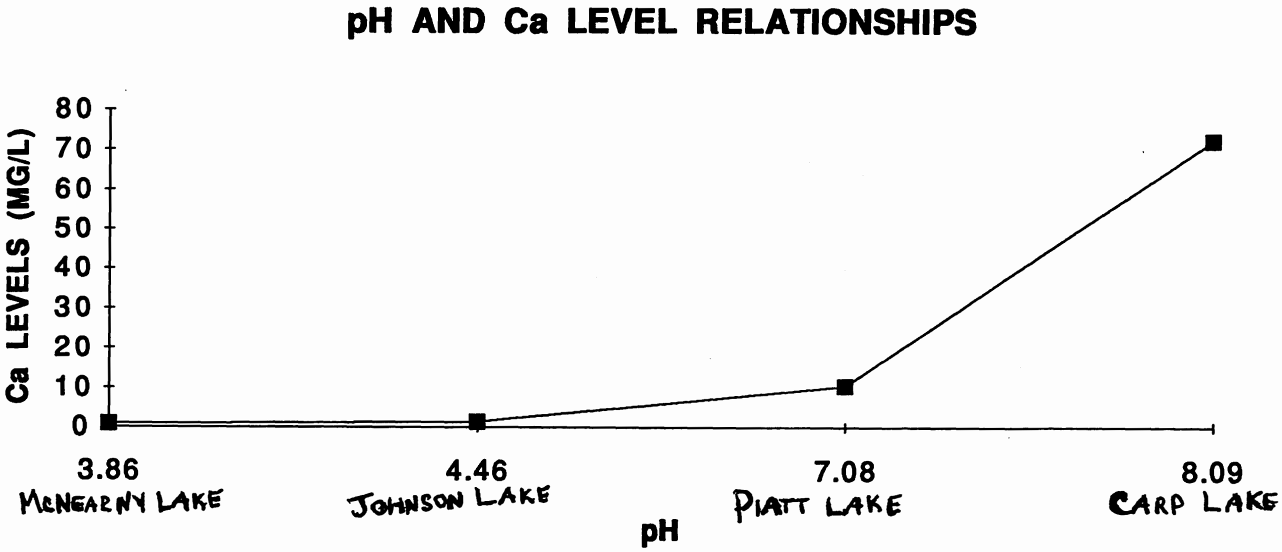
pH AND Ca LEVEL RELATIONSHIPS
Ca LEVELS (MG/L)
80
70
60
50
40
30
20
10
0
3.86
MCNEARNY LAKE
4.46
JOHNSON LAKE
7.08
PIATT LAKE
8.09
CARP LAKE
pH

FIGURE 2

APPENDIX

CARP LAKE SNAIL POPULATION ESTIMATES

CARP LAKE POPULATION ESTIMATES

AMNICOLA LIMOSA ESTIMATION #1

SAMPLE #	#/SAMPLE	TOTAL TAKEN	X^2	X*Y
1	53	0	0	0
2	27	53	2809	1431
3	22	80	6400	1760
4	8	102	10404	816
5	11	110	12100	1210
6	13	121	14641	1573
7	2	134	17956	268
8	4	136	18496	544
9	0	140	19600	0
10	0	140	19600	0
11	1	140	19600	140
12	0	141	19881	0
13	0	141	19881	0
14	0	141	19881	0
15	0	141	19881	0
TOTAL	141	1720	221130	7742
MEAN	9.4	114.67		
SLOPE	-0.3525031			
Y-INTERCEPT	49.8215348			
POP EST	141.336429			

VALVATA ESTIMATION #1

SAMPLE #	#/SAMPLE	TOTAL TAKEN	X^2	X*Y
1	0	0	0	0
2	4	0	0	0
3	4	4	16	16
4	4	8	64	32
5	1	12	144	12
6	0	13	169	0
7	0	13	169	0
8	0	13	169	0
9	0	13	169	0
10	0	13	169	0
11	0	13	169	0
12	0	13	169	0
13	0	13	169	0
14	0	13	169	0
15	0	13	169	0
TOTAL	13	154	1914	60
MEAN	0.87	10.27		
SLOPE	-0.2208648			
Y-INTERCEPT	3.13622747			
POP EST	14.2126316			

SAMPLE #	SNAIL/SM#1	TOTAL TAKEN	X^2	X*Y
1	53	0	0	0
2	31	53	2809	1643
3	26	84	7056	2184
4	12	110	12100	1320
5	12	122	14884	1464
6	13	134	17956	1742
7	2	147	21609	294
8	4	149	22201	596
9	0	153	23409	0
10	0	153	23409	0
11	1	153	23409	153
12	0	154	23716	0
13	0	154	23716	0
14	0	154	23716	0
15	0	154	23716	0
TOTAL	154	1874	263706	9396
MEAN	10.27	124.93		
SLOPE	-0.3327729			
Y-INTERCEPT	51.8433199			
POP ESTIMATE	155.791887			

AMNICOLA LIMOSA ESTIMATION #2

SAMPLE #	#/SAMPLE	TOTAL TAKEN	X^2	X*Y
1	72	0	0	0
2	51	72	5184	3672
3	22	123	15129	2706
4	26	145	21025	3770
5	16	171	29241	2736
6	8	187	34969	1496
7	12	195	38025	2340
8	7	207	42849	1449
9	2	214	45796	428
10	0	216	46656	0
11	0	216	46656	0
12	0	216	46656	0
13	1	216	46656	216
14	1	217	47089	217
15	0	218	47524	0
TOTAL	218	2613	513455	19030
MEAN	14.5333333	174.2		
SLOPE	-0.3251325			
Y-INTERCEPT	71.1714124			
POP EST	218.899727			

MEAN POP. EST. FROM TWO AMNICOLA SAMPLES *180.11808*

VALVATA ESTIMATION #2

SAMPLE #	#SAMPLE	TOTAL TAKEN	X^2	X*Y
1	5	0	0	0
2	8	5	25	40
3	4	13	169	52
4	2	17	289	34
5	2	19	361	38
6	3	21	441	63
7	1	24	576	24
8	0	25	625	0
9	0	25	625	0
10	0	25	625	0
11	1	25	625	25
12	2	26	676	52
13	0	28	784	0
14	0	28	784	0
15	0	28	784	0
TOTAL	28	309	7389	328
MEAN	1.86666667	20.6		
SLOPE	-0.2430637			
Y-INTERCEPT	6.87377882			
POP EST	28.2797428			

MEAN POP. EST. FOR TWO VALVATA SAMPLES *21.246187*

SAMPLE #	SNAIL/SM#2	TOTAL TAKEN	X^2	X*Y
1	77	0	0	0
2	59	77	5929	4543
3	26	136	18496	3536
4	28	162	26244	4536
5	18	190	36100	3420
6	11	208	43264	2288
7	13	219	47961	2847
8	7	232	53824	1624
9	2	239	57121	478
10	0	241	58081	0
11	1	241	58081	241
12	2	242	58564	484
13	1	244	59536	244
14	1	245	60025	245
15	0	246	60516	0
TOTAL	246	2922	643742	24486
MEAN	16.4	194.8		
SLOPE	-0.3144075			
Y-INTERCEPT	77.6465727			
POP ESTIMATE	246.961613			

MEAN POP EST OF SNAIL ABUNDANCE IN CARP *201.37675*

PIATT LAKE SNAIL POPULATION ESTIMATES

IST DAY SAMPLES OF PHYSA AND LIMPET

PHYSA ESTIMATION #1

SAMPLE #	#/SAMPLE	TOTAL TAKEN	X^2	X*Y
1	37	0	0	0
2	32	37	1369	1184
3	31	69	4761	2139
4	30	100	10000	3000
5	29	130	16900	3770
6	28	159	25281	4452
7	19	187	34969	3553
8	15	206	42436	3090
9	16	221	48841	3536
10	12	237	56169	2844
11	9	249	62001	2241
12	5	258	66564	1290
13	2	263	69169	526
14	1	265	70225	265
15	1	266	70756	266
TOTAL	267	2647	579441	32156
MEAN	17.8	176.466667		
SLOPE	-0.1331799			
Y-INTERCEPT	41.3018203			
POP ESTIMATE	310.120427			
MEAN POP ESTIMATE FOR PHYSA			*322.88525*	

2ND DAY SAMPLES FOR PHYSA AND LIMPET

PHYSA ESTIMATION #2

SAMPLE #	#/SAMPLE	TOTAL TAKEN	X^2	X*Y
1	41	0	0	0
2	34	41	1681	1394
3	32	75	5625	2400
4	32	107	11449	3424
5	35	139	19321	4865
6	26	170	28900	4420
7	25	196	38416	4900
8	23	221	48841	5083
9	17	244	59536	4148
10	9	261	68121	2349
11	8	270	72900	2160
12	5	278	77284	1390
13	3	283	80089	849
14	1	286	81796	286
15	1	287	82369	287
TOTAL	292	2858	676328	37955
MEAN	19.47	190.53		
SLOPE	-0.1341648			
Y-INTERCEPT	45.0324123			
POP ESTIMATE	335.650072			

SAMPLE #	SNAIL/SM#1	TOTAL TAKEN	X^2	X*Y
1	58	0	0	0
2	47	58	3364	2726
3	42	105	11025	4410
4	39	147	21609	5733
5	36	186	34596	6696
6	29	222	49284	6438
7	20	251	63001	5020
8	16	271	73441	4336
9	16	287	82369	4592
10	12	303	91809	3636
11	11	315	99225	3465
12	6	326	106276	1956
13	2	332	110224	664
14	1	334	111556	334
15	1	335	112225	335
TOTAL	336	3472	970004	50341
MEAN	37.27	369.67		
SLOPE	-0.1649024			
Y-INTERCEPT	98.2294701			
POP ESTIMATE	595.682478			

LIMPET ESTIMATION #1

SAMPLE	#/SAMPLE	TOTAL TAKEN	X^2	X*Y
1	21	0	0	0
2	15	21	441	315
3	11	36	1296	396
4	9	47	2209	423
5	7	56	3136	392
6	1	63	3969	63
7	1	64	4096	64
8	1	65	4225	65
9	0	66	4356	0
10	0	66	4356	0
11	2	66	4356	132
12	1	68	4624	68
13	0	69	4761	0
14	0	69	4761	0
15	0	69	4761	0
TOTAL	69	825	51347	1918
MEAN	4.6	55		
SLOPE	-0.3143001			
Y-INTERCEPT	21.8865037			
POP EST	69.6356953			
MEAN POP ESTIMATE FOR LIMPETS			*67.130548*	

LIMPET ESTIMATION #2

SAMPLE #	#/SAMPLE	TOTAL TAKEN	X^2	X*Y
1	21	0	0	0
2	12	19	361	228
3	15	31	961	465
4	3	42	1764	126
5	6	51	2601	306
6	2	57	3249	114
7	1	61	3721	61
8	0	62	3844	0
9	0	64	4096	0
10	0	64	4096	0
11	0	64	4096	0
12	1	64	4096	64
13	0	65	4225	0
14	0	66	4356	0
15	0	66	4356	0
TOTAL	61	776	45822	1364
MEAN	4.07	51.73		
SLOPE	-0.3156164			
Y-INTERCEPT	20.396837			
POP ESTIMATE	64.6254004			

SAMPLE #	SNAIL/SM#2	TOTAL TAKEN	X^2	X*Y
1	62	0	0	0
2	46	62	3844	2852
3	47	108	11664	5076
4	35	155	24025	5425
5	41	190	36100	7790
6	28	231	53361	6468
7	26	259	67081	6734
8	23	285	81225	6555
9	17	308	94864	5236
10	9	325	105625	2925
11	8	334	111556	2672
12	6	342	116964	2052
13	3	348	121104	1044
14	1	351	123201	351
15	1	352	123904	352
TOTAL	353	3650	1074518	55532
MEAN	23.53	243.33		
SLOPE	-0.1629431			
Y-INTERCEPT	63.1789481			
POP. ESTIMATE	387.736225			
MEAN POP ESTIMATE OF SNAIL ABUDANCE OF PIAT				*491.70935*

APPENDIX 2