EFFECTS OF WATER HARDNESS ON FISH PRODUCTION IN PLASTIC POOLS

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INTRODUCTION

Several studies have shown a relationship between fish production in lakes and water quality factors correlated with hardness. Hayes and Anthony (1964) and Turner (1960) found correlations between alkalinity and fish production while Ryder (1965) found a correlation between total dissolved solids and fish production. However, natural fertility of the water is correlated with alkalinity, total dissolved solids and hardness, so the effects of one cannot be separated from the effects of another. Moreover, the relationships in lakes are obscured by morphometric and climatic factors, as well as by the difficulty of finding a uniform measure of productivity.

The experiments reported here were undertaken to study the effects of hardness, of bottom soil, and of the interaction between hardness and bottom soil on fish production.

MATERIALS AND METHODS

Circular, plastic-lined pools, 10 ft. in diameter and 18 to 25 in. deep were set up and filled with well water (total hardness about 30 ppm of which about two-thirds was calcium hardness). Each pool was stocked with 50 fathead minnows (*Pimephales promelas*) weighing approximately 50 gm. The pools for 13 of the treatment combinations were set up between April 15 and 19, those for the other 2 (treatments 6 and 11) were set up between May 13 and 16. A drain tile was placed in each pool as a spawning site for the fatheads. The pools were fertilized monthly with the equivalent of 8 pounds nitrogen and 8 pounds P_2O_5 per acre per application. Approximately four inches of Cecil soil from an adjacent hillside were placed in 45 of the pools; the other 30 had no soil. Hardness was increased by applying $CaCO_3$, $CaSO_4$, and $MgCO_3$. Each treatment combination was replicated in 5 pools. Table 1 shows the treatment combinations and the amounts of each chemical added. Water from the pools was analyzed four times at approximately monthly intervals for calcium hardness and total hardness by EDTA titration. Magnesium hardness was calculated by subtraction. The means of the four analyses were used as the calcium and magnesium hardness in each pool.

At the end of the experiment, November 14 through 27, the fish were harvested by poisoning with rotenone. Essentially all the fish were collected because the water was clear enough for dead fish to be visible on the bottom. In a few pools fish had to be picked up on the second and third day. Since few of the stocked adult fish survived until harvest, the weight of fish harvested is considered to be the fish production for the year.

Data was analyzed by computer, using programs for analysis of variance and linear, quadratic and cubic regression.

TABLE 1. Soil and Added Chemicals in Each Treatment Combination

	Soil	Chemical	Amount added, gm.	Equivalent hardness, ppm as $CaCO_3$
1	Cecil	.....	...	0
2	Cecil	$CaCO_3$	276	50
3	Cecil	$CaCO_3$	552	100
4	Cecil	$CaCO_3$	980	... [1]
5	Cecil	$CaSO_4$	475	50
6	Cecil	$CaSO_4$	950	100
7	None	$CaSO_4$	950	100
8	None	.....	...	0
9	None	$CaCO_3$	552	100
10	Cecil	$MgCO_3$	233	50
11	Cecil	$MgCO_3$	466	100
12	Cecil	$CaCO_3$	276	100 [2]
		$+MgCO_3$	233	
13	None	$MgCO_3$	233	50
14	None	$MgCO_3$	466	100
15	None	$CaCO_3$	276	100 [2]
		$+MgCO_3$	233	

RESULTS AND DISCUSSION

Fish production ranged from 27.3 gm/pool (33.4 lb./acre) in a pool receiving 100 ppm $MgCO_3$ to 815.8 gm/pool (998 lb./acre) in a pool receiving 100 ppm $CaSO_4$ The calcium hardness ranged from 16.7 to 157 ppm as $CaCO_3$. The magnesium hardness ranged from 3.7 to 118 ppm as $CaCO_3$. The mean fish production and calcium and magnesium hardness of each treatment combination are shown in Table 2.

Three pools suffered complete or almost complete mortality from unknown causes and a fourth leaked and went dry. Data from these pools are omitted from the analysis.

Effect of Soil:

A comparison of 28 pools with soil against 27 pools without soil receiving comparable added hardness gave the following mean fish productions:

Treatment	Mean gm. fish/pool
Cecil soil	234.1
No soil	190.7

This difference was not statistically significant (p greater than 0.25) because of the large variation between pools treated alike. Thus, the presence of Cecil soil had no measurable effect on fish production in these experiments. It appears that in fertilized pools the nutrients from the soil play a negligible role. In the succeeding discussion the presence of soil in the pool is ignored.

Effect of Added Hardness

The relationships of fish production to calcium and to total hardness in all pools are presented in Figures 1 and 2. Fish production increased significantly (p less than 0.005) as calcium and total hardness increased.

There were significant differences in fish production related to the source of added hardness. Pools treated with $CaSO_4$ had significantly greater (p less than 0.005) fish production than those treated with $CaCO_3$, $MgCO_3$, a combination of $CaCO_3$ and $MgCO_3$, or no additional hardness. The other treatments were not significantly different from

[1] This amount satisfied the lime requirement of the soil.
[2] 50 ppm each of $CaCO_3$ and $MgCO_3$.

TABLE 2. Mean Fish Production and Hardness in Each Treatment Combination

Treatment	mean gm fish/pool	mean Ca as ppm $CaCO_3$	mean Mg as ppm $CaCO_3$
1	247.5	22.9	13.0
2	194.9	37.0	13.2
3	116.6	34.0	12.9
4	151.8	49.9	21.3
5	325.9	49.5	17.5
6	392.9	110.6	21.9
7	482.9	145.0	17.2
8	255.2	27.2	15.5
9	86.6	44.4	5.2
10	217.5	23.0	48.3
11	182.5	24.0	96.7
12	243.3	34.6	40.4
13	142.6	27.7	30.8
14	122.4	29.3	37.8
15	172.3	38.2	12.3

each other. Therefore, the data from the pools receiving each source of hardness were analyzed separately. The 10 control pools, receiving no increase in hardness, were included in each analysis since they represented the zero level of all treatments.

Data from 23 pools were used to calculate the relationship between fish production and hardness resulting from added $CaSO_4$. The relation between calcium and fish production is presented in Figure 3. Fish production increased significantly (p less than 0.025) with the addition of $CaSO_4$ hardness. The relationship between fish production and total hardness was similar to that of fish production and calcium, since in these pools the magnesium content was relatively small and essentially constant. The increase in production related to increase in hardness is primarily a result of the pools receiving $CaSO_4$.

Data from 30 pools were used to calculate the relationship between fish production and hardness due to added $CaCO_3$. Figure 4 shows the linear and quadratic regressions of fish production on calcium hardness. Both curves are significant (p less than 0.05). The quadratic equation fits the data somewhat better as shown by the higher "r" value, but this is probably an accident.

Data from 29 pools were used to calculate the relationship between fish production and hardness because of added $MgCO_3$. Although the pools with the higher levels of magnesium hardness had lower fish production none of the regressions was significant, showing no apparent relationship between magnesium content and fish production.

Overall fish production was related to calcium hardness of the water, but it was also influenced by the anion accompanying the calcium. In those pools where the calcium levels were comparable, production was higher in pools receiving $CaSO_4$ than in those receiving $CaCO_3$. Thus the greater production with added $CaSO_4$ was not simply a result of greater solubility of $CaSO_4$. Moreover, the increased hardness because of the addition of $CaCO_3$ caused a decrease in fish production as shown in Figure 4. It appears possible that the addition of sulfate increases fish production while carbonate or something associated with it inhibits it. The inhibiting factor may be increased pH associated with the increased carbonate. Further work is in progress to clarify this.

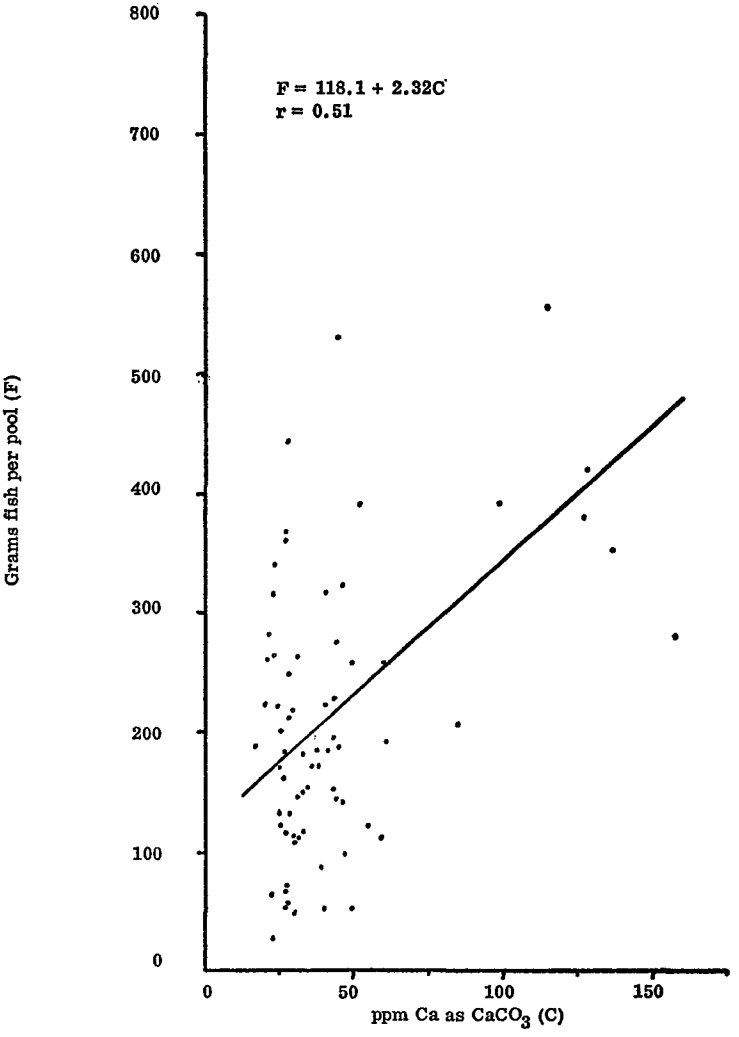

Figure 1. Relationship of Fish Production to Calcium Hardness in All Pools.

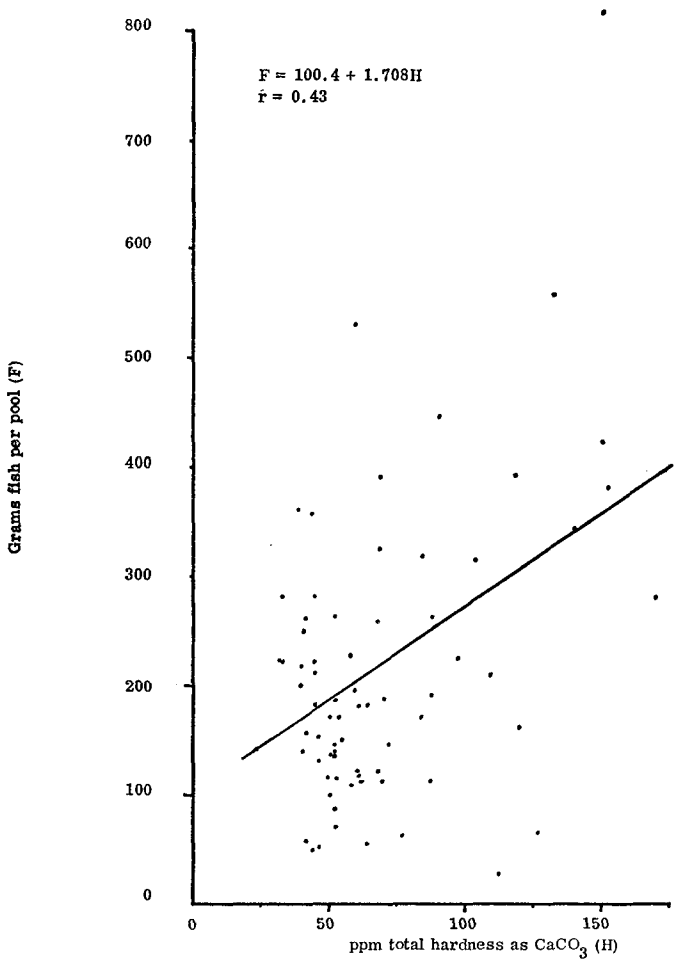

Figure 2. Relationship of Fish Production to Total Hardness in All Pools.

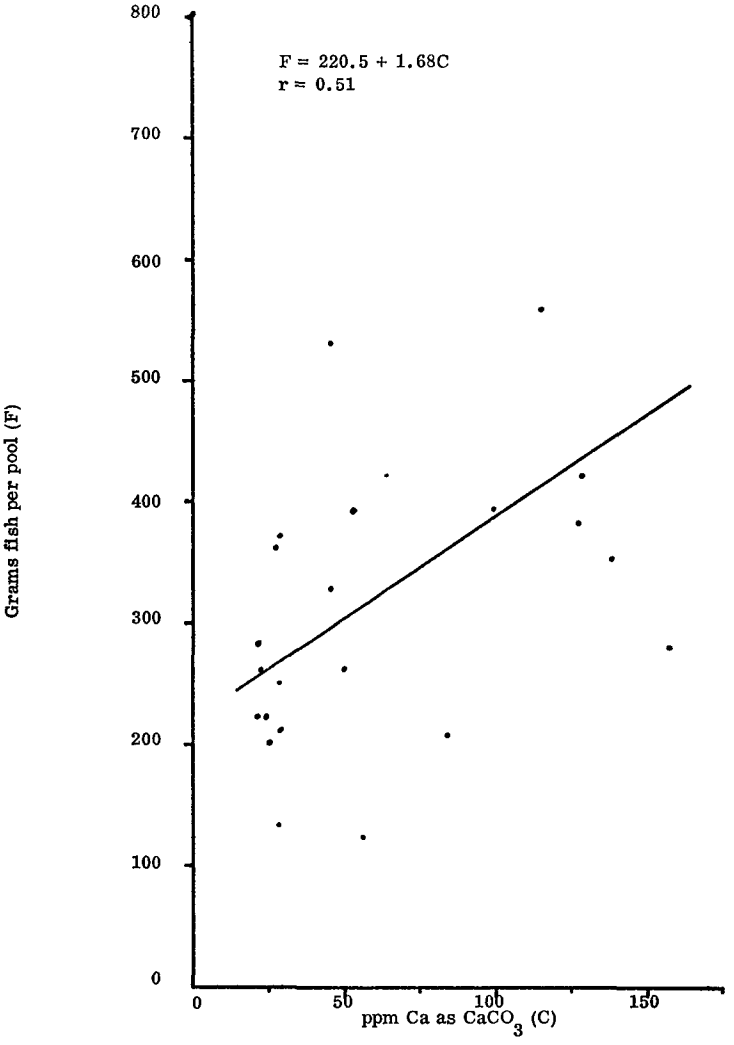

Figure 3. Relationship of Fish Production to Calcium Hardness in $CaSO_4$ Pools.

CONCLUSIONS

1. The presence of Cecil soil in the pools had no significant effect on fish production.

2. Magnesium hardness had no measurable effect on fish production.

3. The increased hardness resulting from the addition of $CaSO_4$ increased fish production.

4. The increase in hardness due to addition of $CaCO_3$ appeared to decrease fish production.

5. The different effects with $CaSO_4$ and $CaCO_3$ may be due to the effects of sulfate and carbonate.

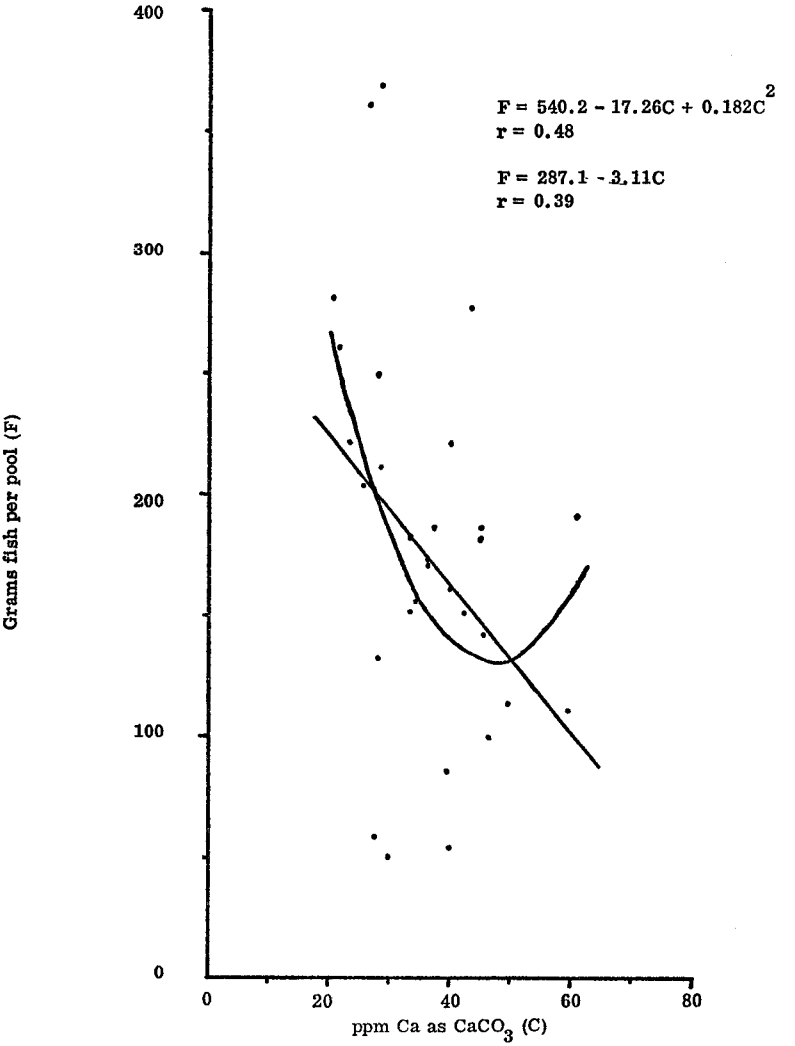

Figure 4. Relationship of Fish Production to Calcium Hardness in $CaCO_3$ Pools.

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