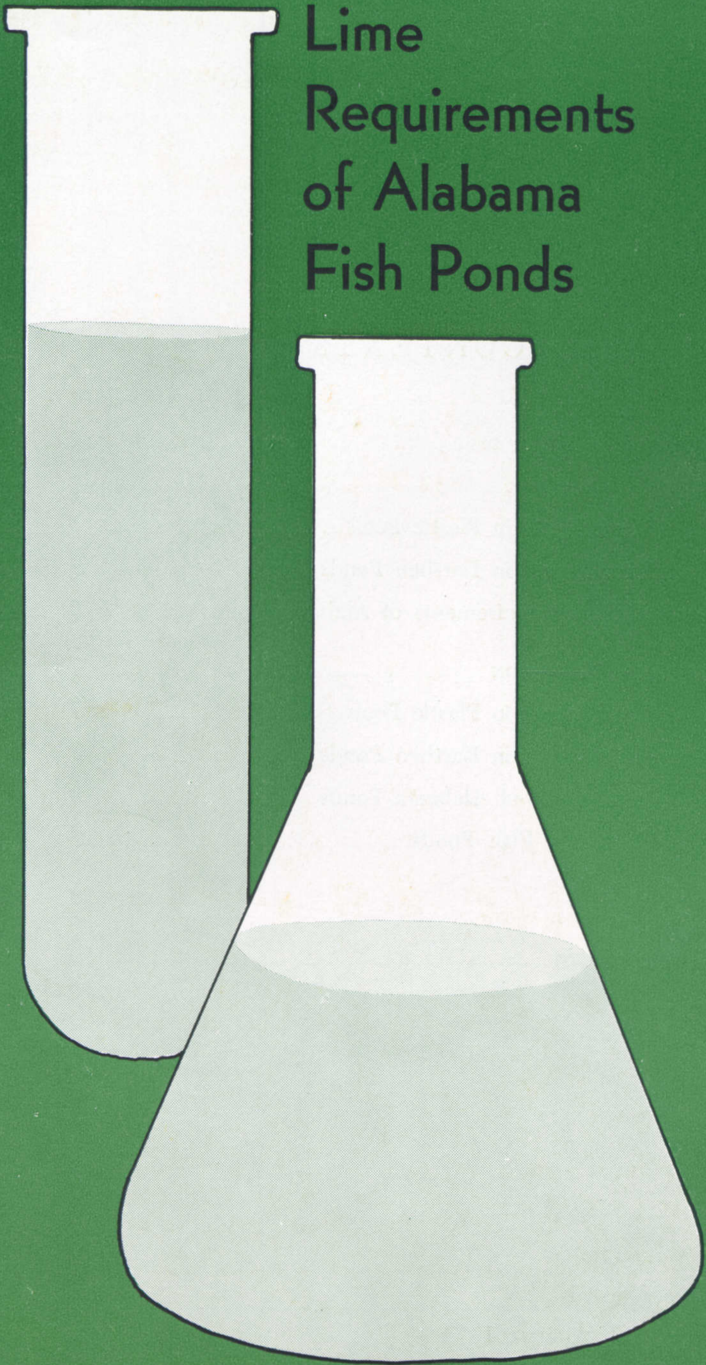
Lime Requirements of Alabama Fish Ponds



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LIME REQUIREMENTS of ALABAMA FISH PONDS

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PHYTOPLANKTON GROWTH in soft waters may be limited by inadequate supplies of carbon dioxide or bicarbonate and low concentrations of calcium *(5,8)*. Fertilization of ponds in Georgia with less than 10 milligrams per liter total hardness did not produce adequate phytoplankton growth for good fish production. Responses to fertilization were variable in waters with 10 to 20 milligrams per liter total hardness, but waters above 20 milligrams per liter consistently produced adequate phytoplankton growth after fertilization *(8)*. The author has made similar pond observations in Alabama.

Applying lime to ponds with soft water increases bicarbonate and calcium concentrations, thereby improving conditions for phytoplankton growth. Lime reacts with bottom muds, neutralizing acidity and increasing base saturation by exchanging basic for acidic ions on cation exchange sites. Schaeperclaus *(6)* recognized that more lime is required for ponds with clay bottoms than for those with sandy bottoms and adopted a crude technique from agriculture, based on pH and texture of muds, for estimating liming rates. Once ponds are properly limed, further application of lime is required only to replace that lost in outflow *(3)*.

The lime requirement of a soil is a function of the soil's pH and buffer capacity, and it is a measure of the amount of acidity which must be neutralized with lime to affect a specified change in soil pH. Adams and Evans *(1)* developed an accurate and rapid method for measuring lime requirements of red-yellow podzolic

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soils commonly found in the Southeastern United States. Unfortunately, there are no data relating this procedure to pond muds. Neither is there agreement on which liming material to use in fish ponds. Agricultural limestone, basic slag, and hydrated lime have been used about equally in the United States.

The present investigation had two basic objectives: to evaluate the lime requirement procedure for use on pond muds, and to test the effectiveness of various liming materials for use in fish ponds.

MATERIALS AND METHODS

Chemical Analyses

Total, carbonate, and bicarbonate alkalinity and total hardness of water samples were measured by standard procedures *(2)*. All pH determinations of waters were with an Orion Model 401 pH meter. Mud samples were spread in thin layers to air dry, gently pulverized with a mortar and pestle, and sieved through a screen with 0.85-millimeter openings. Chemical analyses of muds were made by the Auburn University Soil Testing Laboratory. Amounts of lime required to raise the pH of pond muds to 6.5 were estimated from lime requirement tests *(1)*. Exchangeable calcium, magnesium, and potassium were extracted from muds with 0.05N hydrochloric acid plus 0.025N sulfuric acid and determined by atomic absorption spectroscopy. Cation exchange capacity of muds was estimated from the sum of exchangeable cations and exchange acidity. Base unsaturation was calculated by dividing exchange acidity by cation exchange capacity. Organic matter in muds was measured by the Walkley-Black method *(4)*.

Liming Experiments in Plastic Pools

A Cecil sandy loam top soil was spread to a depth of 4 inches in bottoms of 35 plastic pools (10 feet in diameter). The lime requirement was used to determine dosages of calcitic limestone, dolomitic limestone, hydrated lime, and basic slag. Pools were filled on March 15, 1973, with well water containing 11.0 milligrams per liter total hardness and 13.5 milligrams per liter total alkalinity. Each liming material was sprinkled over the water surface of seven pools on April 17. Seven additional pools served as controls. Beginning April 19 and continuing at monthly intervals, triple superphosphate and ammonium nitrate were added to each pool in amounts equivalent to 40 pounds per acre of 20-20-0 fertilizer. Evaporation losses were replaced with well water at weekly intervals. Water samples collected monthly within 2 hours of sunrise were analyzed for total hardness and alkalinity. The pH of waters was measured on several occasions, and mud pH determinations were made on samples collected September 1, 1973.

Liming Experiments in Earthen Ponds

The eight ponds of this experiment were located on Piedmont soils of the Auburn University Fisheries Research Unit. The length and width of each pond were traversed in an S-shaped pattern by boat and 10 to 15 grabs taken at appropriate intervals with an Ekman dredge. The number of grabs from shallow (less than 4.5 feet) and deeper waters was weighted according to the proportion of shallow and deep water in a pond. About 0.25 liter of mud was removed from each grab sample and placed in a plastic bucket. After all grabs were obtained for a pond, mud in the bucket was thoroughly mixed and spread in thin layers to dry. Lime requirements were used to calculate application rates of dolomitic agricultural limestone. Limestone was broadcast over surfaces of ponds between February 17 and 23, 1973. Water samples were collected periodically for analysis of total hardness and alkalinity and muds were collected in August 1973 and February 1974 for chemical analysis.

An Ekman dredge was used to collect mud samples at 1.5-foot depth intervals along three transects from shallow to deep water in a 5.2-acre pond. Samples were analyzed for lime requirement and data evaluated to determine the necessity for taking samples from various depths.

Survey of Lime Requirements of Alabama Ponds

Ponds located on major soil areas of Alabama were sampled during June, July, and August 1973, Figure 1. The 145 ponds varied in age from 1 to 41 years and in surface area from 0.25 to 35 acres. Ponds were located on a variety of watershed types, including pastures, woodlands, residential areas, and row-cropped fields. A few ponds received inflow from springs, but most were filled by runoff. Forty-two ponds received periodic or occasional

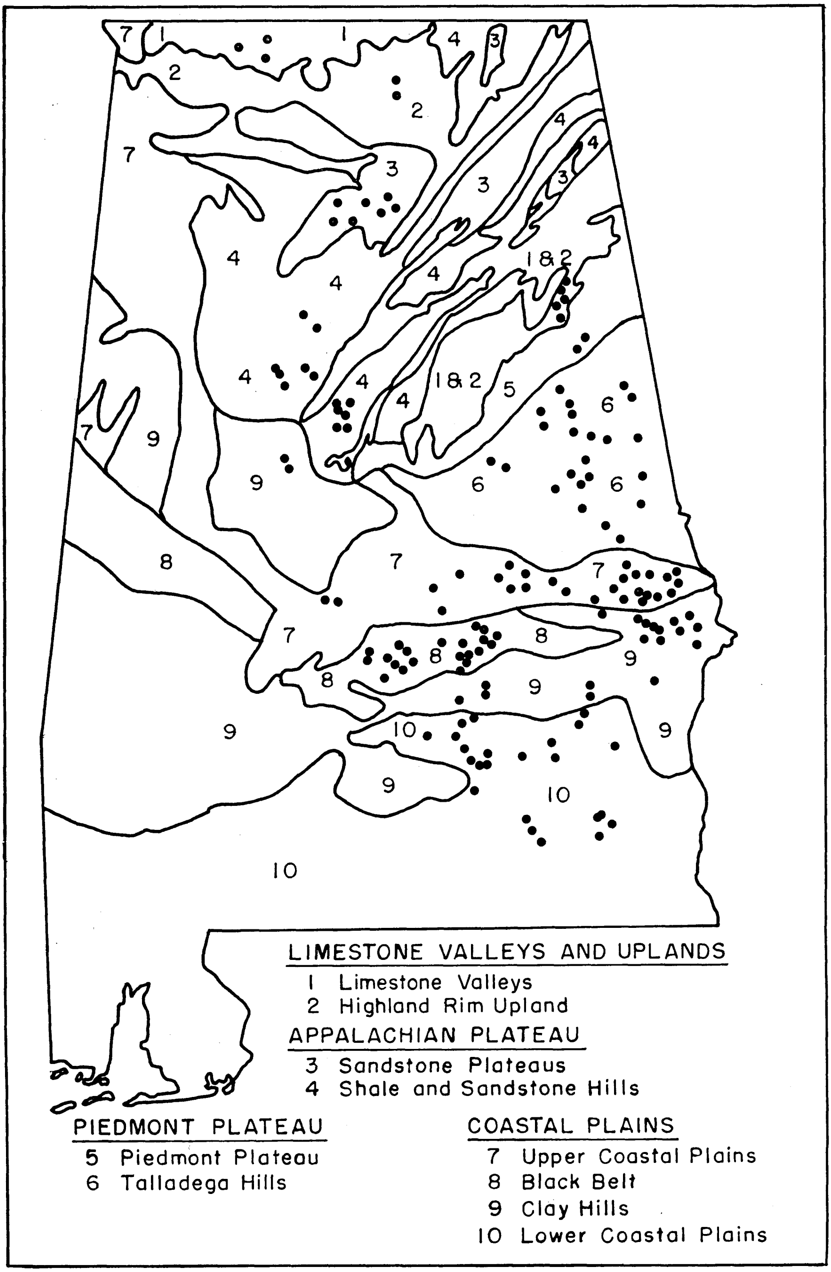


FIG. 1. Locations of the 145 ponds used for investigating relationships between total hardness of water and mud chemistry.

applications of fertilizers or substantial nutrient inputs from watersheds; two had been limed in previous years.

Samples of surface water were collected and analyzed for hardness and alkalinity. Mud samples were collected, processed, and analyzed as previously described.

RESULTS AND DISCUSSION

Calcium and magnesium were the cations associated with the anions of alkalinity in waters of Alabama ponds, as total hardness (the X-variable) and total alkalinity (the Y-variable) were highly correlated ($r = 0.99$; $\hat{Y} = 2.26 + 0.96X$). Liming materials contributed hardness cations and alkalinity anions in equivalent proportions, so there was no alteration of the natural proportionality between total hardness and total alkalinity. The residual effect of lime is related to the influence of calcium or calcium and magnesium ions on base unsaturation of muds. Therefore, total hardness rather than total alkalinity was compared with data on mud chemistry in evaluating the lime status of ponds.

Liming Experiments in Plastic Pools

All pH values for waters of pools were in the range of 7 to 8 before treatment. All liming materials used caused pH values to rise, but calcium hydroxide was the only material that raised pH to levels harmful to fish. Two weeks after application, however, pH values in pools treated with calcium hydroxide were within the pH range of pools treated with other liming materials (pH 8.0 to 9.5). During June, July, and August when phytoplankton was abundant, midday pH values usually exceeded 8.5 in all pools.

Before treatment, total hardness averaged 11.8 milligrams per liter in the 35 pools. All liming agents caused a threefold to fourfold increase, Figure 2. Two weeks after application of hydrated lime, no hydroxide alkalinity was detectable since the hydroxide had either reacted with the mud to neutralize acidity or with carbon dioxide to form bicarbonate. Total hardness in all limed pools was higher than necessary to assure optimum response to fertilization.

Average pH of muds of the five treatments on September 1, 1973, was: control – 5.6, calcite – 7.2, dolomite – 7.0, hydrated lime – 7.2, and basic slag – 6.8.

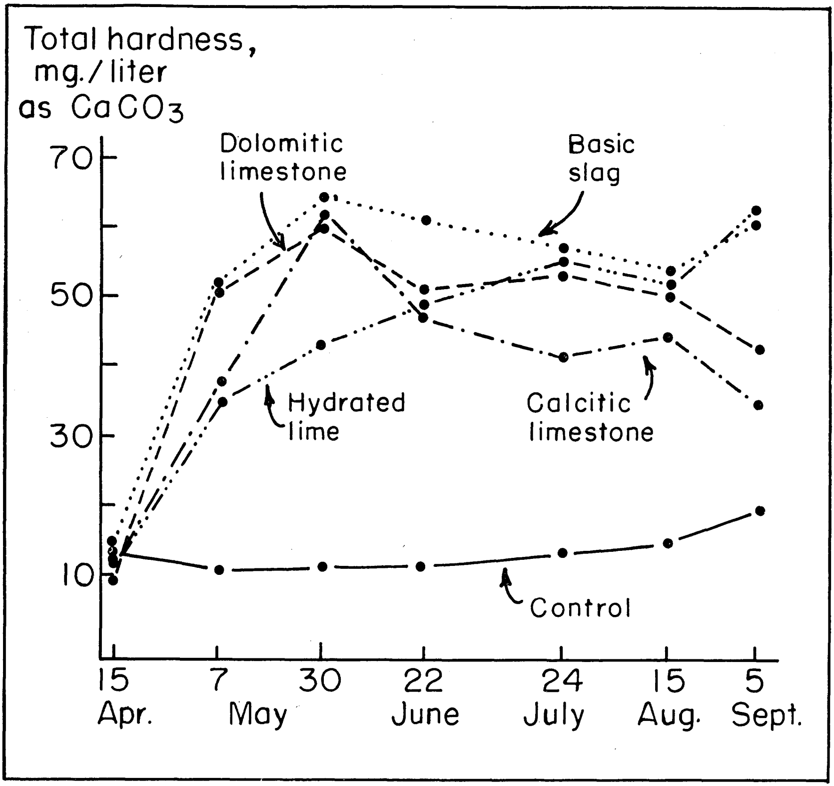


FIG. 2. Total hardness of waters of plastic pools in which bottom muds were treated with various liming agents. Liming rates were calculated by Adams-Evans lime requirement test.

Liming Experiments in Earthen Ponds

Muds from shallow waters of ponds were observed to contain more sand and less clay than muds from deeper waters. Lime requirements were roughly three to five times greater for muds from depths of 6 to 10.5 feet than for muds from depths of 1.5 to 4.5 feet, Table 1. At most depths there were considerable differences in lime requirements of samples from different transects. These findings reveal that the sampling procedure was adequate for obtaining representative samples of mud from ponds.

The eight ponds used in this experiment had total hardness values of 3 to 12 milligrams per liter and mud pH ranging from

TABLE 1. LIME REQUIREMENTS OF MUD SAMPLES TAKEN FROM DIFFERENT DEPTHS ALONG THREE DIFFERENT TRANSECTS IN A POND

Depth, feet	Lime requirement per acre			
	Transect 1	Transect 2	Transect 3	Average
	Tons	*Tons*	*Tons*	*Tons*
1.5	0.7	0.5	0.5	0.6
3.0	0.5	0.5	0.4	0.5
4.5	0.5	0.5	0.5	0.5
6.0	1.3	1.6	1.6	1.5
7.5	2.0	1.7	2.0	1.9
8.0	1.3	2.0	1.2	1.5
10.5	1.7	2.5	2.3	2.2

5.1 to 5.7, Table 2. The larger ponds had greater water:mud ratios than the smaller ponds. Applications of agricultural limestone resulted in immediate increases in total hardness and alkalinity. Six and twelve months after application, values were still twice or more higher than initial values, Table 2. There were considerable losses of water from all eight ponds. Seepage from a well constructed pond in the Piedmont area of Alabama was 95 inches per year (*7*). In addition to seepage, ponds S-11, S-12, S-13, and S-19 also lost considerable water in outflow following most periods of significant rainfall. Therefore, detention time of water in all ponds was probably less than 6 months. Ponds M-16, M-17, M-18, and E-73 were drained 8 months after treatment and refilled with water containing only 10 milligrams per liter total hardness. Amounts of limestone applied were sufficient to replenish calcium and magnesium ions lost in outflow and seepage and maintain total hardness values above 20 milligrams per liter. Ap-

TABLE 2. EFFECT OF APPLICATIONS OF AGRICULTURAL LIMESTONE ON WATERS AND MUDS OF EIGHT PONDS OF THE ALABAMA PIEDMONT

Test pond			Initial values		Values following treatment				
					6 months after		12 months after		
No.	Area, acres	Av. depth, ft.	Mud pH	Total hardness	Mud pH	Total hardness	Mud pH	Base unsaturation	Total hardness
				mg./l.		*mg./l.*			*mg./l.*
S-11	2.8	5	5.5	11.7	6.4	34.5	6.2	0.15	29.9
S-12	2.2	5	5.7	11.1	6.5	23.8	6.0	0.11	23.2
S-13	2.1	5	5.2	12.1	6.5	34.0	6.5	0.12	31.6
S-19	1.7	5	5.1	3.3	7.2	49.5	6.7	0.09	27.4
M-16	0.16	3	5.2	14.0	6.7	53.4	7.1	0.10	42.2
M-17	0.16	3	5.1	9.0	6.8	31.0	7.0	0.13	37.4
M-18	0.16	3	5.1	12.3	6.7	33.0	7.0	0.11	24.4
E-73	0.10	3	5.2	10.2	6.9	24.0	6.9	0.16	23.9

plication of limestone according to the lime requirement test *(1)* probably would cause even greater increases in total hardness in ponds which lose less water through outflow and seepage. Water: mud ratios did not greatly influence the effect of lime. Results presented in Table 2 reveal that total hardness for ponds of both depth groups was similar. However, increases in total hardness following liming were greater in plastic pools, Figure 2, than in earthen ponds, Table 2. Water depth in plastic pools was only 2 feet and no water was lost to seepage or outflow.

Base unsaturation of muds ranged from 0.09 to 0.16 after 12 months, Table 2, indicating that ions responsible for exchange acidity were replaced by calcium and magnesium. The pH of muds increased following reaction with limestone. Six months after application, pH values ranged from 6.4 to 7.2 and 12 months after application pH values were between 6.0 and 7.1, Table 2.

Lime Requirements of Alabama Ponds

Ponds on alkaline soil areas of the Black Belt had pH values above 7.0 and did not require lime. Most ponds of the Limestone Valleys and Uplands, Appalachian Plateau, Upper Coastal Plains, and acid soil areas of the Black Belt had lime requirements of 1.5 to 2 tons per acre as calcium carbonate. Most ponds of the Lower Coastal Plains and Clay Hills areas had lime requirements greater than 2 tons per acre. Excluding ponds from the alkaline soil areas of the Black Belt, all but three ponds required lime. The distribution of lime requirement values is illustrated in Table 3.

Using the Adams-Evans procedure showed that many ponds with total hardness above 20 milligrams per liter needed lime. In the range of 0 to 20 milligrams per liter total hardness, there was

TABLE 3. DISTRIBUTION OF LIME REQUIREMENT VALUES FOR MUDS FROM 145 ALABAMA PONDS

Lime requirement intervals, tons/acre	Ponds in a particular lime requirement interval	
	No.	*Pct.*
0	19	13.1
< 0.5	1	0.7
0.5-1.0	3	2.1
1.1-1.5	21	14.5
1.6-2.0	36	24.7
2.1-2.5	26	17.9
2.6-3.0	19	13.1
3.1-3.5	12	8.3
3.6-4.0	3	2.1
> 4.0	5	3.5

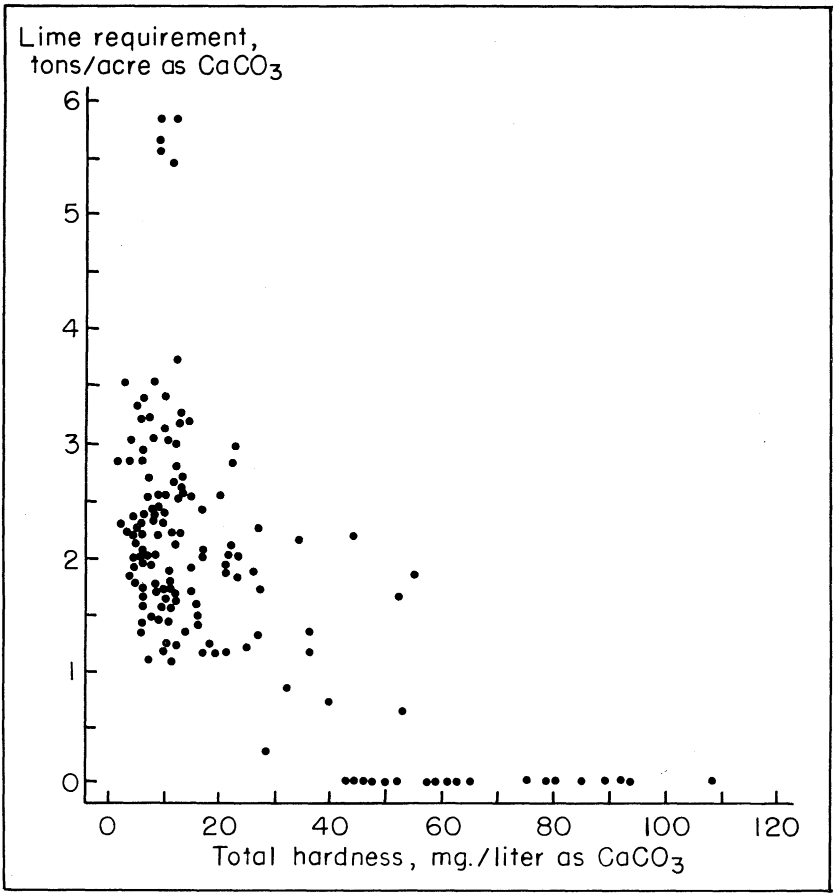


FIG. 3. Scatter diagram of total hardness in waters versus lime requirements in Alabama ponds.

no relationship between total hardness and lime requirement, Figure 3. Obviously, the lime requirement test does not ascertain if liming is a probable prerequisite for effective fertilization. Likewise, total hardness will not predict lime requirement.

Total hardness was below 10 milligrams per liter in 58 ponds (40 percent) and below 20 milligrams per liter in 105 ponds (72 percent). Waters of the 16 ponds in alkaline soil areas of the Black Belt had total hardness values of 31.5 to 108.2 milligrams per liter. Therefore, only 29 of 129 ponds in areas with predominately acid soils had waters with more than 20 milligrams per liter total hardness. Total hardness increased with increasing pH of

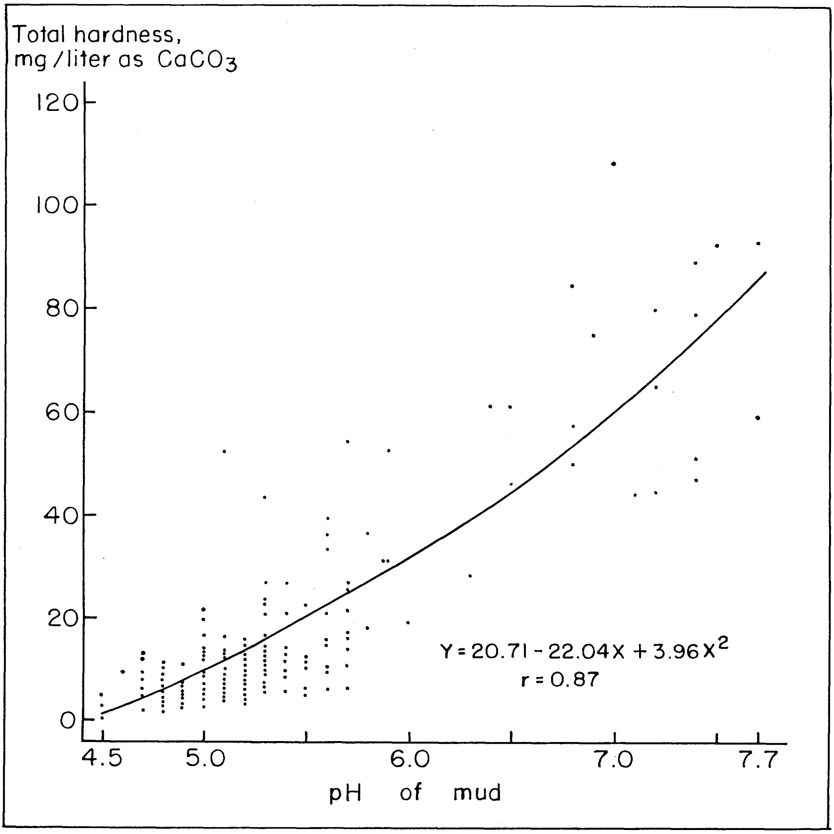


FIG. 4. Influence of mud pH on total hardness of water in Alabama ponds.

muds, Figure 4, and most ponds with muds more acid than pH 5.6 contained water with total hardness values less than 20 milligrams per liter. There was also a positive relationship between the calcium plus magnesium content of muds and the total hardness of waters, Figure 5.

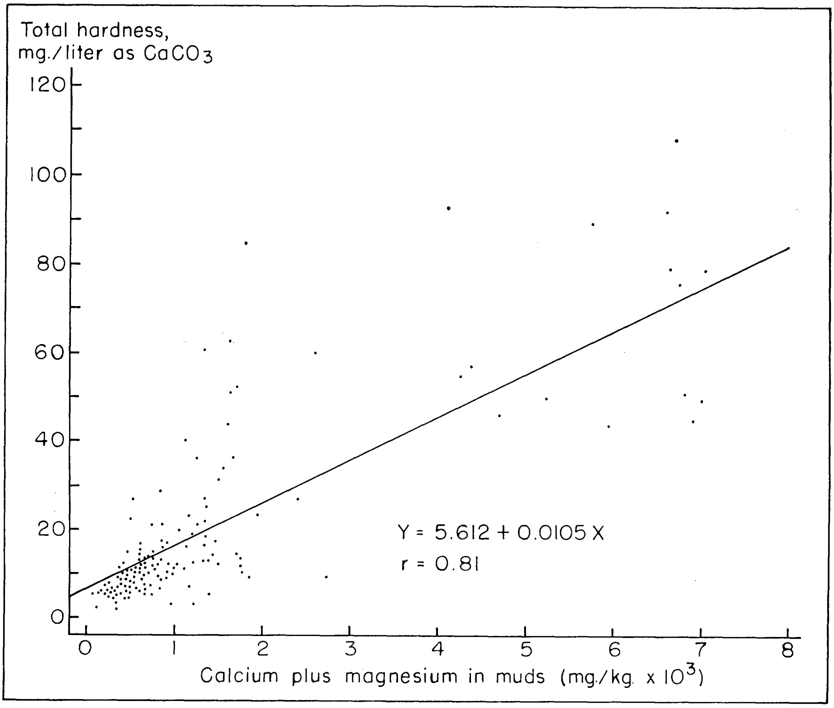


FIG. 5. Relationship between calcium plus magnesium content of muds and total hardness of water in Alabama ponds.

The most meaningful relationship was the decrease in total hardness with increasing base unsaturation of muds, Figure 6. All ponds with base unsaturation of 0.2 or less had waters with more than 20 milligrams per liter total hardness, revealing that liming to a base unsaturation of about 0.2 should cause total hardness to increase to 20 milligrams per liter or more. This relationship is verified by data from the pond liming experiment, Table 2. Application of limestone lowered base unsaturation to 0.16 or less and raised total hardness above 20 milligrams per liter. Ponds in the liming experiment lost more water than expected for most watershed ponds, and the Adams-Evans procedure *(1)* apparently overestimated liming rates.

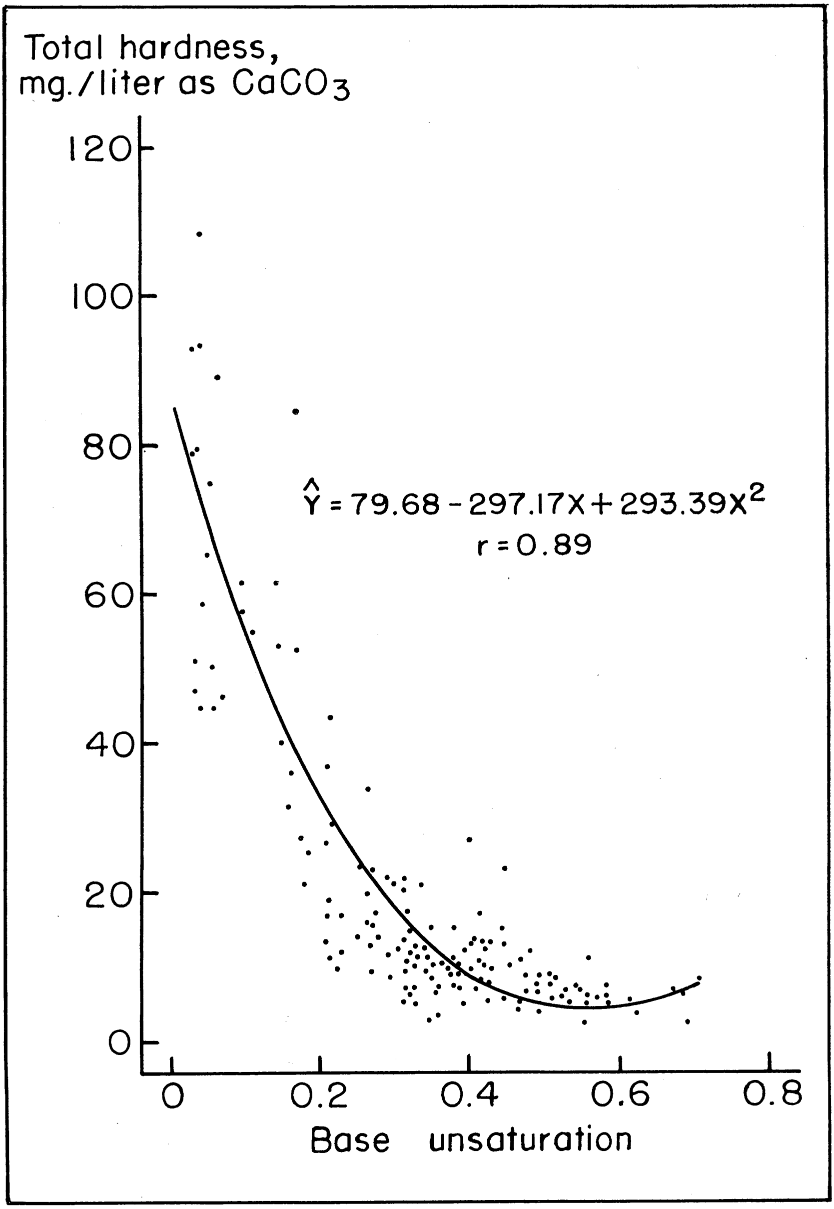


FIG. 6. Influence of base unsaturation of muds on total hardness of waters in Alabama ponds.

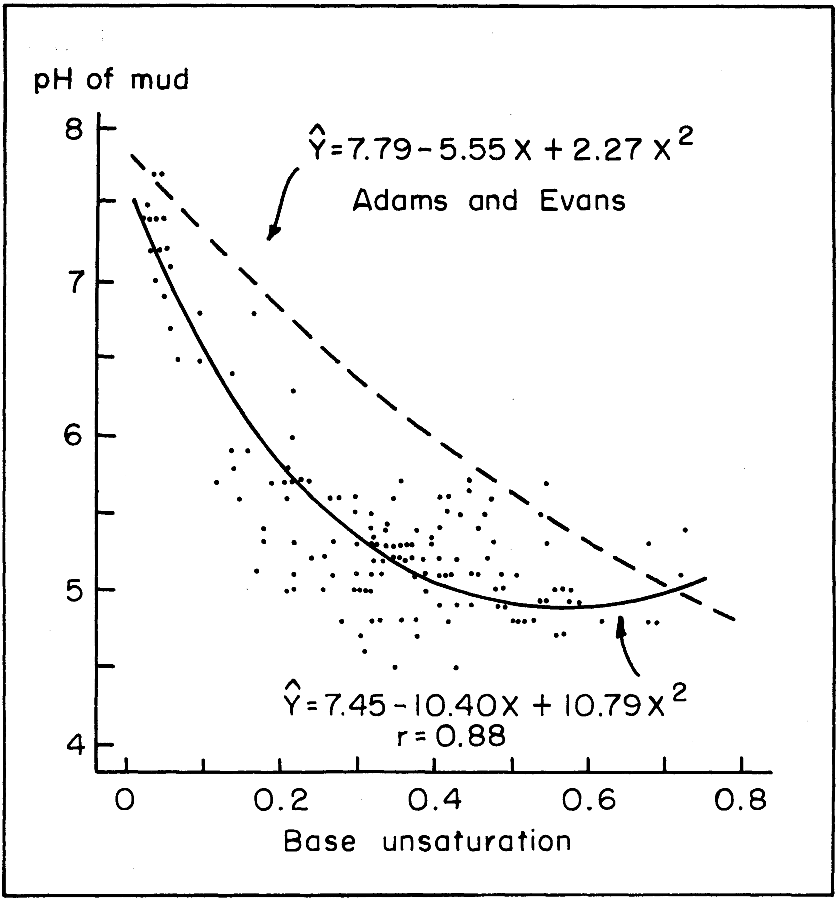


FIG. 7. Relationship between base unsaturation and pH of muds in Alabama ponds is shown, along with the relationship between base unsaturation and pH of terrestrial soils used by Adams and Evans for calculation of liming rates.

The lime requirement is based on the following relationships. Soil or mud pH is used to estimate base unsaturation, Figure 7, and the change in pH of a buffer affected by a quantity of soil or mud allows an estimation of exchangeable acidity. The amount of exchangeable acidity (in milliequivalents) which must be neutralized with lime to produce a desired base unsaturation is calculated from the equation of Adams and Evans *(1)*:

$$\text{Acid to be neutralized} = \frac{\text{exchangeable acidity}}{\text{initial base unsaturation}} \times \text{desired change in base unsaturation}$$

Pond muds in Alabama had lower base unsaturation at most pH values than did terrestrial soils used by Adams and Evans, Figure 7, in preparing their table of liming rates for attaining base unsaturation of 0.25 and soil pH of 6.5. The difference in the relationship between pH and base unsaturation was related to higher cation exchange capacities of pond muds because of their higher content of organic matter. Just over half of the ponds contained above 3 percent organic matter, Figure 8, but normal agricultural soils in Alabama seldom have more than 2 percent organic matter. Many ponds were more than 20 years old and 125 were over 5 years old. Organic matter tended to increase as a

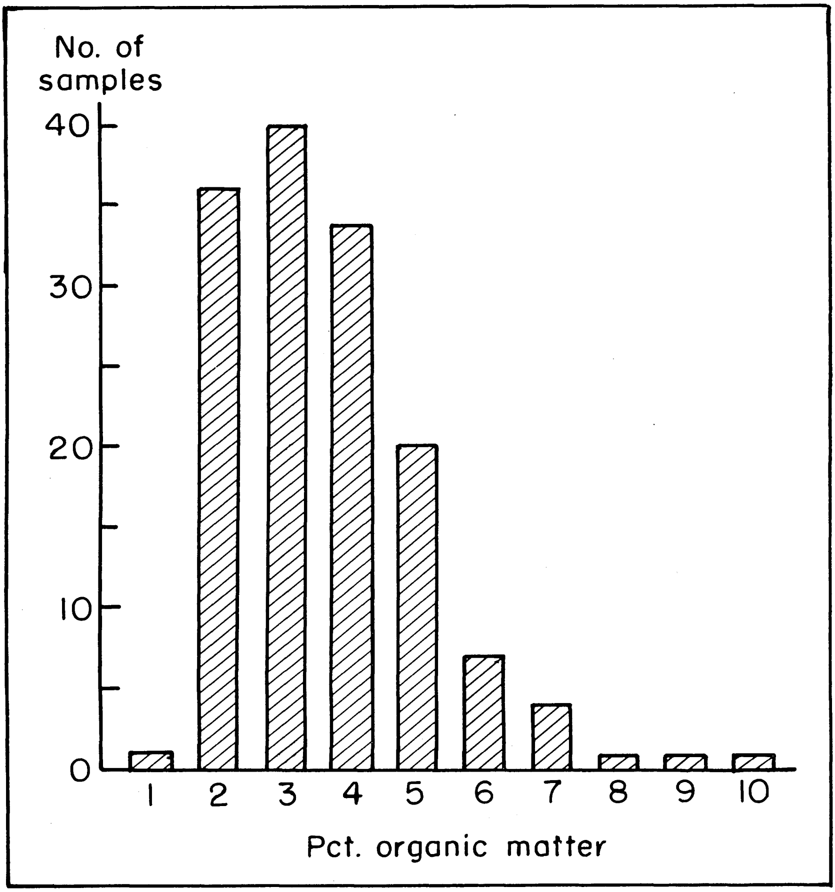


FIG. 8. Frequency distribution of concentration of organic matter in muds of Alabama ponds.

function of pond age ($r = 0.25$; $P < 0.01$), but amount of organic matter produced within ponds was undoubtedly the primary factor governing accumulation of organic matter in muds.

Liming Rates for Fish Ponds

When new ponds are constructed in areas with acid and calcium deficient soils, their bottoms should be limed prior to filling. The table given by Adams and Evans *(1)* can be used to calculate liming rates. Older ponds have different requirements, however, and Table 4 was constructed for calculating rates for such ponds. The equation of the curve relating mud pH to base unsaturation, Figure 7, and the equation for calculating acid to be neutralized were used to compute amounts of lime (in terms of calcium carbonate with a neutralizing value of 100) required to raise base unsaturation to 0.2. Since lime is not completely effective in neutralizing acidity, the usual practice of increasing calculated values by a factor of 1.5 was used in preparing Table 4.

Liming rates calculated from Table 4 are about one-fifth those reported by Adams and Evans *(1)* for muds of pH 5.7, about two-thirds for mud pH of 5.1, and similar for lower mud pH values. Sixteen 0.1-acre ponds with waters containing about 14 milligrams per liter total hardness were limed at rates calculated from Table 4 and total hardness increased to above 20 milligrams per liter in all ponds. This finding verifies that liming rates calculated from data on ponds are more suitable for use with ponds than liming rates established for agricultural soils.

For convenience, the laboratory procedure for measuring lime

TABLE 4. LIME REQUIREMENT IN POUNDS PER ACRE OF CALCIUM CARBONATE (NEUTRALIZING VALUE OF 100) TO ADJUST MUD TO pH 5.8 AND INCREASE TOTAL HARDNESS OF WATER ABOVE 20 MILLIGRAMS PER LITER

Mud pH in water	Calcium carbonate per acre required according to mud pH in buffered solution									
	7.9	7.8	7.7	7.6	7.5	7.4	7.3	7.2	7.1	7.0
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
5.7	108	216	324	432	540	648	756	864	972	1,080
5.6	150	300	450	600	750	900	1,050	1,200	1,350	1,500
5.5	240	480	720	960	1,200	1,440	1,680	1,920	2,160	2,400
5.4	345	690	1,035	1,380	1,725	2,070	2,415	2,760	3,105	3,450
5.3	405	810	1,215	1,620	2,025	2,430	2,835	3,240	3,645	4,050
5.2	465	930	1,395	1,860	2,325	2,790	3,255	3,720	4,185	4,650
5.1	525	1,050	1,575	2,100	2,625	3,150	3,675	4,200	4,725	5,250
5.0	600	1,200	1,800	2,400	3,000	3,600	4,200	4,800	5,400	6,000
4.9	780	1,560	2,340	3,120	3,900	4,680	5,460	6,240	7,020	7,800
4.8	800	1,600	2,400	3,200	4,000	4,800	5,600	6,400	7,200	8,000
4.7	840	1,680	2,520	3,360	4,200	5,040	5,880	6,720	7,560	8,400

requirement is given: (1) dry the sample of mud and gently grind with mortar and pestle to pass a 0.85-millimeter screen, (2) prepare a *p*-nitrophenol buffer of pH 8.0 ± 0.1 by diluting 15 grams boric acid, 74 grams potassium chloride, and 10.5 grams potassium hydroxide to 2 liters with distilled water, (3) to 20 grams dry mud in a 100-milliliter beaker, add 20 milliliters of distilled water and stir intermittently with glass rod for 1 hour, (4) measure pH, (5) add 20 milliliters of concentrated *p*-nitrophenol buffer and stir intermittently for 20 minutes, (6) after setting pH meter at 8.0 with a 1:1 mixture of concentrated *p*-nitrophenol buffer and distilled water, read pH of the soil-buffer-distilled water mixture while stirring vigorously. Use the values of mud pH in water and mud pH in buffered solution to obtain liming rate from Table 4. If the pH of mud in the buffered solution is below 7, repeat with 10 grams of dry mud and double the liming rate from Table 4.

The four liming materials evaluated in this study are equally effective, but their neutralizing values relative to calcium carbonate must be considered when using Table 4. Also, hydrated lime must not be added to waters containing fish or other valuable aquatic organisms. Although the procedure for estimating lime requirement was developed for ponds in Alabama, it may be used in other regions with similar soils.

SUMMARY

Ponds on alkaline soils of the Black Belt have hard waters, but on other soil areas of Alabama, many ponds have acid bottom muds and waters with total hardness below 20 milligrams per liter. Total hardness of pond waters increased with increasing mud pH and calcium plus magnesium content of muds. Ponds with pH above 5.8 and base unsaturation below 0.2 contained waters with more than 20 milligrams per liter total hardness. Ponds in Alabama and Georgia with total hardness above 20 milligrams per liter respond well to inorganic fertilization. Experiments on pond liming indicated that the Adams-Evans lime requirement overestimated liming rates. A table of liming rates for fish ponds to accompany the lime requirement procedure was prepared with data from 145 ponds. Basic slag, hydrated lime, calcite limestone, and dolomitic limestone were equally effective as liming materials for ponds. Hydrated lime caused pH values to rise above 11 for several days.

LITERATURE CITED

(1) ADAMS, F. AND C. E. EVANS. 1962. A Rapid Method for Measuring Lime Requirements of Red-Yellow Podzolic Soils. Soil Sci. Soc. Amer. Proc. 26: 355-357.

(2) AMERICAN PUBLIC HEALTH ASSOCIATION. 1971. Standard Methods for the Examination of Water and Wastewater. 13th ed., New York. 874 pp.

(3) HICKLING, C. F. 1962. Fish Cultures. Faber and Faber. London. 295 pp.

(4) JACKSON, M. L. 1958. Soil Chemical Analysis. Prentice-Hall, Inc., Englewood Cliffs, N. J. 498 pp.

(5) NEESS, J. C. 1948. Development and Status of Pond Fertilization in Central Europe. Trans. Amer. Fish. Soc. 76: 335-358.

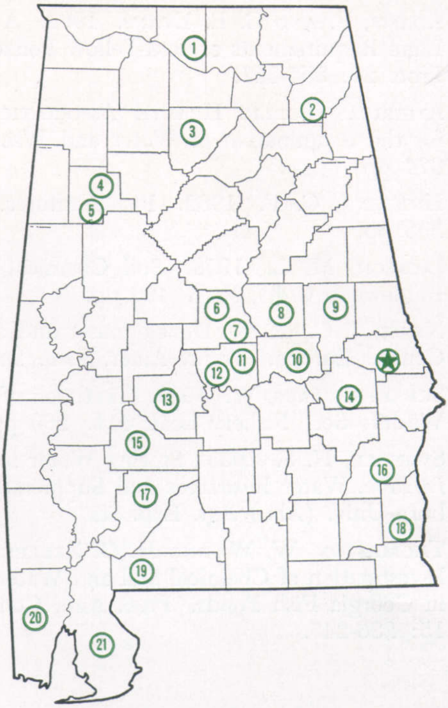
(6) SCHAEPERCLAUS, W. 1933. Textbook of Pond Culture. U.S. Fish and Wildlife Ser. Fishery Leaf. 311. 260 pp.

(7) SWINGLE, H. S. 1955. Storing Water for Use in Irrigation, pp. 50-55. *In* Proc. Water Resources and Supplemental Irrigation Workshop. Auburn Univ. (Ala.) Agr. Exp. Sta.

(8) THOMASTON, W. W. AND H. O. ZELLER. 1961. Results of a Six-Year Investigation of Chemical Soil and Water Analysis and Lime Treatment in Georgia Fish Ponds. Proc. Ann. Conf. SE Game and Fish Comm. 15: 236-245.

Alabama's Agricultural Experiment Station System
AUBURN UNIVERSITY

With an agricultural research unit in every major soil area, Auburn University serves the needs of field crop, livestock, forestry, and horticultural producers in each region in Alabama. Every citizen of the State has a stake in this research program, since any advantage from new and more economical ways of producing and handling farm products directly benefits the consuming public.



Research Unit Identification

★ Main Agricultural Experiment Station, Auburn.

1. Tennessee Valley Substation, Belle Mina.
2. Sand Mountain Substation, Crossville.
3. North Alabama Horticulture Substation, Cullman.
4. Upper Coastal Plain Substation, Winfield.
5. Forestry Unit, Fayette County.
6. Thorsby Foundation Seed Stocks Farm, Thorsby.
7. Chilton Area Horticulture Substation, Clanton.
8. Forestry Unit, Coosa County.
9. Piedmont Substation, Camp Hill.
10. Plant Breeding Unit, Tallassee.
11. Forestry Unit, Autauga County.
12. Prattville Experiment Field, Prattville.
13. Black Belt Substation, Marion Junction.
14. Tuskegee Experiment Field, Tuskegee.
15. Lower Coastal Plain Substation, Camden.
16. Forestry Unit, Barbour County.
17. Monroeville Experiment Field, Monroeville.
18. Wiregrass Substation, Headland.
19. Brewton Experiment Field, Brewton.
20. Ornamental Horticulture Field Station, Spring Hill.
21. Gulf Coast Substation, Fairhope.