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# IMPROVING CONDITIONS FOR FISH IN BROWN-WATER BOG LAKES BY ALKALIZATION \*

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The object of this study was to discover methods for increasing the productivity of small kettle lakes which have characteristically brown-colored water. Owing to the light-absorbing action of the pigmented solutes and suspensoids of the water, the sun's energy cannot express its optimum effect on the basic fish food supply—plants. Hence, any treatment which would free the water of its brown color and still not be toxic to fish would enhance productivity, since such a treatment would increase the depth of light penetration and therefore the volume of the food-producing (trophogenic) zone. Increased fish production should follow.

James and Birge (1938) and Sauberer and Ruttner (1941) demonstrated that the colored materials of lake water reduced the depth to which the light penetrated. Their results showed also that it was absorbed selectively, especially those wave lengths which were most effective in photosynthesis.

It has been generally observed that seepage water from limed and undrained peat marshes now in use for agriculture is clear, while that from unlimed ones is tea-colored. This observation suggested to us (Hasler and

Einsele, 1948) that lime treatment of acid, brown-water, lakes might likewise clear up the water and therefore increase the depth of the trophogenic zone. Theoretically, if lime were added to lakes the calcium would combine with the humic colloids forming a humate which would flocculate and fall to the bottom. Moreover, alkalization of the water would produce a better medium for bacteria so that suspended organic colloids would be, in part, degraded.

It is well known that acid conditions are unfavorable to decomposition by micro-organisms. We therefore postulated that alkalization through lime treatment might also augment the activities of organic decomposition at the bottom as has been observed in European fish ponds and reviewed by Neess (1948). This action would, theoretically, reduce the rate of accumulation of debris and therefore retard the aging process of the lake and give it additional years of life.

## *Procedure and Results:*

In 1947 a treatment study was initiated on a lake in Langlade County but was given up because of a number of extraneous reasons. However, in 1948 owing to the generous cooperation of Mr. Ben S. McGiveran, Milwaukee, and the International Minerals and Chemical Corporation, Chicago, the project was reestablished on two McGiveran lakes which are in Chippewa County, Wisconsin (T. 32 N.R. 9W).

\* Supported by grants of funds from Mr. Ben S. McGiveran, Milwaukee, Wisconsin, and International Minerals and Chemical Corporation, Chicago, Illinois, through the efforts of Dr. David D. Long. Acknowledgment is also gratefully made for numerous services from the Wisconsin Conservation Department and its personnel.

They are small kettle lakes with an average depth of 5-6 m. and lie in terminal moraine.

HYDROGRAPHIC DATA  
IN ENGLISH AND METRIC UNITS

Lake	Turk		Cather	
	<i>English</i>	<i>Metric</i>	<i>English</i>	<i>Metric</i>
Area	8.8 a.	3.5 ha.	8.4 a.	3.4 ha.
Av. Depth	11.5 ft.	3.5 m.	16.4 ft.	5.0 m.
Max. Depth	19.7 ft.	6.0 m.	32.8 ft.	10.0 m.

Their catchment basins are small, and the soils are poorly drained clay underlaid by hard pan. These edaphic conditions explain the acidity and the paucity of solutes, especially P, N, and Ca (Table 1). The average July air temperature is 68° F.; January, 11.3° F.

Observations on limnological features, including the fishery, were made two years (1948 and 1949) prior to treatment. After removal of the resident fish population by application of derris root, rainbow and brown trout were stocked; a more complete record of the fishery will be published after an examination of the results in the second year of post-treatment.

To alkalinize the water before the ice was out in April 1950, finely ground

lime\* (calcium and magnesium hydroxide) was used. The chemical was scattered on the ice, but in subsequent additions it was poured over the bow or stern of a rowboat so that the turbulence from an outboard motor churned the powder into the water. Later, a small amount of CaCO<sub>3</sub> was spread near shore. A record of the amounts added and the before and after levels of methyl orange alkalinity, pH, and transparency are given in Table 2. Initial application of lime should be done during the spring or fall circulation (turnover) periods to obtain maximum mixing and hold to a minimum the risk of getting localized lethal concentrations.

By July the water had cleared remarkably in Cather Lake as can be seen from the disk reading in Fig. 1. Because a light meter was not available for pretreatment records a nearby lake, Skow Lake, was chosen for comparison. Limnological and edaphic conditions on this lake are similar to those of Cather and, in addition, transparency readings

\* limate = CaO:48.3; MgO = 33.2; H<sub>2</sub>O = 16.8. Mfg. by Western Lime and Chemical Company, Milwaukee, Wisconsin.

TABLE 1.—JULY 18, 1949

	Cather		Turk	
	18 July '49	9 Oct. '50	18 July '49	9 Oct. '50
Sol. P.....	—	0.006	—	0.0
Tot. P.....	0.116	0.16	0.120	0.551
SiO <sub>2</sub> .....	0.266	—	0.320	—
Fe.....	0.112	0.035	0.031	0.05
SO <sub>4</sub> .....	1.83	1.2	2.25	1.4
Mn.....	0.150	0.076	0.126	0.06
NO <sub>3</sub> —N.....	0.100	0.09	0.072	0.064
NO <sub>2</sub> —N.....	0.0026	0.0	0.0016	0.0
NH <sub>3</sub> —N.....	0.094	0.051	0.166	0.047
T. O. N.....	0.673	0.474	0.266	0.551

Chemical Analysis by courtesy of Prof. G. A. Rohlich, Division of Sanitary Engineering, University of Wisconsin.

TABLE 2.—ADDITION OF LIME TO CATHER LAKE AND TURK LAKE, WISCONSIN, AND SUBSEQUENT CHANGES IN ALKALINITY, pH AND TRANSPARENCY

Date	Cather				Turk			
	Lime added in lbs.	pH	Alk. in mg./1 CaCO <sub>3</sub>	Disk	Lime added in lbs.	pH	Alk. in mg./1 CaCO <sub>3</sub>	Disk
10 III.....	1700	5.6	3.0	ice	—	—	—	—
19 V.....	—	6.3(a)	13.0	2.0	—	—	—	—
19 V.....	1100	8.4(b)	13.0	—	—	—	—	—
15 VI.....	—	7.2	—	4.3	—	—	—	3.5
19 VI.....	—	—	—	4.4	—	5.4	3.0	3.5
28 VI.....	450	7.1	17.0	5.0	—	—	—	4.0
4 VII.....	—	—	—	5.2	800	—	3.0	3.8
21 VII.....	—	—	—	5.3	200	7.2	9.0	4.5
25 VII.....	—	—	—	—	250	6.9	—	—
12 VIII.....	—(c)	7.1	16.0	> 5.0	(c)	6.8	—	4.0
24 VIII.....	—	7.5	19.0	5.7	400	6.8	11.0(d)	4.0
30 VIII.....	—	—	—	—	300	7.0	—	—
1-2 IX.....	—	7.3	16.0	5.7	400	6.9	11.0	4.5
6 X.....	—	7.1	15.0	5.1	1000	6.9	13.0	3.3
6 X.....	1000	8.7(b)	—	—	—	—	—	—

(a) Reading before introducing lime.

(b) Reading after introducing lime.

(c) 320 lbs. of CaCO<sub>3</sub> introduced.

(d) 18 August 1950.

were identical in 1949. Fig. 2 shows the curves of the photocell readings. These lend more precision to the Secchi disk readings and demonstrate that the light penetration of the treated lake is double that of the untreated.

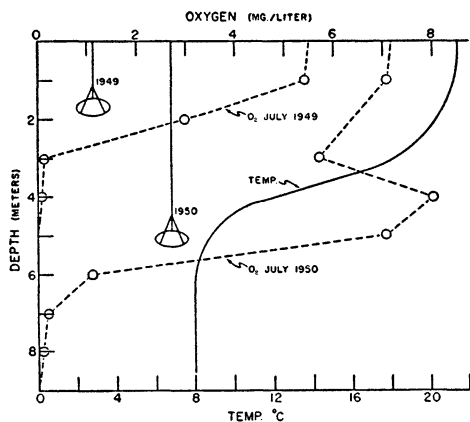


FIG. 1. Transparency and oxygen in Cather Lake before and after treatment with lime.

Throughout the summer the pH of the bottom water was always less than

neutrality in Cather, varying from pH 6.3 to 6.5, while the methyl orange alkalinity was always greater at the bottom than at the surface; 2 mg./liter more in July and as much as 15 mg./liter in October. A comparison of the before and after alkalinity and pH readings is given below:

Depth Meters	Alkalinity as mg./l. CaCO <sub>3</sub>		pH	
	1949	1950	1949	1950
0	5.0	20.0	5.4	7.1
9	4.8	22.0	5.2	6.4

An initial precautionary estimate can be made of the amount of lime necessary to change the pH of a water from acid to alkaline if the pH and methyl orange alkalinity are known in advance but it is advised that samples of water be taken from a lake to determine, by experiment, that quantity of lime which

is necessary to attain a desired pH under laboratory conditions. If then the total volume is known computations can be made for additions of lime in conservative amounts so that damage to aquatic organisms can be avoided.

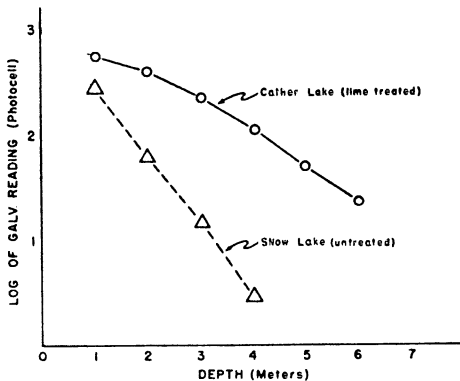


FIG. 2. Comparison of Light Penetration on two bog lakes: Cather Lake, lime treated; Skow Lake, untreated. (Galv. reading in milliamps).

For Cather Lake with pH 5.4 and M.O.A. 5.0 p.p.m. a treatment of 0.77 lbs./1000 cu. ft. (66 kg./1000 cu.m.) raised the pH to 7.2-7.4.

Bottom muds will neutralize the lime to some extent; consequently, additions must be made to compensate. Moreover, the photosynthetic action will remove  $\text{CO}_2$  from the bicarbonate leaving carbonate which will settle out. We believe, therefore, that continuous additions must be made to maintain neutrality. Just what the magnitude of these factors are we do not know at this stage of management. In this case it was considerable; while 1,095 lbs. would have been necessary to get the desired pH change of Turk Lake water in a glass container, in actual practice 3500 lbs. were necessary.

In contrast to Cather Lake, alkalization of Turk Lake was done gradually

by small additions periodically throughout the summer (Table 2). This method did not bring the water to neutrality by the end of the summer nor did the transparency improve. Rapid alkalization where neutrality was accomplished at the start of the season, as was done on Cather Lake, appears to give the most satisfactory result. Chemical analysis before and after alkalization did not reveal any striking differences in the essential fertilizing nutrients (Table 1).

#### Significance:

Throughout the glacial lake regions, where the catchment basins are low in carbonate, bog lakes and other lakes with acid tea-colored water are common. Without exception their production of fish is low compared with lakes in nutrient rich areas. In many instances the fishes in these lakes are dwarfed making them of little use to the sport fishery but the causal factors are not well understood. Three possibilities of some significance are:

1. Low penetration of sunlight owing to the brown pigments and their selective light absorbing action (James and Birge, l. c.), resulting in a restriction of the production of algae to the upper waters.

2. Acid water, low in nutrients.

3. A very low reservoir of available  $\text{CO}_2$  (Ohle, 1937, and Juday et al., 1935), which furnishes a basic compound for the most fundamental energy process, photosynthesis.

A method for improving habitat conditions in these unproductive lakes is highly desirable. Lime treatment will increase light penetration and allow for capture of more of the sun's energy.

Such an improved lake, if cleared of its resident dwarfed pan fishes, would have conditions favorable for trout production since sufficient  $O_2$  is then present in the cooler layers, whereas before there was insufficient  $O_2$  below the epilimnion. Furthermore, a generally increased volume of productive water might also make a treated lake more fertile also for shore fishes. For those who would make ultimate use of increasing fish production bass could be used for creating a "two-story" lake; bass in the littoral, epilimnetic zone and trout in the cooler waters of the thermocline. This scheme has been used where trout were introduced into bass lakes, provided that sufficient oxygen persisted in the deep cooler strata.

Many bog and other shallow dark-water lakes in northern Wisconsin are subject to frequent winter-kill owing to a rapid uptake of the oxygen reservoir by decomposition and to poor light-transmitting qualities. Clearing up the water with lime would encourage greater light penetration. Also because of the removal of organic suspensoids the  $O_2$  reservoir would not be depleted as fast and thus would hold intermittent winter-kills to a minimum.

These results make it appear that alkalization may prove to be a valuable, but cheap, management tool, costing, in this instance, \$0.60 per acre-foot for the first year and probably a fraction of this in subsequent years. Also, alkalization of the water tends to mobilize nutrients bound up in acid undecomposed lake soils. Moreover, the lime treatment raises the bicarbonate content and hence makes available an abundant source of  $CO_2$ , an essential nutrient.

Furthermore, it is our belief that extinction of a bog lake under acid conditions is more rapid than extinction of an alkaline lake of similar size and in a similar climate. The rapid encroachment of the bog mat (Dachnowski-Stokes, 1933) in addition to the slow rate of decomposition under acid conditions, augments the process of encroachment of the shore on the main body of the lake. This rate is probably faster under acid than under alkaline conditions. It is quite likely therefore that liming of a bog lake may delay this ("Verlandung") process and lengthen its life span.

Bog and tea-colored kettle lakes in their natural state have a definite beauty which should be retained, in some measure at least, and not exchanged for better fishing. Consequently, appraisal of esthetic values should be made before wholesale treatment is undertaken.

Finally, in addition to increasing lake productivity for the sport fishery and marsh management this method could be given serious consideration for increasing protein supplies in times of emergency. When one is considering matters of national defense every food resource must be taken into account as well as the means for increasing it. Contamination of coastal fisheries and Great Lakes fisheries is a possibility. Any method which might increase protein productivity of the smaller inland lakes may eventually have survival value. Growing concern for adequate protein diets is being posed with an advancing human birth rate. More research along this line should be forthcoming from our fishery biology laboratories.

SUMMARY

Alkalization of an acid brown water Wisconsin lake with lime resulted in a two-fold increase in transparency of the water in addition to an increase in oxygen levels at cooler strata.

The resulting clearer waters makes possible the capture of more energy, therefore increasing general lake productivity. The production of fish can thus be raised by increasing the volume of the trophogenic zone by a relatively inexpensive procedure.

Specifications and method of application of the chemical are described.

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COMPOSITION OF SOME PLANTS EATEN BY DEER IN THE BLACK HILLS OF SOUTH DAKOTA <sup>1,2</sup>

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<sup>1</sup> Approved for publication by the Director of the South Dakota Experiment Station as publication No. 261 of the Journal Series.

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The white-tailed deer (*Odocoileus virginianus macrourus*) and the mule deer (*O. hemionus*) of the Black Hills of South Dakota are largely dependent upon browse plants for food as shown by 263 stomach analyses reported by Hill and Harris (1943). The browse plants are especially predominant in the diet during the winter months. For the critical period, January to April in the years 1940 to 1944, browse plants made up 70.9 per cent of the deer diet by volume; forbs were 12.1 per cent, grains 4.9 per cent, grass 7.2 per cent and miscellaneous items 4.9 per cent. Ten species of browse plants made up practi-