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PRACTICAL CONSIDERATIONS OF LIME APPLICATION TO SOFT-WATER LAKES

By

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Introduction

A usable management tool which would increase the productivity of soft-water lakes would find wide application in Michigan, particularly in the Upper Peninsula where, because of the acid soils, glaciated topography, and cool, humid climate, the development of such lakes is favored. Lakes with low concentrations of alkalinity (5 ppm and less) are abundant in the Upper Peninsula and in certain areas of the Lower Peninsula as well; these lakes are characteristically of low biological productivity and contribute less to the sport fishery than do medium-hard-water lakes.

The correlation between productivity and alkalinity has led to research attempting to determine whether increasing the alkalinity of lake waters by lime application would bring about increased biological production. In Michigan, field experiments have been conducted upon two general types of soft-water lakes: (1) unstratified, colored, non-bog, seepage lakes with sand shores, and (2) colored, meromictic (permanently stratified), bog lakes with marginal bog mats. Two reports have been prepared for publication describing these experiments. A non-bog lake (Stoner Lake, Alger and Delta counties) received its first experimental lime treatment in 1943 when a small amount of hydrated lime was applied. Little effect of the application was noted. The same lake received a larger application of crushed limestone in 1946, and again little effect was observed (Ball, 1947). In 1952, Stoner Lake was treated with both hydrated lime and limestone, and in 1953 it was treated with a larger application of hydrated lime (Waters, 1953, 1954, and Waters and Ball, 1957); this project, initiated in 1952, was continued through 1955 for evaluation. In 1953, an experimental program was initiated upon two bog lakes (Starvation Lake, Alger County, and Timijon Lake, Schoolcraft County) which received applications of hydrated lime in 1954. The project was continued through 1955 (Waters, 1956, 1957).

As a result of these experiments, some general statements as to the effects of lime treatment can be offered at this time. For example, the dividing line between poorly producing lakes (soft-water) and productive lakes (medium-hard-water) may be as low as 15 to 20 ppm total alkalinity. Furthermore, the following results may be expected upon lime application to lakes with an original alkalinity of less than the above figure, in order: higher alkalinity and pH; improved availability of nutrients and higher concentrations of immediately available carbon dioxide; increased production of both phytoplankton and zooplankton; increased production of bottom organisms; and increased growth rate of fish. All of these results were observed, or at least indicated, in portions of the two research projects conducted in Michigan. In Wisconsin, lime applications to colored bog lakes have resulted in clearing the colloidal color and improving such lakes for trout by increasing light penetration and the depth at which oxygen is produced by photosynthesis (Hasler, Brynildson, and Helm, 1951); however, this result was not observed in the lakes treated in Michigan.

This report is intended as an interpretation of the results of the two research projects involving lime application, with particular reference to the use of these results in the management of soft-water lakes.

Lime application as a management tool in bog lakes

The results of the liming experiments on the two bog lakes showed increases in the standing crops of both phytoplankton and zooplankton; the release of phosphorus from the bottom muds was observed; and a plankton bloom occurred in one of the bog lakes which utilized more carbon dioxide from the bicarbonates resulting from lime application than would have been available before the treatment. The increased plankton production was thought to be due to both of these chemical effects.

The increased availability of phosphorus (and possibly other nutrients) occurred in the epilimnion following lime application while the lakes were stratified. It also occurred in the hypolimnion following an application while the lakes were not stratified, when the lime solution fell to the bottom. The value of increasing phosphorus availability at the bottom of a meromictic bog lake is questionable, since this phosphorus presumably would never be transported to areas of the lake where it could be utilized by plants in photosynthesis. Therefore, if lime is added to such a lake care should be taken to make the application effective in the epilimnion.

The decrease of colloidal color after lime application observed in Wisconsin, permits deeper penetration of sunlight and a subsequent enlargement of the trophogenic zone down into layers of cooler water, thus improving conditions for trout. Since such decrease of color was not observed in the bog lakes in Michigan, this valuable effect of lime application cannot be utilized here with certainty unless a method can be developed to achieve such a clearing of color.

The two experimental lakes, Starvation and Timijon lakes, do not appear at the present time to be suitable for trout because of poor oxygen conditions during the summer and possibly during the winter. The recommendations which may be made for utilizing lime in colored bog lakes must therefore be directed toward the warm-water fishery. The bog lakes in the vicinity of Starvation and Timijon lakes appeared to contain yellow perch primarily and fishing pressure in these lakes was extremely low. Probably little value could be realized from using lime in the management of these lakes at the present time; presumably, management for the purpose of increasing fish production would be practicable only when fishing pressure upon the warm-water fishery in this area becomes great enough.

Lime application as a management tool in non-bog, soft-water lakes

The application of lime to Stoner Lake, a non-bog, soft-water lake in Alger and Delta counties, increased production of phytoplankton; increased bottom organisms (following the spread of aquatic plants over a previously barren sand bottom); and increased the growth rate of stunted yellow perch (primarily young of the year). There were no significant increases in standing crop of zooplankton, as there were in the two bog lakes; this may have been due to the zooplankton having been already at the "threshold of security" because of the predation by an extremely dense population of small perch. Any increase in zooplankton production may have been absorbed immediately by the stunted perch.

Stoner Lake did not stratify thermally, and high temperatures were present throughout all of the lake volume during the summer; it must therefore be considered a warm-water fishery resource. There are other similar lakes in the vicinity of Stoner Lake, and lime application for the purpose of increasing production in this type of lake may be useful if demand for a greater warm-water fishery develops in the future.

In the management of Stoner Lake itself, it should be pointed out that the lime applications which have been made probably have not increased the yield to the angler since the level of stunting has merely been moved up slightly. Proper management should include, in addition to lime application, a drastic reduction of the perch population and the introduction of a predator species.

Since there were indications that the lime application affects the production of fish-food organisms primarily in the form of zooplankton, a possible use of this technique may be to increase the production of forage fishes which would utilize zooplankton to a greater extent than would larger, game fishes. The research on Stoner Lake indicated that lime application affected the growth of the young-of-the-year perch, which fed primarily on zooplankton, to a greater extent than the older and larger perch.

Methods of application

The selection of the proper method of applying liming compounds is probably most important from the standpoint of efficiency in utilizing materials and labor, since it appears that the desired biological effects may be expected as long as alkalinity is increased to the proper level <u>by any method</u>. One factor which should be constantly recognized is that the concentration of bicarbonates, after first being increased through lime application, will, in all probability, decrease to pre-application levels unless replenished periodically, or unless the original method of application is designed to provide automatic replenishment. The factors responsible for such decrease of alkalinity are primarily the adsorption of calcium by organic colloidal material, either in the water or at the mud-water interface, or through precipitation of calcium carbonate by photosynthetic activity. The latter factor is probably important only in that type of lake (such as a meromictic lake similar to the bog lakes, Timijon and Starvation) where the precipitated carbonates will not have an opportunity to re-dissolve and become available again in the food-producing (trophogenic) zone. The direct utilization of calcium by phytoplankton, even under bloom conditions, does not appear to be a significant factor in the removal of calcium from the water.

It is strongly recommended that hydrated lime, or slaked lime (calcium hydroxide) be used, rather than the less expensive limestone (calcium carbonate), although both materials may eventually form calcium bicarbonate through reaction with carbon dioxide. Hydrated lime is much more soluble than limestone, even in acid waters, and the higher efficiency of dissolution more than compensates for the higher cost of hydrated lime. The 20 tons of limestone applied to Stoner Lake in 1946 did not increase the alkalinity by as much as 1 ppm.

Another point which should be emphasized is that even hydrated lime will not dissolve readily unless thoroughly agitated. If merely dumped into the water it appears to have the property of "caking" and remaining in the caked form if not agitated. Even if poured into the wake of an outboard motor such caking (in smaller particles) still occurs, although such a method certainly effects greater dissolution than merely dumping. Caking would be an especially important factor in a bog lake with a bottom composed entirely of peat; the "cakes" would merely fall to the bottom, sink into the flocculent peat, and be permanently lost. In Stoner Lake, the dumping method was used over barren sand bottom; the piles of caked lime remained on the bottom for nearly three years, and, in all probability, still are undissolved (no later observations). Only a short time after application, the piles of lime appeared to have a brown, slimy coating, which may have been an accumulation of organic colloidal material which had been adsorbed to the surface of the pile, probably inhibiting further dissolution. The fact that the piles of lime did remain on the bottom may have been responsible for the sustained high alkalinity observed in Stoner Lake; in other words, as certain factors, such as adsorption of calcium by the mud, tended to reduce the concentration of calcium in the water, a slow dissolution of the lime piles (caused perhaps by violent storms or ice movement) caused an "automatic" replenishment. In fact, the dumping method may be the most desirable from this standpoint in Stoner Lake or a similar lake with sand bottom; it would not, of course, be applicable in lakes with an entire peat bottom where the lime piles would sink.

In the two meromictic bog lakes no sand bottom was available upon which to deposit the lime. For applications in this type of lake, thorough agitation is absolutely necessary. The pump-and-raft system which was used for the application in the two bog lakes appeared to supply adequate agitation and a high percentage of dissolution was effected. The practice of applying the lime at one point appeared to be satisfactory since wind-induced circulation distributed the lime throughout the entire epilimnion in only a few hours. In a larger lake such complete distribution of the lime solution may not occur, and the application of the lime from a moving raft or boat, or the application at several points, may be necessary. Attempts should be made in a stratified lake, particularly one which is meromictic, to prevent sinking of the solution--because of its greater density--to the hypolimnion; this may be done by placing the discharge from the pump in shallow water where the lake bottom lies in the epilimnion. If the application is made while the lake is stratified, the application will be effective in the epilimnion only, as was the case with the summer applications to Timijon and Starvation lakes; of course, during subsequent times of circulation the concentration in the epilimnion will be diluted. Perhaps the ideal time of application would be in the late summer while stratification is still present, but the application should be great enough to permit dilution and still sustain the desired concentration of bicarbonates after circulation.

The desired concentration of bicarbonates cannot yet be determined, and the possibility remains that different concentrations may be desirable in different lakes. The results of the research in the Upper Peninsula lakes indicate that increasing the alkalinity from less than 5 ppm to 15 or 20 ppm may be sufficient; however, Moyle (1949) suggests that 40 ppm is a valid separation point between the nonproductive and the productive lakes.

Another result which was observed in the two bog lakes and which may be of some importance is the toxic effects to plankton (and possibly to higher aquatics as well) of an application of lime heavy enough to cause extremely high pH values. An application calculated on the basis of the entire lake volume and made under stratified conditions when the effects of the lime would be concentrated in the epilimnion--which was the case with the summer applications to Timijon and Starvation lakes--may produce pH values as high as 11 or 12. The plankton recovers when enough carbon dioxide is produced by the lake to react with the hydroxide and form bicarbonates, thus lowering the pH. The application should be made (if such an effect is, in fact, disadvantageous to the productivity of the lake) at such a time when the loss of existing plankton populations would be of little consequence. Hence the recommendation above that such an application be made during late summer. More favorable conditions of pH and the return of plankton can probably be expected within two or three weeks after the application.

Finally, the distinct difference between fertilization and lime application should be emphasized. Fertilization, as the word is usually taken to mean, is the application of nutrients which are subsequently utilized directly by assimilating plants; lime application does not supply directly nutrients which are utilized by plants, but, rather, does bring about favorable chemical modification, causing improved nutrient availability because of the changed conditions. The effects of lime application persist as long as the modified chemical conditions remain; the effects of fertilization are, on the other hand, temporary unless assimilated nutrients are returned to the organic cycle. Fertilization provides the "food" for plants; lime application provides a more efficient method to supply previously unavailable "food."

Recommendations for further research

The following are suggested:

1. As final evidence of the value of lime applications to soft-water lakes, the increased productivity should be traced completely through the food chain so that increased yield to the angler may be determined; the increased yield should then be evaluated in terms of the costs of the lime application.

2. The use of lime (or other materials) to clear colloidal color from bog lakes should be further investigated; the development of such a clearing technique would greatly increase the number of lakes in Michigan which could be modified to support trout. The colored bog lakes already have suitable temperatures for trout, but oxygen conditions remain unfavorable due to the colloidal color. Hasler, Brynildson, and Helm (1951) achieved a clearing of color in Wisconsin bog lakes with lime applications. The two Michigan bog lakes which did not clear after lime application lie in the Lake Superior Lowlands, whereas the Wisconsin lakes which were treated lie in the Lake Superior Highlands. The reason for different effects of lime application

may lie in the differences in soil and subsoil type, resulting in a different source of lake color for the two regions. Perhaps lime would clear the color in lakes of the highlands region of the western Upper Peninsula.

3. The use of lime for the purpose of increasing fish-food production may be useful in clear-water bog lakes in the Upper Peninsula which support trout but which are low in alkalinity.

4. A continuing attempt should be made to gain knowledge of the basic processes involved in such chemical modification. The exact reasons why lime apparently clears the color in some lakes and not in others; the source and chemical composition of "color"; the exact mechanisms by which nutrients such as phosphorus, nitrogen, etc., are or are not made more available to plants; and the role that calcium bicarbonate plays in furnishing carbon dioxide for the photosynthetic activity of plants, are all important problems. The answers, generally unknown at the present time, would provide us with basic knowledge from which valuable management techniques may be developed.

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