PRELIMINARY OBSERVATIONS ON THE LOWERING OF DISSOLVED OXYGEN BY SODIUM SULFITE AND ITS EFFECTS ON CERTAIN FISHES, WITH PARTICULAR REFERENCE TO PROBLEMS IN FISH MANAGEMENT

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THE NEED FOR AN EFFECTIVE AND ECONOMICAL METHOD OF SALVAGING CERTAIN FISHES FROM LAKES AND PONDS, and thinning the populations of other species, has long been manifest in the field of fish management. Rotenone, though varyingly effective for "wiping out" fish life, has the disadvantage of (1) dooming fish to almost certain death, and (2) rendering the lake or pond unfit for fish life for several days or weeks unless followed by treatment with an oxidizing agent such as was described by Lawrence (1956). Electronic devices, effective in certain stream situations, are as yet inadequate for the desired results in lakes and ponds. Cresol, reported on by Embody (1940), Embody and others (1941), and Wilkens (1955), acts quickly in streams; and it leaves a stillwater habitat in a highly undesirable condition for an unknown period of time.

Laboratory and pond experiments in lowering dissolved oxygen content by the addition of sodium sulfite have indicated that this treatment may be a valuable means of salvaging and thinning fish populations in small ponds and in lakes that can be lowered to a few acre-feet of water. The method is apparently nontoxic, and the degree and speed of response can be controlled to desired extents. Further, the treatment renders the pond unsuitable for aquatic life for little longer than a day or so.

The procedures and results of the laboratory experiments will be described first; next, the procedures and results of the field experiment.

Laboratory Observations

All laboratory experiments, preliminary or otherwise, were conducted under certain consistent procedures as follows:

1. All aquaria were of commercial, 5-gallon capacity and dimensions.
2. The quantity of water employed in each aquarium was 12 liters.
3. The water employed was taken from municipal supply and was put into the aquaria at least 20 hours before experiments were started.
4. All experimental fish were young-of-the-year largemouth bass from a stock supply that had been maintained in a 65-gallon aquarium for several weeks prior to this experimental work. These fish were 2 to 3 inches in length.
5. Three fish were transferred to each of the experimental aquaria approximately 5 minutes before experimentation was begun.
6. Sodium sulfite, either in the form of powder or in a saturated, aqueous solution, was added to the aquaria.
7. All measurements of dissolved oxygen, including measurements that were made in the field experiment, were made

by the polarographic method of Rand and Heukelekian (1951). This method was selected because it is a simple procedure adaptable to the determination of dissolved oxygen in the presence of a reducing agent such as sulfite.

Series of preliminary experiments were first conducted to observe the reactions of the bass when various amounts of sodium sulfite were added to the water. The dosage rates were: 56 p.p.m., 112 p.p.m., 168 p.p.m., 224 p.p.m., 280 p.p.m., and 560 p.p.m. The dosage of 56 p.p.m. represented the approximate amount of sodium sulfite theoretically necessary to reduce the dissolved oxygen content to zero if no reoxygenation of the water took place. The water temperature in all 7 of the experimental aquaria was maintained between 72° and 74° F.

In all the foregoing experiments that involved dosages of 112 p.p.m. or higher, the fish came to the surface after an interval of time and began to gulp. Shortly after the fish began to gulp at the surface, they became easily catchable by hand or with a small dip net. The period of time during which the fish remained easily catchable at the surface by these means will be referred to as the period of catchability or catchability period. This period of catchability ended when the fish sank to the bottom; and if fish were to be revived, it was necessary to transfer them before they had remained on the bottom for a half minute or so. All fish transferred during the catchability period revived. It was discovered that the young bass could be subjected to the treatment at least three times within a week without exhibiting any symptoms of injury or weakness.

The duration of the catchability period, and the interval of time before its onset, varied with the dosage of sodium sulfite. At 56 p.p.m., for example, there was no catchability period; whereas at 560 p.p.m., the time before onset was usually about 15 minutes and the period of catchability lasted only about 5 minutes. At a dosage of 168 p.p.m., both the time interval and the catchability period were sometimes more than an hour.

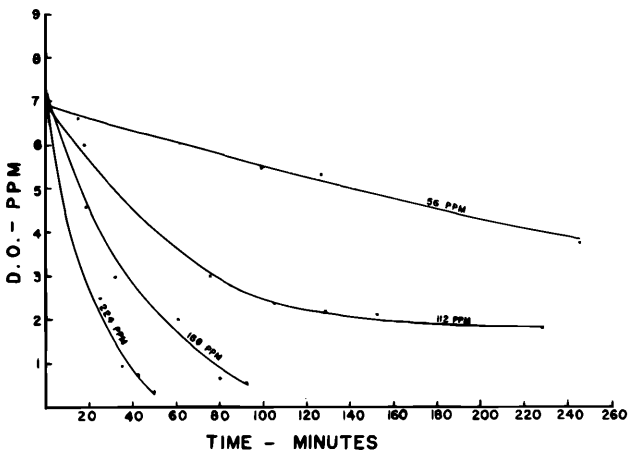

FIGURE 1.--The rates of decreases in dissolved oxygen at various dosages of sodium sulfite. (Curves have been sight-fitted.)

After these preliminary observations, a second series of experiments was conducted at 72° F. with dosages consisting of 56 p.p.m., 112 p.p.m., 168 p.p.m., and 224 p.p.m. Determinations of dissolved oxygen were made by the polarographic method during these experiments, and pH values were obtained colorimetrically.

Decreases in the amounts of dissolved oxygen at the various dosages of sodium sulfite, together with the rates of these decreases, are shown in figure 1. Measurements of pH gave a value of 7.0 for the untreated water, a rise to 8.4 at dosages of less than 224 p.p.m., and a rise to 8.6 at the 224 p.p.m. rate. Total alkalinity of the untreated water was approximately 33.

The catchability period in these experiments took place when the dissolved oxygen had decreased to approximately 1 p.p.m., and it was observed that the fish died within a few minutes at a dissolved oxygen level of less than 1 p.p.m. when they were denied access to the surface. If, on the other hand, the fish were permitted to gulp at the surface, they could survive for an hour or more at a dissolved oxygen level of approximately 0.8 p.p.m.

After these experiments with various dosages of sodium sulfite at a temperature

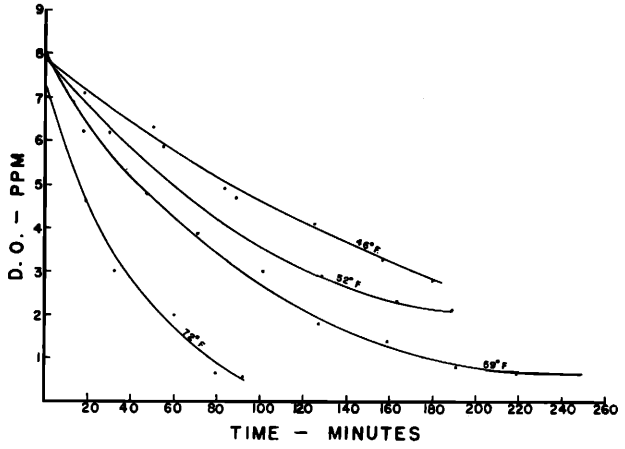

FIGURE 2.--The rates of decreases in dissolved oxygen at various temperatures, at a dosage of 168 ppm of sodium sulfite. (Curves have been sight-fitted.)

FIGURE 3.--Farm pond used in field experiment. The near (lower) end shows the dock and boat mentioned in the text. (Illustrations courtesy of the authors)

of 72° F., another series was conducted at different temperatures employing a constant dosage (168 p.p.m.) of sodium sulfite. The temperatures were 46°, 52°, and 59° F., and they were maintained by placing the aquaria on different levels in an open-type refrigerated display case. (It should be mentioned in passing that this type of refrigerated case proved to be an excellent piece of equipment for obtaining any constant temperature desired between near-freezing and room temperature.)

Polarographic measurements of dissolved oxygen were made again during these experiments, and the retarding effects of the lower temperatures on the action of the sodium sulfite have been portrayed in figure 2. It will be noted from this graph that the action of the chemical at 52° and 46° F. was not sufficiently rapid to combat the rate of re-aeration at the surface and produce a catchability threshold. On the other hand, there was a long period of catchability at 59° F.

It was also learned from these experiments that the sodium sulfite powder would lump badly and sink to the bottom at temperatures below 59° F. This occurred even when an N. F. grade of exsiccated powder--a product that dissolves almost instantly at temperatures above 58° F.--was used.

Field Observations

On October 9, 1955, a small farm pond (figure 3) on the property of the senior author at New Market, New Jersey, was treated with sodium sulfite (N. F. grade of exsiccated powder) at a dosage of approximately 168 p.p.m. This pond had been stocked 3 years previously with some adult golden shiners (Notemigonus crysoleucas) and a few dozen catfish (Ameiurus nebulosus). It had also been stocked, 2 years previously, with 26 juvenile largemouth bass. During 1954 and 1955, several thousand bait-sized golden shiners had been removed. Further, the pond had been invaded--possibly in 1953--by common sunfish (Lepomis gibbosus) and by some other undesired species, through a muskrat tunnel under the outlet screen.

The pond was 145 feet by 45 feet, with an estimated mean depth of 4 feet and a maximum depth of 6 feet.

The banks of the pond were steeply sloped except at the upper end (far end in figure 3), where there was a shallow area; and the location of the pond within 100 feet of the house provided excellent opportunity for long and close observation in experimental work.

At the time of experiment, the pond was supporting a moderate plankton bloom

and the day was characterized by bright sunlight and a fresh-to-strong wind sweeping the pond from the lower to the upper end. The surface temperature at the lower end was 63° F., and the bottom temperature was 61° F. Dissolved oxygen was approximately 6.3 p.p.m.

Treatment was begun at 12 o'clock noon by throwing 2 or 3 quarts of sodium sulfite at a time into the wash of a 7.5-horsepower outboard motor that was running at two-thirds speed on a boat fastened to the dock at the lower end of the pond (figure 3). After some 175 pounds were put into solution in this manner, 60 pounds more were put into the wash of the outboard as the boat was cruised slowly on the pond. The boat was then cruised 10 minutes more to ensure thorough mixing of the chemical.

Within 15 minutes after the application, golden shiners began to gulp at the surface and salvage operations with dip nets started. Largemouth bass, catfish, chubsuckers (Erimyzon oblongus), common suckers (Catostomus commersonni), carp, goldfish, and common sunfish began to surface some minutes later.

As it was desired that only catfish and adult golden shiners should be returned to the pond, only these, together with samples of the other species, were selected for salvage experiment. On the other hand, some of all the observed species were allowed to remain in the pond in order that their fate might be determined. Salvaged fish were first placed in containers of water and then transferred, within a matter of minutes, to five bathtubs that were connected in series with running water.

All fish salvaged revived within 5 minutes and included the following:

Species	Approximate number
Largemouth bass --	17 adults, 3 "zeros"
Golden shiner ----	225 adults
Catfish ----------	87 adults (?) up to 14 inches in length
Carp -------------	1 adult
Goldfish ---------	1 adult
Common sunfish ---	5 adults, 2 juveniles
Chubsucker -------	3 adults
Common sucker ----	1 juvenile

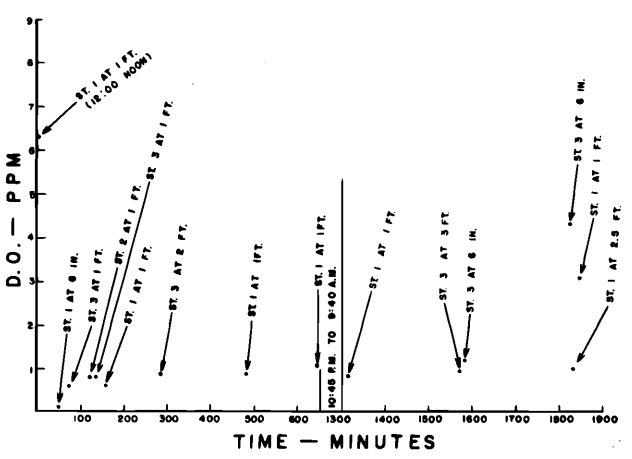

FIGURE 4.--Effects of sodium sulfite on dissolved oxygen in a farm pond (see figure 3) when applied at a rate of approximately 168 ppm. Station locations: (1) at lower end of pond, (2) middle of pond, (3) 40 feet from other end of pond.

Particular attempts were made to destroy as many sunfish as possible during this experiment, and it was discovered that thousands of "zeros" and juveniles could be scooped up in a small scap net from shore during the several hours before nightfall. Adult common sunfish seemed to be somewhat resistant to the conditions for several hours, but upwards of 400 were found, together with several "zero" bass, dead and floating at the surface of the pond the morning after the treatment.

Carp, goldfish, and suckers did not seem able to endure, for more than an hour or so, the low oxygen content portrayed in figure 4. All exhibited a characteristic behavior of skipping or "greyhounding" over the surface of the water and expiring shortly thereafter.

The behavior of largemouth bass was unique in that they did not surface near the middle of the pond but rather hid among, or under, the vegetation of the shoreline. Indeed, special efforts were necessary to detect them.

The most remarkable behavior was that of the catfish and golden shiners that were allowed to remain in the water. During

the afternoon of October 9 and until 5:15 p.m. on October 10, both these species, singly or in groups, gulped at the surface of the pond. Suddenly, at 5:15 p.m. on October 10, they disappeared from the surface. A measurement of dissolved oxygen some 45 minutes later showed a content of 4.3 p.p.m. near the surface (figure 4). All of the salvaged catfish and golden shiners were returned to the pond during the evening of October 10, and no mortality was observed at that time or later.

Comment

It seems apparent that use of sodium sulfite has considerable value as a means of salvaging fish in certain types of situations and as a simple means of observing the reaction of fishes under conditions of reduced amounts of dissolved oxygen.

It also seems obvious that the method, owing to the cost of the chemical (approximately 10 cents a pound), is not practical for large bodies of water and is limited to small ponds or to lakes that can be lowered to a few acre-feet of water.

The results of the field experiment suggest that effective salvage might be effected through the use of a somewhat lower dosage of sodium sulfite--for example, between 112 and 140 p.p.m.--particularly at higher temperatures.

The exact means by which oxygen is obtained at the surface through gulping is not understood. Samples of water that were taken from within 3 millimeters of the surface in experimental laboratory aquaria failed to show any significant difference in dissolved oxygen. It was noted, however, that all fishes with inferior mouths--that is, carp, goldfish, and suckers--in the pond experiment appeared to suffer a hundred percent mortality.

Acknowledgments

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