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AERATION OF WINTERKILL LAKES[1]

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Introduction

In February, 1963, two experiments were conducted with the intent of developing a method of inducing oxygen into lakes that periodically winterkill. Outboard motors were used to pump lake water over the surface of the ice. It was reasoned that this technique would take advantage of two sources of oxygen: (1) water flowing over the surface of the ice would absorb oxygen from the atmosphere, and (2) the lake water would melt the snow on the ice surface. The resulting increase in light penetration should increase dissolved oxygen by enhancing the photosynthesis of aquatic vegetation.

Most attempts to prevent winterkill with compressed air have been unsuccessful. The failure of this method has been attributed to several factors. In shallow lakes the compressed air produces turbulence which circulates water over the sediments which have a high oxygen demand. Such circulation brings about a loss of oxygen at the mud

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1 Contribution from Dingell-Johnson Project F-27-R Michigan.

surface which may be as great or greater than the oxygen input at the lake surface. Previous attempts have been made to pump water onto the surface of the ice (Greenbank, 1945). However, in these experiments the pumps used were of low capacity.

Methods

The method of operating the motors was (essentially) the same for each of the two experiments attempted. Two 6-inch holes were cut in the ice approximately 10 feet apart. Two 2" x 6" boards were pushed through the holes and into the bottom mud so that they penetrated approximately 2 feet of sediment. About 1 foot of each board was left projecting above the ice. A 12-foot 2" x 8" was nailed to the 2 x 6's so that the 2 x 8 rested on the surface of the ice. A rectangular hole, 18" x 36", was cut in the ice under the 2 x 8 mid-way between the upright 2 x 6's. An outboard motor was mounted on the 2 x 8 with the shaft extending into the hole. The shaft of the motor was cocked upward on the tilt adjusting bar so that the propeller was approximately 6 inches under the surface of the water. The motors were run at about 3/4 throttle with the gear shift in the forward position. Mounted in this way the propellers threw water out of the hole onto the ice surface. No pipes or extension hoses were used. Motors of 5.5, 7.5, 10 and 18 horsepower were used. It was estimated that the 5.5 hp motor pumped water onto the ice surface at a rate of 5 cfs and that the 18 hp pumped at a rate of 15 cfs.

When the motors were started, the water spread rapidly across the ice until approximately 1 acre was flooded. If holes were not drilled through the ice within the flooded area, sufficient water accumulated to depress the ice surface. As the depth of water on the ice increased, the rate of absorption of oxygen undoubtedly was reduced. The most efficient aeration was achieved by allowing the water to drain back through the ice through a series of 6-inch holes arranged in an arc approximately 200 feet behind the motors. The holes in the ice eventually limit the length of time that the motors can be operated effectively since they are continually enlarged by the melting action of the water. New holes are produced by seepage through pressure cracks and where stems of emergent plants extend to the surface. The dark colored plant stems absorb sufficient heat to melt the surrounding ice. In areas of dense weed beds, the ice is honeycombed with holes after 3 or 4 hours of flooding.

Movement noted under the ice of air bubbles, and in one instance dead fish, indicated that the motors created a strong current. This current was observed up to 200 feet behind the motors, but undoubtedly extended greater distances.

The holes in which the motors were operated enlarged rapidly. After about 4 hours they were 20 feet wide and 50 feet long and the motors were unable to pump water up onto the ice surface. In order to pump effectively more than 4 hours, it was necessary to move the motors to new locations.

All dissolved oxygen values were determined by the sodium azide modification of the Winkler method. Unless specified otherwise, samples were taken through a hole drilled with a 6-inch auger. It is unlikely that any variations in dissolved oxygen resulted from differences in sampling technique.

Results

An attempt was made to increase the dissolved oxygen in Winnewana impoundment in Washtenaw County, Michigan, T. 1 S., R. 3 E., Secs. 28, 29, 32. Winnewana is highly productive and is subject to winterkill. It has a maximum depth of 7 feet and the dissolved oxygen concentration becomes critical almost every winter. There have been several instances of winterkill since water was impounded in 1959.

Fish were observed in distress and dying on January 28, 1963. At this time the dissolved oxygen concentration was 0.4 ppm at the surface and 0.3 ppm at a depth of 3 feet. When we attempted aeration on February 5, 1963, few live fish were evident, so there was little hope of alleviating the winterkill. However, the situation offered an opportunity to test the practicability of using outboard motors to increase the oxygen content. On this date the dissolved oxygen content was 0.1 ppm from the surface to a depth of 3 feet. Oxygen was not detectable at greater depths. The odor of hydrogen sulfide was evident. Once a lake has reached these conditions, it is difficult to increase the oxygen supply because the oxidation of hydrogen sulfide utilizes the added oxygen.

One 7.5 hp outboard motor was operated for 45 minutes on February 5. The water which was pumped on the ice drained back through holes which had been made by fishermen. One hole, approximately 3 feet square and 25 feet behind the motor (in the direction of water flow), drained most of the water. Even with such a large hole the water spread over nearly one half acre of ice. After the motor was stopped, time was allowed for most of the water to drain through the ice before re-checking the oxygen concentration.

Water samples were collected for analysis from (1) the hole in which the motor was operated (station 1), (2) the large hole mentioned above located 25 feet behind the motor (station 2), (3) a small hole 45 feet behind the motor (station 3), and (4) a new hole opened 50 feet behind the motor (station 4) after all the water had drained back through the ice. This hole was located near the edge of the flooded area but was 50 feet from any point of drainage. An increase in oxygen at this hole could arise only from the circulation of aerated water under the ice. Water samples were collected at depths of 20 inches and 36 inches. At station 1 the dissolved oxygen was 2.3 ppm at 20 inches and 0.3 ppm at 36 inches. At station 2 the dissolved oxygen had increased to 1.3 ppm at 20 inches and 0.5 ppm at 36 inches. Station 3 had a dissolved oxygen content of 3.9 ppm at 20 inches and 2.2 ppm at 36 inches. At all of the above stations water drained directly into holes during the operation of the motor. At the new hole (station 4), where there was no drainage, the oxygen increased to 0.6 ppm at both 20 inches and 36 inches. This represents a small increase in dissolved oxygen but indicates that the motor produced currents under the ice. The fact that the highest dissolved oxygen values were 45 feet from the motor suggests that greater aeration is achieved by moving the water as far as possible over the ice before returning it to the lake.

Since the operation of one motor for 45 minutes produced an effect, it was decided to attempt a second experiment with a greater number of motors. Four outboard motors were installed on Mud Lake (Washtenaw County, T. 1 S., R. 3 E., Sec. 31) on February 7, 1963. Mud Lake has an area of approximately 90 acres and a maximum depth of 7 feet. The location of the motors and the two areas which were flooded are shown in Figure 1. The larger flooded area covered approximately 6 acres and the smaller area was about 2 acres. A 7.5 hp motor was used at station 1, a 10 hp at station 2, an 18 hp at station 3 and 5.5 hp motors were used at stations 4 and 5. The motors at stations 1 through 4 were started simultaneously. After 30 minutes of running time it was apparent that motors 2, 3 and 4 were too close together (approximately 100 yards). The pumping capacity of the 18 hp motor (station 3) was sufficient to nearly flood the motor at station 4. For this reason the motor at station 4 was stopped after 1 hour, and moved to station 5 where it was operated for 2.5 hours. After 2 hours, the 18 hp motor was no longer operating efficiently because of the increased size of the hole in which it was running. It was then moved to station 4 and run for 1 hour. The motors at stations 1 and 2 were run continuously for 4.5 hours. The depth of lake varied from 2.5 feet at station 3 to 3.75 feet at station 5. The motor at station 3 produced a considerable disturbance of the bottom mud. No disturbance was evident at any other station. For all future work a depth of 3 feet should be considered minimal.

Water samples were collected from a depth of 20 inches at each motor station before the motors were operated (Table 1). The dissolved oxygen values varied between 1.7 ppm (station 2) and 2.8 ppm (station 1). A second set of samples was taken after the motors had been stopped and all water had drained back through the ice. Samples taken at a depth of 20 inches from the motor stations ranged from 5.2 ppm to 8.3 ppm in dissolved oxygen. Samples from these stations collected at a depth of 36 inches varied in dissolved oxygen from 3.4 ppm to 5.2 ppm. Since reoxygenated water drained back through these holes throughout the motor operation, the possibility existed that these samples were not representative of all of the water within the flooded areas. To test this hypothesis samples were also taken from a new hole, within the larger flooded area, where there had been no known seepage through the ice. The dissolved oxygen values at this point were 6.1 ppm at 20 inches and 4.7 ppm at 36 inches.

If an appreciable circulation is induced by the motors, the oxygen concentration should become more uniform in distribution several hours after the motors have been stopped. In order to determine the uniformity of oxygen distribution, the flooded area in the vicinity of station 5

Figure 1. --Partial map of Mud Lake showing location of motors, direction of flow of the water and the areas flooded.

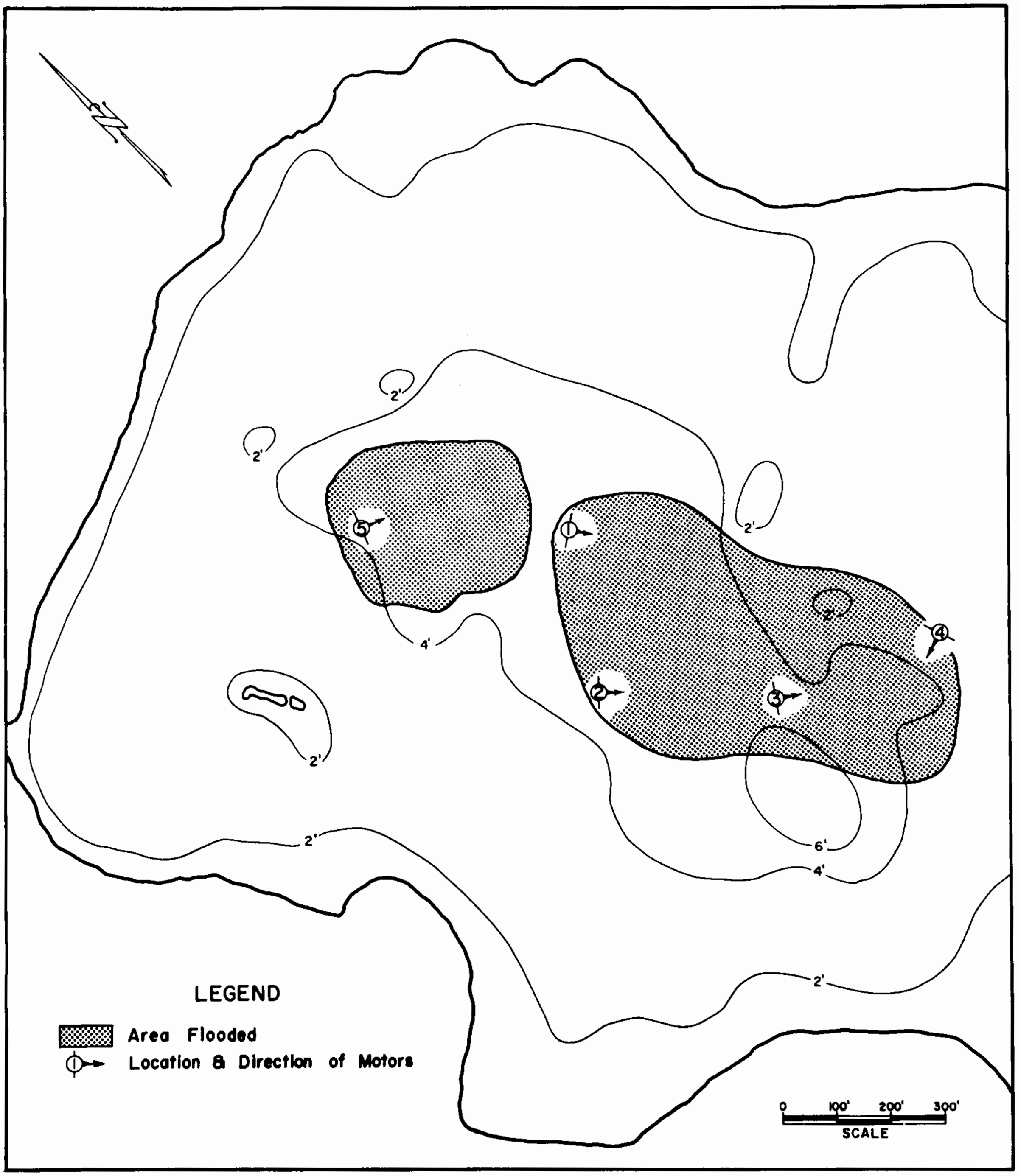
2'
2'
2'
4'
2'
2'
2'
6'
4'
2'
2'
LEGEND
Area Flooded
Location & Direction of Motors
0 100' 200' 300'
SCALE

Figure 1

Table 1.--Dissolved oxygen content of water samples collected at a depth of 20 inches in Mud Lake before and after the operation of outboard motors

Station	Depth of water (inches)	Oxygen before operation of motor (ppm)	Oxygen after operation of motor (ppm)
1	39	2.8	5.2
2	30	1.7	8.3
3	42	2.0	7.6
4	42	2.2	6.1
5	45	2.4	7.2

was sampled intensively on February 8, 1963 (24 hours after pumping). This flooded area was measured by the use of a plane table and an iron sight alidade and was then plotted on a map of the lake (Figure 2). The flooded area was then marked off in a 50-foot square grid pattern and water samples were taken every 50 feet. Additional samples were collected outside the flooded area wherever high dissolved oxygen values were found at the periphery.

Figure 2 shows the 3.5 ppm, 4.0 ppm, and 4.5 ppm oxygen contours. We did not collect sufficient data to complete the 3.5 ppm contour. One rather surprising finding in the oxygen distribution was the relatively high concentration west of the flooded area opposite to the direction of flow set up by the motor. The 4.0 ppm contour extended nearly 100 feet beyond the flooded area on the intake side of the motor. The flow of water over the ice and consequently the shape of the oxygen contours were influenced by a strong north wind during the day the motors were run. The oxygen distribution may also have been influenced by the motors running at stations 1 and 2. These motors undoubtedly had the effect of pulling water from the direction of the motor at station 5.

On February 11, 1963 (4 days after treatment), water samples were collected for oxygen analysis at 11 widely scattered locations on the lake. These samples were taken at a depth of 20 inches. Oxygen concentrations varied between 3.1 ppm and 4.8 ppm. These values represent a general increase in oxygen content throughout the lake. This widespread oxygen increase was believed to be due to the aeration

Figure 2. --Oxygen contours, direction of water flow and area flooded by 5.5 hp motor on Mud Lake.

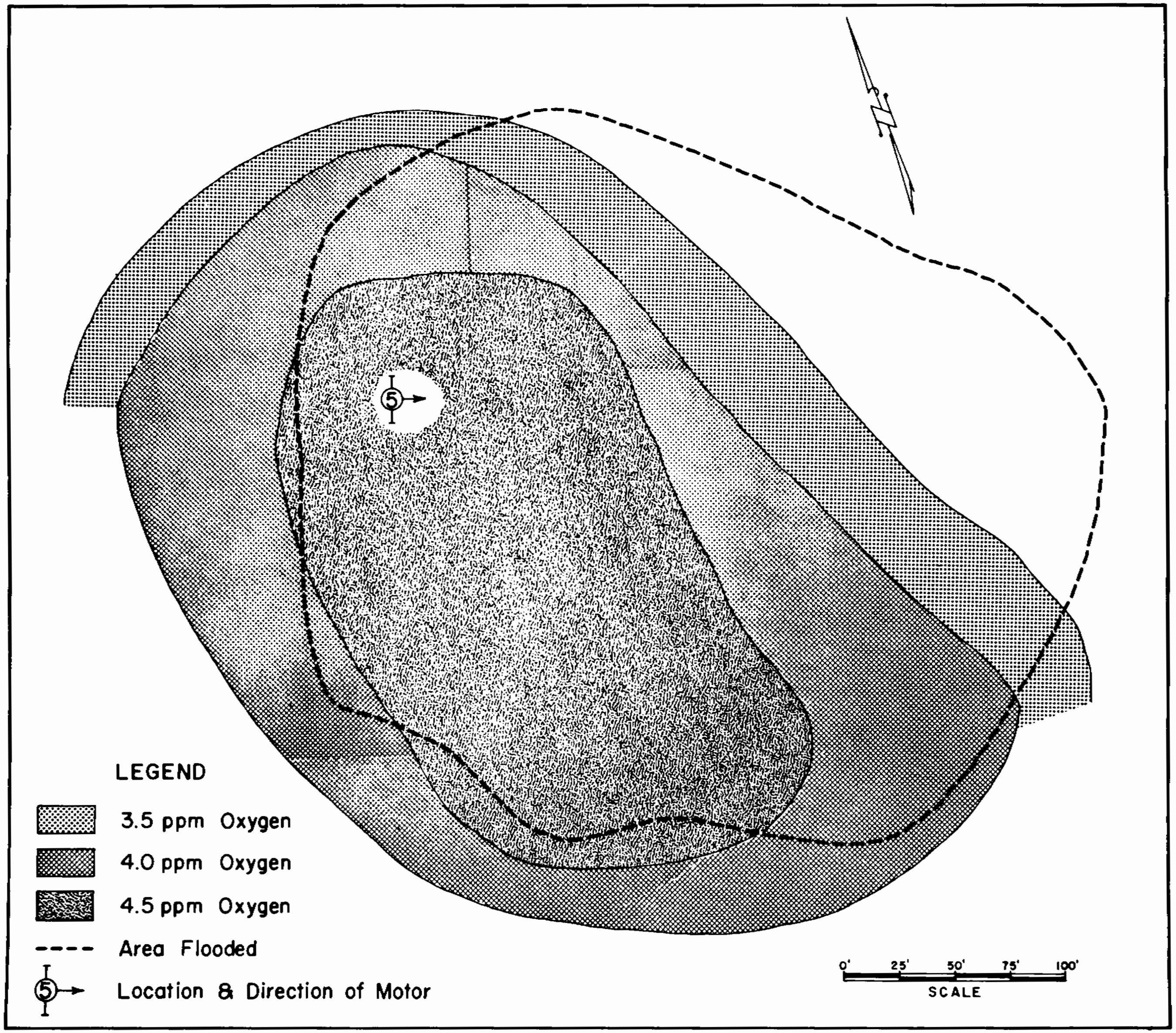
LEGEND
3.5 ppm Oxygen
4.0 ppm Oxygen
4.5 ppm Oxygen
Area Flooded
Location & Direction of Motor
5
0' 25' 50' 75' 100'
SCALE

Figure 2

and circulation produced by the motors. These samples were collected in areas where the snow had not been melted by the motor operation, so the increase in dissolved oxygen could hardly be due to photosynthesis. There had been no melting, during the intervening period, which would have caused an increase in oxygen concentration.

The oxygen concentration did not drop to a critical level in Mud Lake during the remainder of the winter. By February 25, a period of warm thawing weather produced an increase in dissolved oxygen which persisted until spring.

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Literature cited

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