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A TEST OF A COMMERCIAL DEVICE TO PREVENT WINTER OXYGEN DEPLETION IN A MICHIGAN LAKE

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Introduction

In recent years (1958-1962) several attempts were made to prevent critical winter oxygen depletion in Lodge Lake (formerly Loon Lake) on the Rifle River Area by artificially circulating water beneath the ice by means of compressed air.[1] The objective was to produce an area of open water so that air and water would be in contact. This was accomplished by laying a perforated hose line on the lake bottom and forcing compressed air through it. The rising air bubbles produced an upwelling of the warmer bottom waters which melted the ice above the hose; in the open channel lake water came in contact with the air and absorbed oxygen from the atmosphere. The bubbling disturbance at the surface presumably increased the rate of oxygen diffusion.

The amount of oxygen absorbed into the water and carried throughout the upper part of the lake by lateral currents, produced by the upwelling water, was insufficient to overcome the oxygen demand

[1] Institute for Fisheries Research Report No. 1628.

beneath the ice. Bringing the bottom layer of oxygen-deficient water and bottom material into contact with the upper aerated strata created a greater oxygen demand than could be overcome by artificial aeration. Despite two modifications of the physical set-up, these attempts to prevent oxygen depletion were unsuccessful and probably induced winterkills instead of preventing them. Modifications included suspension of the air conductor at a depth of 5 feet in 1959-60, and laying a 28 x 500-foot sheet of transparent plastic material beneath the air conductor in 1961-62.

In 1962, a representative of the Besly-Welles Corp., of South Beloit, Illinois, asked the staff at the Rifle River Fisheries Research Station to test an aeration device called the "Aqua-Lator." This unit consists of a submerged electric water pump (suspended beneath a circular styrofoam float) designed to throw several thousand gallons of water per hour into the air through a plastic pipe (Fig. 1). The volume varies with the horsepower of the pumping unit. The Aqua-Lator can be operated continuously over a long period of time or controlled by a timing device. The water is forced up into the air in a thin sheet, absorbs oxygen during this brief exposure to the air, and is re-circulated beneath the ice throughout the pond or lake. Presumably the device was used successfully in small ponds and raceways but its effectiveness in a larger natural lake had not been tested. We agreed to test the device during the winter of 1962-63 in Lodge Lake. This 16.8-acre lake has a

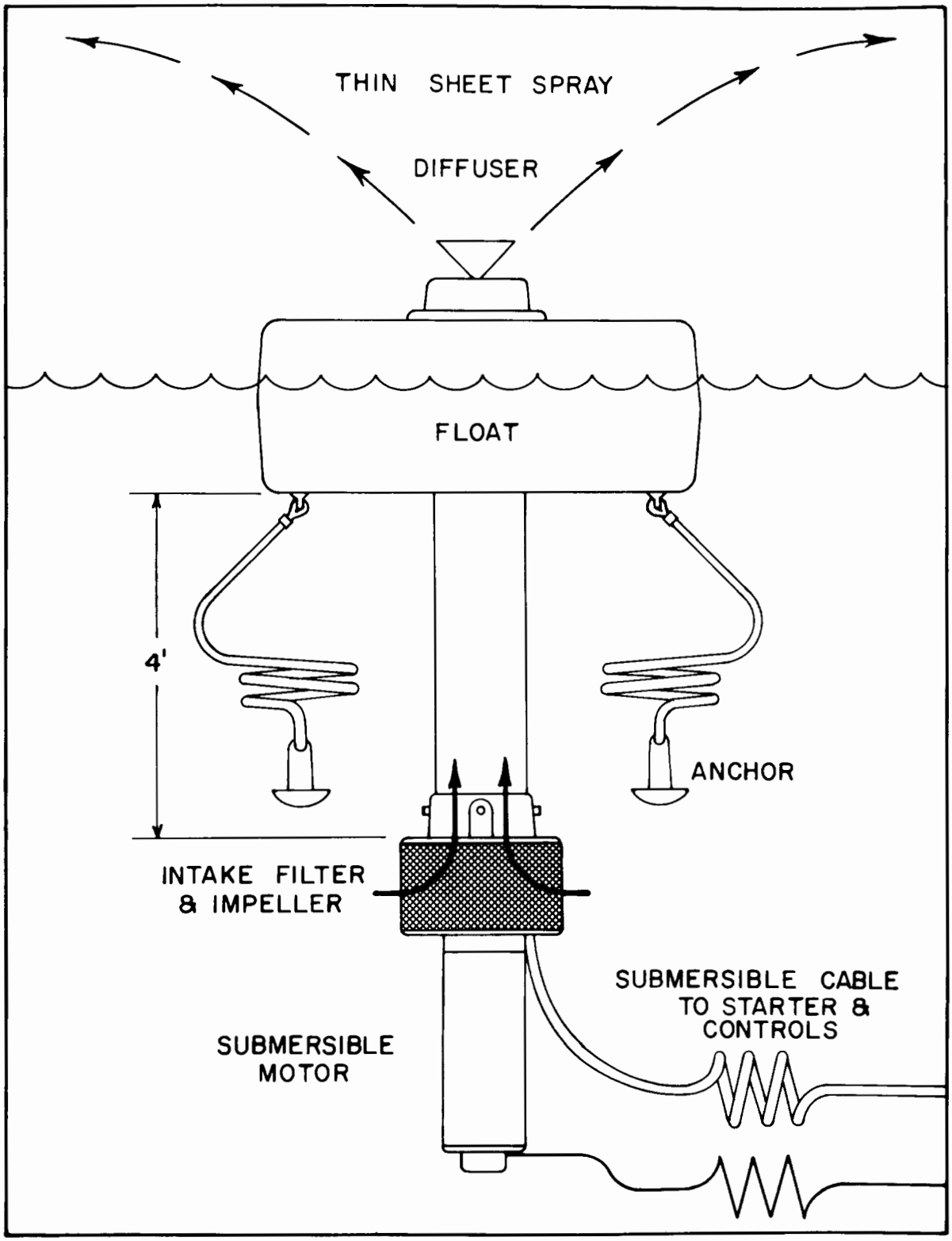

Figure 1.--Diagram of the Besly Aqua-Lator tested in Lodge Lake, 1962-63.

maximum depth of 16 feet, an abundance of aquatic vegetation, a soft bottom of organic ooze mixed with marl, and contains several species of fish.

Methods

An Aqua-Lator unit was delivered to us in October, 1962, by personnel from the Mayfair Marine Co. of Detroit and installed in the lake October 30 (Fig. 2). This particular unit consisted of a 1/3-H.P. submersible pump, a 4-foot piece of plastic pipe, styrofoam float, diffuser, and two anchors. For this installation, 175 feet of No. 8 wire (supplied by the Besly-Welles Corp.) was connected to the fuse box in the basement of the Lodge and run down the side of the hill to the grounded control box fastened to a stake on shore. The floating Aqua-Lator was anchored in the lake 160 feet out from shore and in approximately 6 feet of water. Electricity was supplied to the Aqua-Lator by means of No. 12, 3-strand, covered wire laid on the bottom of the lake. The length of wire used (160 feet) was about the maximum distance that current can be carried by No. 12 wire without serious line loss.

Periodic tests of oxygen (Winkler Method) and water temperature readings were made at depths of 2, 5, and either 8 or 10 feet beneath the surface of the ice. The sampling stations were approximately 100 and 300 feet from the Aqua-Lator. Usually on the same dates oxygen

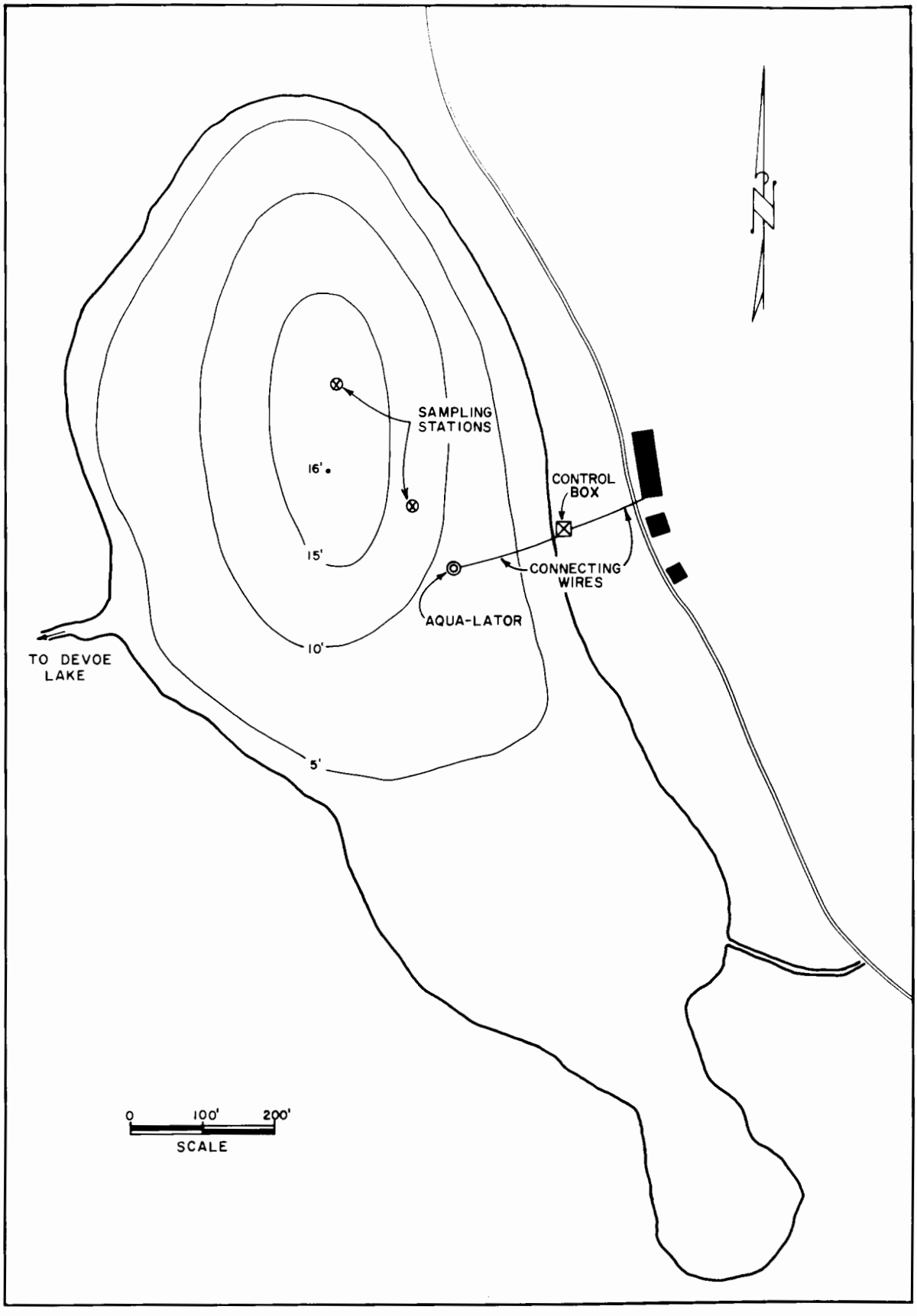

Figure 2.--Hydrographic map of Lodge Lake showing location of Aqua-Lator.

tests were made in nearby Grebe (formerly Spring) Lake and Jewett (formerly Dollar) Lake. Grebe Lake (72 acres) has a past history of frequent winterkills, but the 12.9-acre Jewett Lake has never winterkilled. Grebe Lake contains fish, but Jewett Lake was treated with toxaphene in the fall of 1962 and had no fish in it during the winter of 1962-63.

Performance of Aqua-Lator

The Aqua-Lator was started on November 1 and operated continuously until February 19. The fall turn-over in the lake was completed by October 31, and water temperatures from top to bottom varied by only 0.2 degree (41.8°-41.6° F.); the oxygen content, 11.7 ppm, was close to the saturation point of 12.2 ppm (42°). The lake froze over temporarily on November 25 but re-opened December 3. On December 9 the surface froze for the duration of the winter. The ice was covered with snow continuously after December 23.

The winter of 1962-63 was one of the coldest on record. The lowest temperature recorded on the U. S. Weather Bureau thermometer at this station was minus 34° on January 15. The average minimum temperatures for the months of December, January, and February were, respectively, 8.3°, minus 1.2° and minus 3.9°. Respective average maximum temperatures for these months were 31.7°, 21.1°, and 25.2°. During the operation of the Aqua-Lator (November 1-February 19), snow depths up to 6 inches were recorded on the lake and ice thickness reached at least 24 inches.

The Aqua-Lator ran flawlessly during the 111 days of continuous operation and opened an elliptical area in the ice which varied from an estimated 100 x 40 feet to 60 x 36 feet. The smaller estimate was made following a week of nightly sub-zero temperatures. The area of open water was estimated by pacing. The height of the jet of water above the float was approximately 12 inches. The cost of operation of the unit for the period December 18-January 17 was about seven dollars.

Water temperatures

Weekly water temperatures, taken at several depths at the sampling stations (with occasional checks in the open water), revealed that an inverse stratification pattern was established, similar to that described by Patriarche (1961) for previous experiments with compressed air. The temperature of the top 4 feet of water was virtually uniform. Below four feet (depth of water intake) there was a rapid change to the winter maximum of approximately 40° F. (Fig. 3). In both Grebe and Jewett lakes normal winter inverse stratification was established and maintained. Thus, as in previous experiments with vertical upwelling of bottom water, the turbulence created by the water pump induced lateral currents (along with eddy diffusion) which formed an isothermal zone to a depth corresponding to that of the pump (4 feet). Beneath this depth a narrow zone of considerable temperature gradient was established between the 4- and 8-foot contours. A minimum water temperature of 35° developed by mid-January.

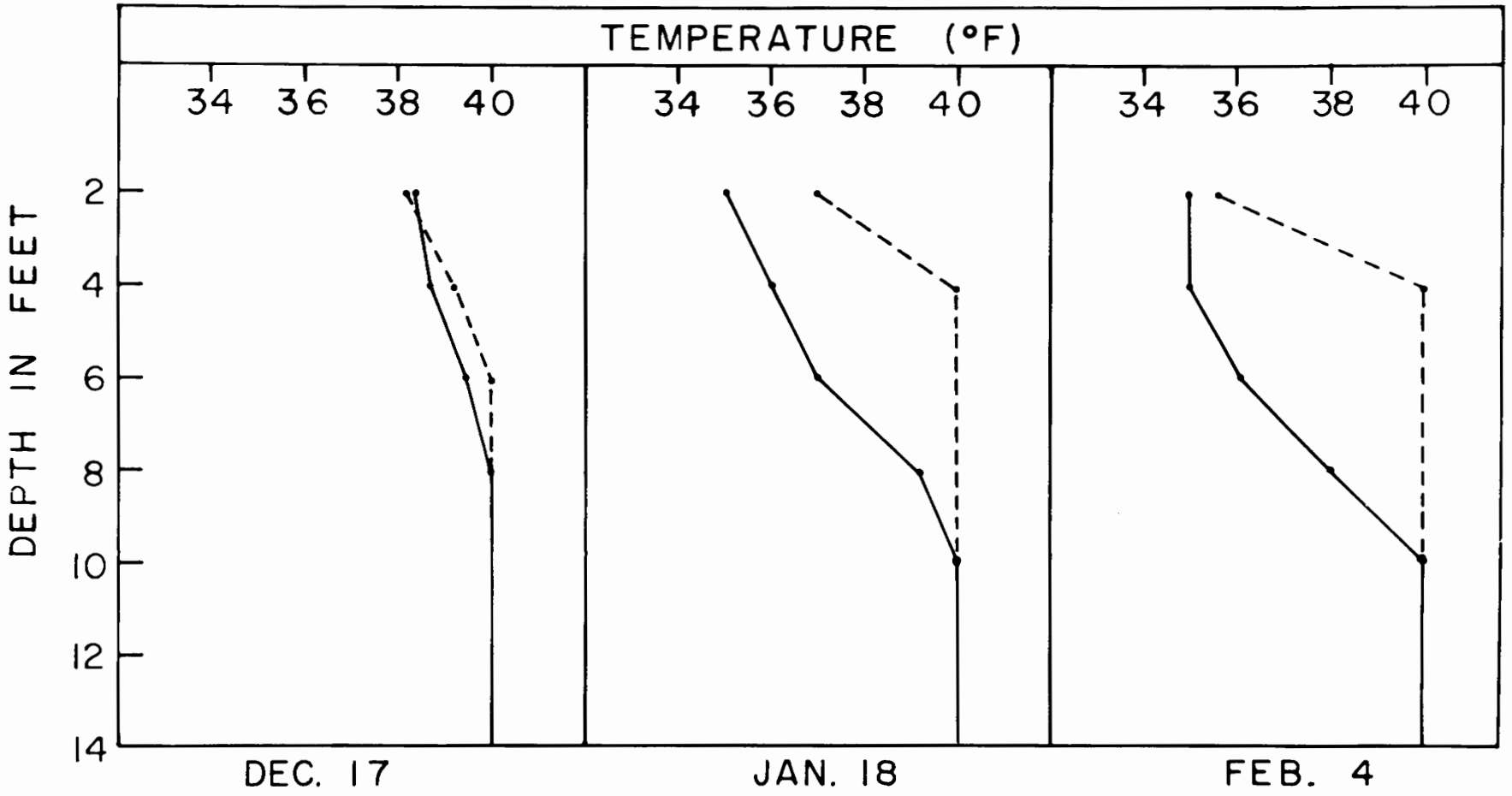

Figure 3. --Water temperatures in Lodge (solid line) and Jewett (dotted line) lakes on three selected dates.

Oxygen

Despite a brief period of ice cover in November, Lodge Lake was still virtually saturated with oxygen on December 3, but within one week after the permanent ice cover was established on December 9, a decline in oxygen began (Table 1). This decline was much more pronounced than in Jewett and Grebe lakes (Fig. 4), although subsequently there was a marked drop in oxygen in Grebe Lake. By February 18 Lodge Lake oxygen had dropped to 4.1 ppm in the upper 5-foot stratum; 3.0 ppm at 8 feet. In an attempt to improve its performance, the Aqua-Lator was tilted up on the edge of the ice so that a flow of water was forced out along the ice surface for about 50 feet. This arrangement permitted a longer exposure to the air before the water flowed back into the open-water hole. An increase of 0.3 ppm of oxygen was noted in the vicinity of the Aqua-Lator over that measured in samples taken 100 feet away. However, within 18 hours the water had melted the ice shelf around the unit and no more horizontal flow occurred. The unit was relocated to induce more water flow over the ice. After four hours there was no change of oxygen in the vicinity of the Aqua-Lator. Most of the water ran back into the open water instead of spreading out. The attached wires restricted the re-positioning of the Aqua-Lator. The Aqua-Lator was removed on February 19 because, with six weeks of ice cover remaining, it seemed probable that a winterkill would occur if the downward trend in oxygen content induced by artificial circulation, were permitted to continue. A subsequent mean low of 3.2 ppm was detected in samples taken about 2.5

Table 1.--Oxygen values (ppm.) in Lodge Lake at sampling stations 100 and 300 feet from Aqua-Lator, 1962-63

Date	100 feet[1]				300 feet			
	Depth below ice surface (feet)				Depth below ice surface (feet)			
	2	5	8	10	2	5	8	10
Dec. 3	13.3	12.5	...	12.2	...	...	...	...
17	12.6	12.3	...	10.7	...	...	...	...
Jan. 2	10.9	10.6	...	5.1	...	...	...	...
10	9.1	8.8	...	5.9	...	...	...	...
18	7.8	7.2	...	2.1	7.6	7.4	...	2.5
25	6.6	6.0	4.9	...	...	...	...	...
Feb. 4	5.3	5.1	4.2	1.9	5.1	5.0	4.2	1.5
18	4.2	3.7	2.5	...	3.9	4.2	3.4	...
Mar. 8	3.4	2.2	0.9	...	3.0	1.9	1.4	...
18	4.0	1.5	...	1.3	2.5	2.3	...	0.5
25	3.8	4.0	...	2.7	3.9	3.2	...	0.8

[1] Two sampling stations 100 feet north and west of the Aqua-Lator were used between December 3-January 10. Mean values are recorded in the table for the first four sampling dates.

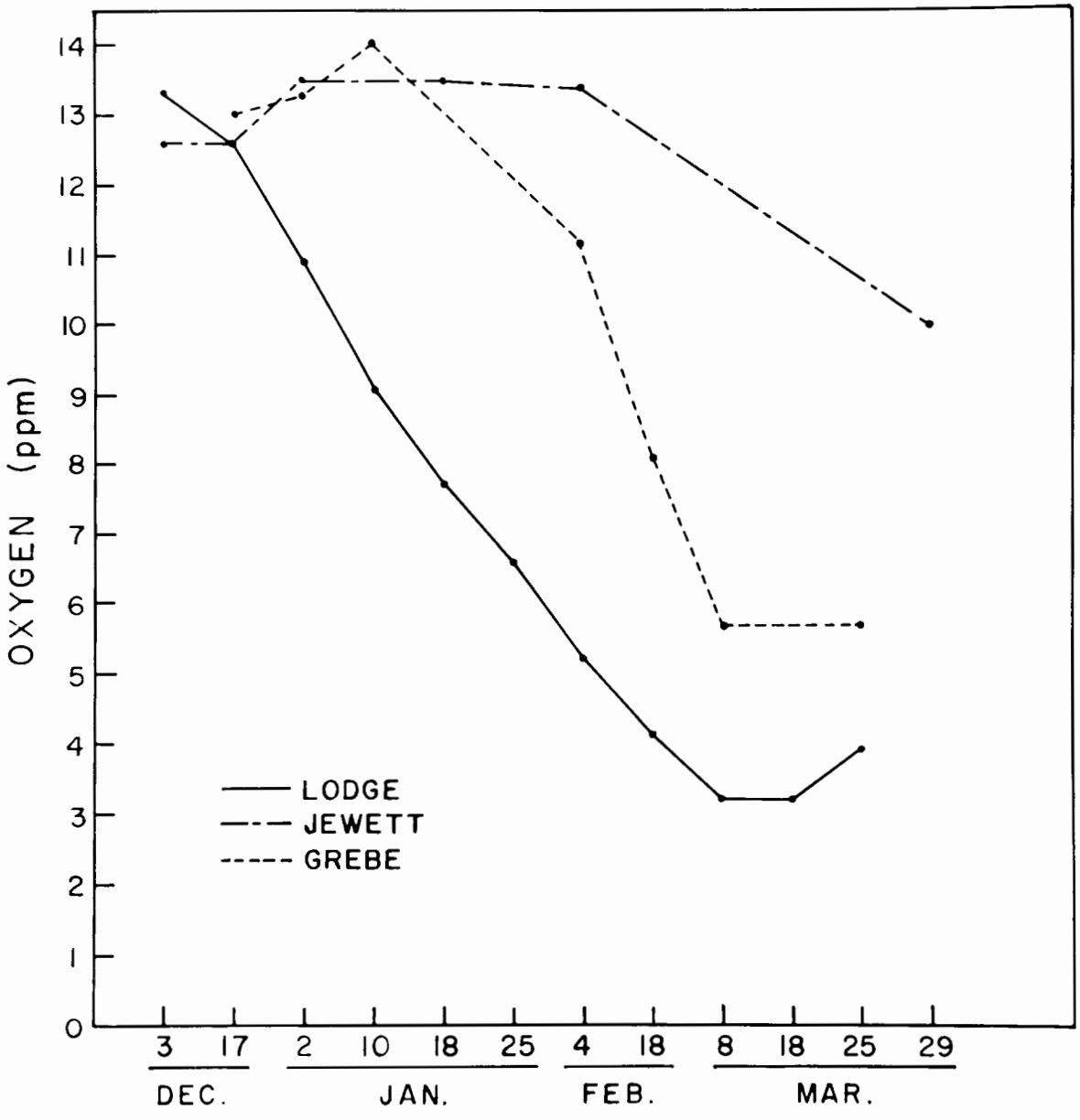

Figure 4.--Oxygen values for Lodge, Jewett, and Grebe lakes during the winter of 1962-63.

feet below the ice surface on March 8, but no evidence of a winterkill was found after the ice break-up April 4.

The oxygen decline at the 5-foot depth noted in 1962-63 was similar to the one observed in 1961-62 when compressed air was used to circulate water (Fig. 5). It is interesting to note, however, that the decline which occurred in 1960-61, when no effort was made to alter natural conditions, was not so great. The total drop in oxygen (5-foot depth) between mid-December and mid-February in 1960-61 was only 5.8 ppm whereas in 1961-62 and 1962-63 the total oxygen decline was 7.8 and 8.3 ppm, respectively.

Discussion

The explanation for the failure of the Aqua-Lator unit to prevent a rapid decline of oxygen probably lies in the amount of time and volume of water which was exposed to the atmosphere. On February 5 a sample of spray water was analyzed for oxygen content and compared with samples taken close to the pump intake. The spray sample (collected just before the water fell back into the lake) showed an increase of 1.6 ppm (1.6 mg/1) over that taken near the intake. The performance data for the Aqua-Lator indicates an output of 792,000 gallons per day (3,009,600 liters). This means that there was a daily input of 4.8 kgm/1 or 10.6 pounds of oxygen. However, under the artificial conditions created in 1962-63, oxygen consumption amounted to an average of 23.9 pounds per day. This value was computed by comparing actual oxygen deficits computed for December 3, 1962 and March 8, 1963, using the method described in Welch (1948).

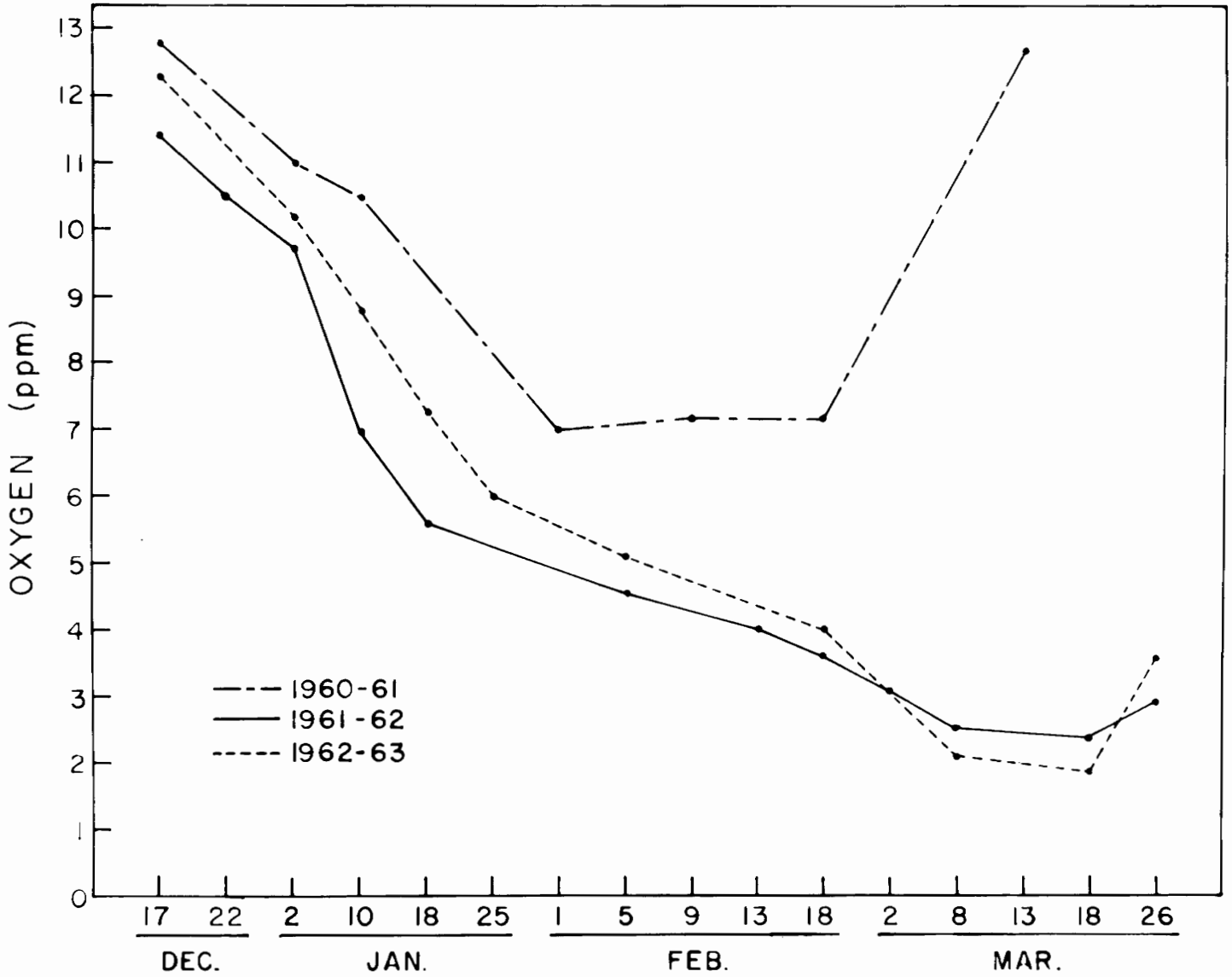

Figure 5. --A comparison of oxygen curves at the 5-foot level for three successive winters in Lodge Lake: 1960-61 (no treatment), 1961-62 (compressed air), 1962-63 (Aqua-Lator).

Similarly, in the previous winter, the mean daily oxygen consumption beneath the ice amounted to 23.4 pounds. Unfortunately there are no adequate data for similar computations in a "normal" year, but obviously the oxygen input fell considerably short of requirements.

The solution to the problem appears to lie either in producing a greater volume of water which is exposed to the air for a longer period of time, or actually diffusing air into the water by some mechanical means.

Acknowledgments

The Aqua-Lator unit and most of the material needed for its installation were furnished by Mayfair Marine, Inc., 15203 West Seven Mile Road, Detroit, Michigan. The Besly-Welles Corporation, South Beloit, Illinois, supplied the No. 8 wire and the No. 12 wire required for the installation. A. W. DeClaire supervised the installation and made some of the oxygen determinations. K. R. Sammons and George Smith, Jr. assisted with the water sampling throughout the winter.

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