HYPOLIMNETIC AERATION AS A FISHERIES MANAGEMENT TECHNIQUE

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Abstract. Artificial aeration of lakes and reservoirs can be accomplished either by total mixing (Destratification) or by aeration/oxygenation of the hypolimnion without thermal destratification (Hypolimnetic Aeration). Destratification results in the elimination of oxygen depletions, but it also eliminates cold waters. With destratification, the entire lake becomes as warm as the surface waters were without destratification. This may create unsuitable thermal conditions for coldwater fishes. Hypolimnetic aeration will maintain cold waters while at the same time eliminate hypolimnetic oxygen depletion. This will allow the yearlong survival of coldwater fishes. Hypolimnetic aeration can be accomplished by using compressed air, liquid oxygen or mechanical means.

INTRODUCTION AND RATIONALE FOR AERATION

Artificial aeration is a widely used treatment for eutrophic lakes. It is used most commonly for domestic water quality control, but it is increasingly used for fisheries management as well. Artificial aeration is often as effective and economical means of eliminating oxygen depletions, and reducing concentrations of iron, manganese, carbon dioxide, hydrogen sulfide and other substances which degrade water quality. In some cases, artificial aeration also reduces algal densities. Aeration can greatly increase the available fish habitat, and/or it can allow the yearlong survival of coldwater fish where previously only warmwater fish could survive through the summer. These effects not only improve domestic water quality and fisheries recreation, but they also improve the aesthetic value of the lake or reservoir. Aesthetic values are often intangible or difficult to quantify, but their impact on property values are real and often substantial.

Most of the proven benefits of aeration are related to controlling or reversing the symptoms of eutrophication rather than controlling the underlying cause of eutrophication. Eutrophication is caused by excessive nutrient loading either from the watershed, or from the lake's sediments. These are respectively called: "external loading", and "internal loading". Aeration

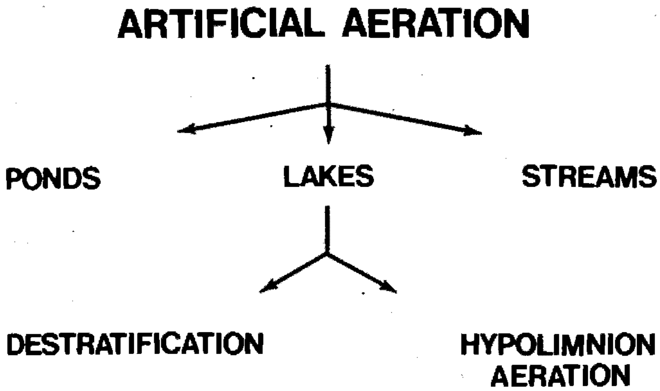

Figure 1. Artificial aeration systems have been developed for ponds, lakes and streams. There are two categories of lake aerators.

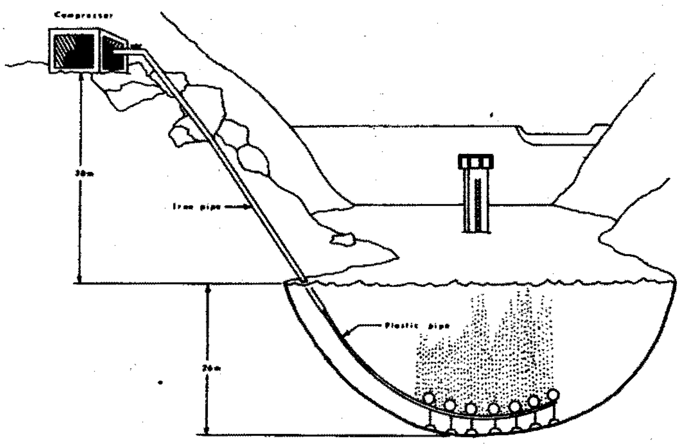

Figure 2. A typical destratification system. It consists of an air compressor on shore and an air line along the bottom of the lake. Air is released through holes in the air line.

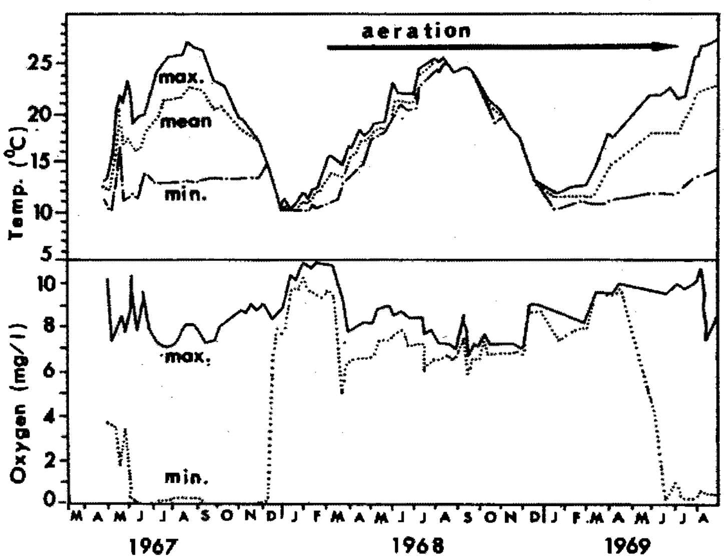

Figure 3. Temperature and oxygen conditions associated with the artificial aeration of Puddingstone Reservoir. The bottom waters were warmed greatly during aeration (Fast and St. Amant, 1971).

can not affect external loading, but it may affect internal loading or the cycling of nutrients once they enter the lake. At one time, we thought that artificial aeration would seal nutrients into the profundal sediments and thereby retard or prevent their recycling back into the water. This has never been proven, and it now appears that in some cases substantial amounts of nutrients may be released from the sediments even under aerobic conditions (Fast, 1975; Smith, Knauer and Wirth, 1975). Fast (op. cit.) reviewed this problem and concluded that we must be able to more accurately measure the nutrient sources, and nutrient exchanges between the water and sediments before this question can be resolved.

The purpose of this paper is a discussion of artificial aeration for fisheries management, especially for coldwater fisheries management. I will give an overview of aeration and then discuss several hypolimnetic aeration projects.

TYPES OF AERATION

There are a wide variety of artificial aeration systems, but we will concern ourselves only with lake aeration systems (Fig. 1). These fall into two broad categories: Destratification and Hypolimnetic Aeration. Destratification systems operate by reducing or eliminating thermal stratification. When a lake is destratified, the temperature will be nearly uniform from the surface to the bottom, and oxygen will be distributed throughout. One of the most common destratification systems consists of an air compressor on the shore with a single air line along the bottom (Fig. 2). Air is released from perforations in the air line, and the rising air causes upwelling of cold water from the bottom of the lake. This water mixes with surface waters until the lake is isothermal. About 10% of the dissolved oxygen increase during destratification comes from the injected air, while the remainder comes from the air/water interface and photosynthetic oxygen sources.

Destratification will eliminate barriers to fish distribution and allow fish to distribute throughout the lake (Gebhart and Summerfelt, 1975; Miller and Fast, in prep.). However, destratification also eliminates the cold water and the entire lake will become about as warm as the surface waters were before aeration began (Fig. 3) (Fast, 1968; Fast and St. Amant, 1971; Fast, 1971). If the surface waters were too warm for coldwater fish before aeration, then destratification will preclude the yearlong survival of these fish.

Hypolimnetic aeration is an alternative means of lake aeration. It is a process whereby the hypolimnetic waters are aerated or oxygenated, but thermal stratification is maintained. This has been achieved by mechanical means (Mercier and Perret, 1949), compressed air injection (Bernhardt, 1967, 1974; Fast, 1971), and by pure oxygen injection (Fast, Overholtz and Tubb, 1975). I will now discuss several hypolimnetic aeration installations.

HYPOLIMNETIC AERATION

Most of the early hypolimnetic aerator development occurred in Europe. These systems utilized compressed air injection or mechanical aeration means, and were used for domestic water quality control, fishery management and aesthetic reasons. The first North American hypolimnetic aerator was operated in Hemlock Lake, Michigan during 1970 (Fig. 4). These tests demonstrated its efficacy as a fishery management technique (Fast, 1971). Prior to aeration, 24% of the lake's volume was too warm for trout, 41% had insufficient oxygen and only 35% had both adequate oxygen and temperature. During aeration, 97% of the water volume had suitable oxygen and temperature, and rainbow trout (*Salmo gairdneri*) distributed throughout the lake. Proposed modifications of this design now appear to be one of the most efficient (KW-hr. per lb. oxygen dissolved) and least costly (capital and operating costs)

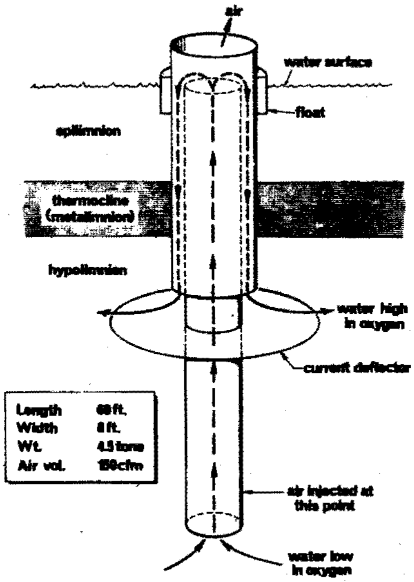

Figure 4. Hypolimnetic aerator used in Hemlock Lake, Michigan (Fast, 1971). Compressed air was injected near the bottom of the deepest pipe, and air was provided by a shore-based compressor.

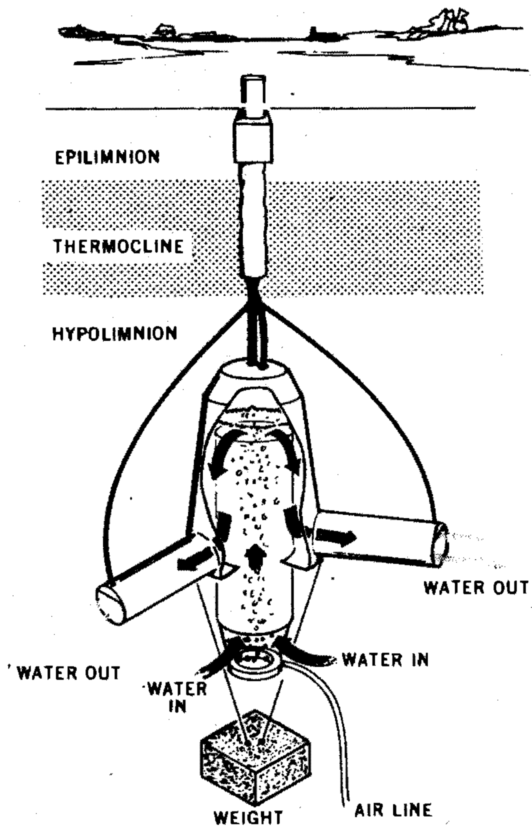

Figure 5. Exposed view of hypolimnetic aerator used in Lake Wassabuc, New York (Fast, Dorr and Rosen, 1975). Compressed air was supplied by a shore-based compressor.

means of hypolimnetic aeration (Fast, Lorenzen and Glenn, 1975).

A Swedish hypolimnetic aerator was operated in Lake Waccabuc, New York beginning in 1973. The aerator, called Limno (Fig. 5), also used air injection. The unique feature of this design is that the aeration occurs entirely within the hypolimnion without upwelling water to the lake's surface. Before hypolimnetic aeration, Lake Waccabuc was anaerobic much of the year from within the thermocline to maximum depth (Fig. 6), and coldwater fish were never observed in the lake. Aeration began during July 1973 after the hypolimnion was anaerobic. Within one month, hypolimnetic oxygen concentrations were increased above four mg/l. Oxygen concentration of more than six mg/l were achieved during the second summer of aeration. During August 1973, 2,100 rainbow trout, brook trout (Salvelinus fontinalis) and brown trout (Salmo trutta) were stocked in the lake. The fish had to be "piped" into the hypolimnion using a system similar to one described by Overholtz (1974). This was necessary to avoid thermal shock since the fish were acclimated to 10°C water, while Waccabuc's surface temperatures exceeded 26°C. We observed no mortality due to this stocking technique. Fish depths were observed with vertical gill nets and sonar. These indicated that the fish initially remained in the thermocline but later dispersed throughout the hypolimnion. In effect, we created a classical "two story" fishery with warmwater species in shallow water, and coldwater species in deep water. Using hypolimnetic aeration, we were able to establish yearlong trout survival where such survival was not possible before.

A third hypolimnetic oxygenation system was tested in Ottoville Quarry, Ohio beginning July 1973 (Fast, Overholtz and Tubb, 1975). This system used a mechanical water pump and liquid oxygen (Fig. 7). Since nearly pure oxygen was used, it was possible to achieve much greater dissolved oxygen concentrations in the hypolimnion than is possible with compressed air injection. Maximum hypolimnetic oxygen concentrations of 8 mg/l during 1973 and 21.5 mg/l during 1974 were achieved using this system (Fig. 8).

Gartman (1973) previously attempted to establish yearlong trout survival in Ottoville Quarry. The trout would not survive during normal conditions because of excessive surface temperatures and anaerobic bottom waters. Gartman destratified the quarry during 1970, 1971 and 1972 but the entire water column then became too warm for the trout even though oxygen concentrations were satisfactory. He also tried hypolimnetic aeration during 1972, but his system was undersized. Hypolimnetic oxygenation using liquid oxygen created a two story fishery with rainbow trout at the bottom, and with largemouth bass (Micropterus salmoides) and gizzard shad (Dorosoma cepedianum) in the surface waters.

LITERATURE CITED

Bernhardt, H. 1967. Aeration of Wahnbach Reservoir without changing the temperature profile. Amer. Water Works Assoc. 63:943-963.

______________. 1974. Ten years experience of reservoir aeration. Presented: Internat. Assoc. Water Poll. Conf., Paris, France.

Gartman, D. K. 1973. Artificial aeration and destratification of Ottoville Quarry. Ph.D. Thesis. Ohio State University, Columbus, Ohio. 93 pp.

Gebhart, G. E. and R. C. Summerfelt. 1975. Effects of destratification on depth distribution of fish. Presented: Symposium on Reaeration Research, A.S.C.E., Gatlinburg, Tenn., Oct. 28-30, 1975.

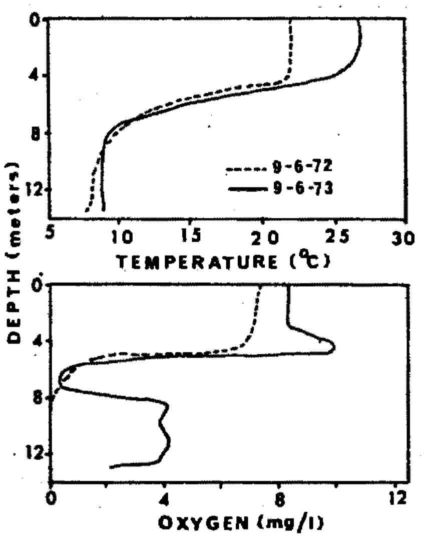

Figure 6. Oxygen and temperature profiles in Lake Waccabuc, New York before aeration (Sept. 6, 1972) and during aeration (Sept. 6, 1973) (Fast, 1974). Aeration began July 9, 1973.

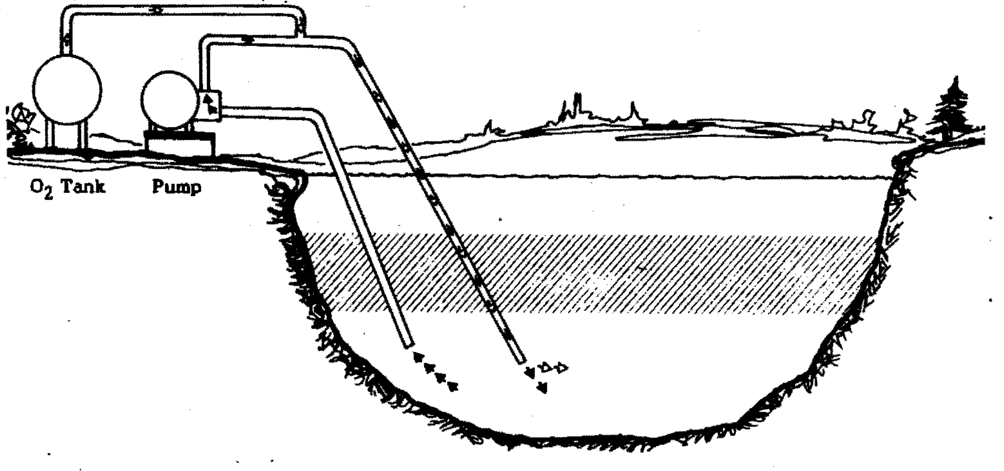

Figure 7. Schematic illustration of the hypolimnetic oxygenation system used in Ottoville Quarry, Ohio (Fast, Overholtz and Tubb, 1975). The crosshatched area represents the thermocline.

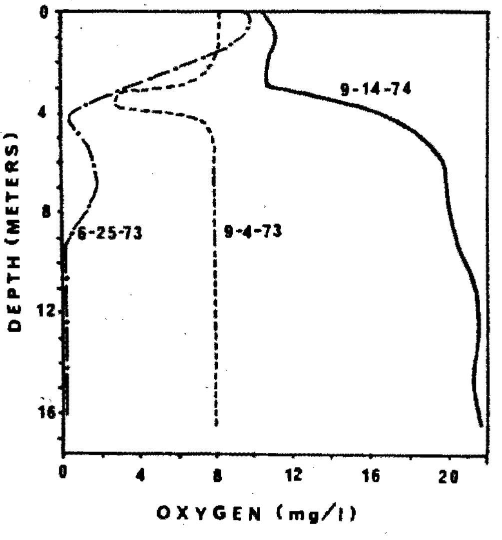

Figure 8. Oxygen profiles in Ottoville Quarry, Ohio before oxygenation (June 25, 1973) and during two summers of oxygenation (Sept. 4, 1973 and Sept. 14, 1974). Strong thermal stratification was maintained both years during oxygenation (Overholtz, 1974).

Fast, A. W. 1968. Artificial destratification of El Capital Reservoir, part I, effects on chemical and physical parameters. Fish Bull. 141, Calif. Dept. Fish and Game. 97 pp.

______________. 1971. The effects of artificial aeration on lake ecology. Environ. Prot. Agency, Water Poll. Control Series 16010 EXE 12/71. 470 pp.

______________. 1974. Restoration of eutrophic lakes by artificial hypolimnetic oxygenation. In Proc. Human-Accelerated Eutrophication of Fresh-Water Lakes, Dec. 1973. Teatown Lake Reservation, Brooklyn Botanical Garden, Ossining, New York. Pp. 21-34.

______________. 1975. Artificial aeration and oxygenation of lakes as a restoration technique. Presented: Symposium on the Recovery of Damaged Ecosystems. March 28-30, 1975, Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

______________ and J. A. St. Amant. 1971. Nighttime artificial aeration of Puddingstone Reservoir, Los Angeles County, California. Calif. Fish & Game 57(3):213-216.

______________, W. J. Overholtz and R. A. Tubb. 1975. Hypolimnetic oxygenation using liquid oxygen. Water Resources Research 11(2):294-299.

______________, M. W. Lorenzen and J. H. Glenn. 1975. Hypolimnetic aeration/oxygenation: A comparison study with costs. Presented: Symposium on Reaeration Research, A.S.C.E., Gatlinburg, Tenn. Oct. 28-30.

______________, V. A. Dorr and R. J. Rosen. 1975. A submerged hypolimnetic aerator. Water Resources Research 11(2):287-293.

Mercier, P. and J. Perret. 1949. Aeration station of Lake Bret. Monast-bull., Schweiz, Ver. Gas. u. Wasserfachm 29:25.

Miller, L. W. and A. W. Fast. (in prep.). Effects of artificial destratification on fish depth distribution in El Capitan Reservoir.

Overholtz, W. J. 1974. A method for stocking trout in the hypolimnion of a lake. Prog. Fish Cult. 36(13):175-176.

______________. 1975. An ecological evaluation of hypolimnetic oxygenation by the side stream pumping process at Ottoville Quarry, Ottoville, Ohio. M.S. Thesis. Ohio State University, Columbus, Ohio. 100 pp.

Smith, S. A., D. R. Knauer and T. L. Wirth. 1975. Aeration as a lake management technique. Tech. Bull. 87. Wisc. Dept. Natural Resources, Madison, Wisc., 39 pp.