Vertex Water Features
Lake Aeration Systems & Floating Fountains

Aerators Case Study: Winston Park

Nutrient reduction and oxygen transfer efficiency in a South Florida retention pond using artificial destratification aeration

Amanda Quillen, Ph.D.

Objectives: To determine the amount of oxygen transferred to the lake after startup of aeration system, estimate the efficiency of an aeration system in an actual lake setting, and determine the effects of aeration on water chemistry parameters, including nutrient levels.

Introduction

Various sources have quoted the efficiency of oxygen transfer from the diffuser bubbles to be around 5%, but after observing the flow of water and change in oxygen profiles after turning on aeration systems, it is obvious that the vast majority of oxygen transfer takes place at the water-atmosphere interface. Aeration allows a greater volume of water to come in contact with this interface. In order to estimate the total transfer of oxygen brought about by aeration, I monitored lake oxygen levels through startup of the system. I followed a variety of other water chemistry parameters, including nitrogen and phosphorus levels, to investigate other positive changes in the lake.

Winston Park lake northern border

TURNOVER: refers to the number of times a day an aeration system pumps the total lake water volume from the bottom to the surface. For example, a 0.8 “turnover” means that the volume of water pumped by an aeration system to the surface in 24 hours is equal to 80 percent of the total lake water volume. A 1.0 “turnover” would therefore equal a daily pumping rate of 100 % of the total lake water volume.

Site description

Winston Park is a residential community in subtropical Coconut Creek, Florida. The study lake is a borrow pit and retention pond, surrounded by landscaped lawn and partially by single-family homes. Winston Park Lake is 12.7 acres (5 hectares) and has a maximum depth of 32 feet (10 meters) with an average depth of 19.5 feet (6 meters). The lake experienced massive fish kills every fall due to a reduction in oxygen during fall turnover, so Vertex installed an aeration system consisting of six XL5 AirStations© powered by 3 Brookwood© compressors totaling 2.25 hp which produced 14 CFM of air at 19 PSI. This system is sized to turn the water over in the lake at a rate of 0.8 turnovers per day. In February of 2009 the system was turned off.

By June, the lake had restratified, and oxygen levels were not high enough to sustain fish below a depth of 6 feet (1.8 meters). Oxygen levels were so depleted that despite careful reinstatement of the aeration system, a small fish kill occurred on June 24, 2009, just as the system began running full-time.

Winston Park lake aerial view

Methods

Field

The lake was monitored periodically with more frequent sampling during startup. A sampling location was chosen in the middle of the lake, in between aerators. Samples were taken in approximately the same place each time, as determined by line of sight and GPS. The boat was anchored prior to sampling.

Secchi disc transparency was observed on the shaded side of the boat by lowering and raising the disc to determine the depth at which it was no longer visible.

A YSI 556 multi-probe system was used to record pH, oxidation-reduction potential (ORP), specific conductivity, dissolved oxygen (DO), and temperature at 1 foot intervals from just below the surface to the sediment-water interface.

Water samples were taken first at the surface (at arm's length) then at various depths in the water column using a Van Dorn style water sampler. Samples were initially taken at the surface, thermocline, and 20 feet. Thermocline sampling was abandoned because results were similar to those from the surface, and the thermocline became difficult to define. As samples from 20 feet showed improvement, the need for a sediment interface (approximately 30ft at the sampling site) sample was apparent. Samples were kept on ice and taken back to the lab to be tested for turbidity, apparent color, ammonia nitrogen, orthophosphate, carbon dioxide (CO_2). Tests for Nitrate, TP and TN were added later. On some occasions, additional water was sent to an external laboratory (Genapure Analytical Services, Inc.) for testing biological and chemical oxygen demand (BOD & COD).

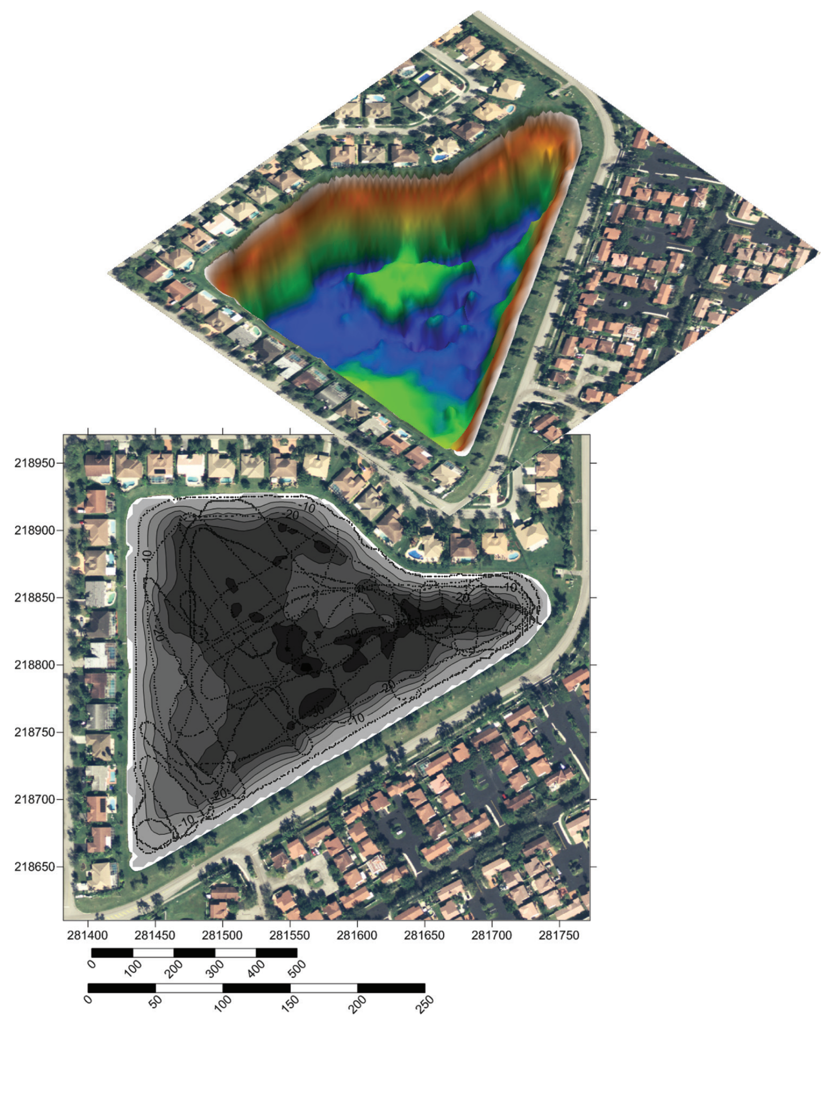
Laboratory

BOD and COD samples were transported to Genapure within 24 hours and analyzed using standard method 5210B and USEPA method 410.4, respectively. Other water chemistry variables were measured within 48 hours of returning to the laboratory. Carbon dioxide (CO2) concentrations were estimated with a Hach field test kit employing a NaOH titration with phenolphthalein indicator. Turbidity was measured with a Hach 2100P turbidimeter.

A Hach DR/2010 spectrophotometer was used for the colorimetric determination of color, nitrogen, and phosphorus levels. Apparent color was determined using Hach method 8025 (Hach, 2000), adapted from Standard Methods for the Examination of Water and Wastewater (Eaton, 2005), an APHA Platinum-Cobalt standard method for water, wastewater, and seawater. Ammonia nitrogen was determined using Hach method 8038 (Hach, 2000), adapted from Standard Methods for the Examination of Water and Wastewater (Eaton, 2005), a USEPA accepted method for wastewater analysis. Orthophosphate (reactive phosphorus) was determined using Hach method 8048 (Hach, 2000), adapted from Standard Methods for the Examination of Water and Wastewater (Eaton, 2005), a procedure equivalent to USEPA method 365.2 and Standard Method 4500-P-E for wastewater. Total phosphorus was determined using Hach method 8190 (Hach, 2000), adapted from Standard Methods for the Examination of Water and Wastewater (Eaton, 2005), a procedure equivalent to USEPA Method 365.2 and Standard Method 4500-P-B, 5 & P-E.

Mapping

In order to accurately estimate lake volume and surface area, a 3-dimensional map was created using GPS and sonar data. A Lowrance HDS5 fishfinder/GPS chartplotter recorded depth and location information on the water while a Magellan Triton 400 handheld GPS was used to collect shoreline data. SonarViewer software was used to convert Lowrance data into xyz points. VantagePoint and GPSBabel software converted Magellan data for use in Excel. Didger software (Golden Software, 2007) was used to line up location information from USGS orthophotos (USGS, 2007) and the two GPS units. Surfer software (Golden Software, 2009) was used to create 3-dimensional surface and contour maps. Volumes and surface area were calculated in Surfer.



Calculations

By combining data from the YSI and Surfer, I calculated the amount of oxygen present in each 1 foot slice of depth on each day of interest. Choosing the time between minimum measured oxygen and recovery, I determined the amount of oxygen transferred to the lake per hour. Dividing this number by the amount of oxygen pumped into the lake gives the efficiency of the system in this lake.

DO (mg/L) * VOLUME (L) = DO (mg)

DO (mg) / HOURS = DO (mg/hour)

Results

Nutrients

The highest orthophosphate levels were observed at the sediment-water interface. These levels were reduced from 0.34 mg/L on July 15, 2009 to 0.01 mg/L on April 7, 2010, a 97% decline. Ammonia levels were also highest in the bottom waters, and were reduced 55% from 0.60 mg/L in July to 0.27 in April. Biological oxygen demand (BOD) improved steadily, decreasing to the background detection limit (2 mg/L) by October 23, 2009. This represents a 60% decline in BOD since the start of the study.

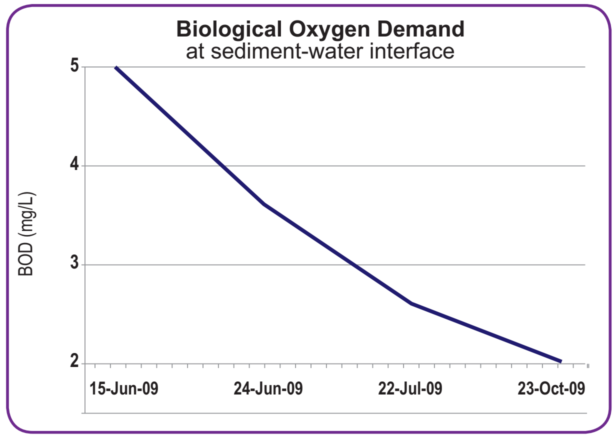
Nutrient reductions may be attributed to the increase in ORP brought about by aeration. It is interesting to note, however, that the ORP in the hypolimnion increased prior to increases in oxygen. The proximate cause of ORP increase is unknown, and warrants further investigation.

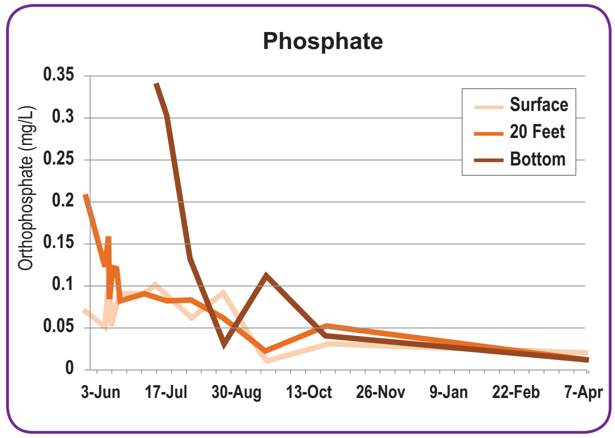
Oxygen transfer

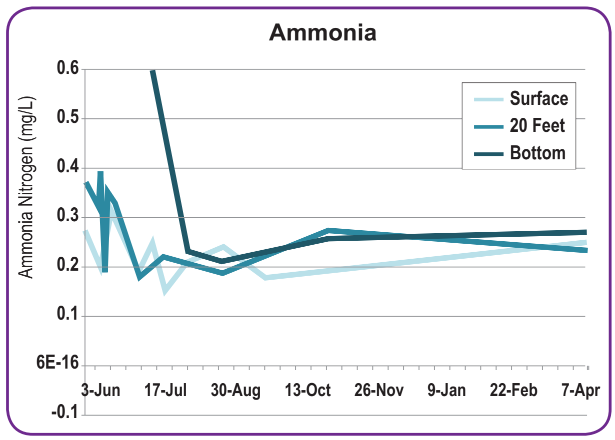
Stratification was most enhanced at the beginning of and during the startup period rather than at the beginning of the sampling period due to hot weather between the June 3 and June 15 sampling dates. Rainy, cloudy, stormy weather leading up to the end of the startup period likely led to more rapid destratification of both temperature and oxygen profiles than may have occurred with aeration alone.

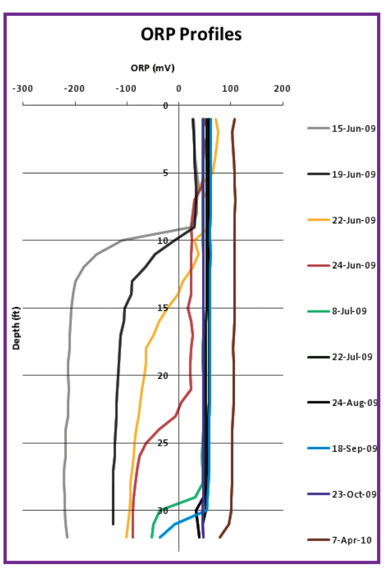
On the morning of June 24, the day after the aerators were turned on full-time, oxygen concentrations averaged only 0.7 mg/L (225 kg of oxygen in the entire lake), with surface values topping out at only 1.75 mg/L. These conditions resulted in a small fish kill involving mostly shad. Conditions likely improved rapidly, as no further fish kills were reported by the residents.

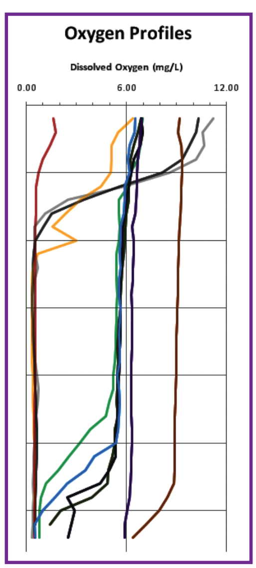
Near complete destratification of temperature was achieved by July 8, after 2 weeks of running the aerators fulltime. At this time, average oxygen levels plateaued at 5.4 mg/L (1682 kg total oxygen). This works out to approximately 4 kg oxygen transferred to the lake per hour (about 0.2 mg/L per day). If calculating efficiency of the system based on this and the amount of oxygen pumped into the lake, you get about 65% of what you pump in.

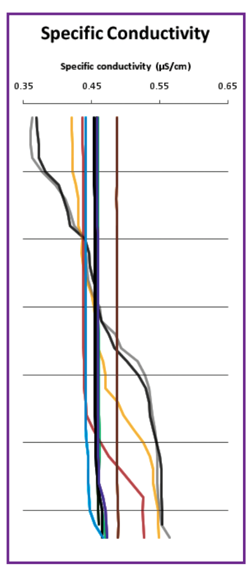


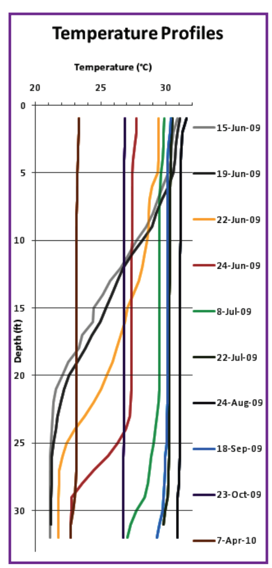


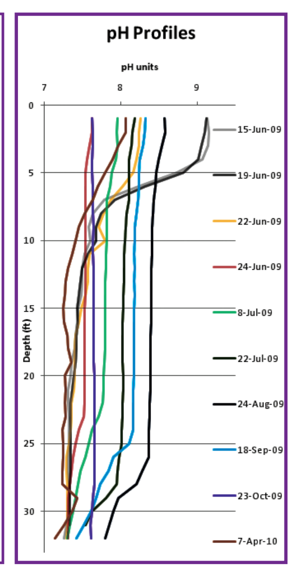












Discussion

Aeration startup considerations

The volume of anoxic water is important to consider when starting up an aeration system. If a lake has already begun to stratify, and bottom waters are anaerobic, hasty startup may result in a fish kill. This results not only from mixing, but also from exposing high nutrient bottom waters to oxygen. The oxygen supply of the surface waters cannot keep up with the oxygen demand of the bottom waters, resulting in oxygen depletion. If installing aeration in a lake or pond that does not have a significant fish population, or if the aerators are installed prior to the onset of summer stratification, careful startup procedures are not as important.

Efficiency estimates

The objective of this study was to estimate aeration efficiency in a “real-world” setting. Lakes are subject to stratification, metabolism, and weather while artificial tanks are not. I know that aeration works with natural variables to change water chemistry, yet most estimates of efficiency are done in as sterile of an environment as possible.

There are some caveats to the in situ method of estimating oxygen transfer rates and efficiency. Natural systems always have many unknown or incalculable variables that complicate these sorts of estimates. The effects of respiration and photosynthesis on oxygen levels are not considered, and lakes with a higher oxygen demand will not be as efficient. Depth and turnover rate will also affect efficiency. Deeper diffusers result in more water movement. The biggest effect on oxygen transfer will be the number of turnovers you get per day. The more turnovers, the more contact the water has with the atmosphere, which is where most of the oxygen transfer takes place. This study illustrates the need for a turnover rate greater than 0.8 to provide complete water column oxygenation so as to derive the subsequent benefits of decreased nitrogen and phosphorus levels and other water quality advantages. Vertex therefore recommends aeration system designs providing a minimum of 1.0 turnover per day.

Works Cited

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