Spring 2010

Relatin Dissolved Oxygen Concentration to Fish Distribution in Jarecki Lake

Adam Sutton
University of Nebraska at Lincoln

Disclaimer: The following thesis was produced in the Environmental Studies Program as a student senior capstone project.

Relating Dissolved Oxygen Concentration to Fish Distribution in Jarecki Lake

by

Adam Sutton

An Undergraduate Thesis

Presented to the Faculty of
The Environmental Studies Program at the University of Nebraska-Lincoln
In Partial Fulfillment of Requirements
For the Degree of Bachelor of Science

Major: Environmental Studies
With Emphasis of: Natural Resources

Under the Supervision of Tadd Barrow

Lincoln, NE

May, 2010

Abstract

Water temperature and dissolved oxygen (DO) profiles were measured once every month from mid July to mid February in a relatively deep sand-pit lake in southeast Nebraska. These profiles showed depleted DO concentrations below the thermocline during summer stratification indicating areas fish will likely avoid in summer months. Colder temperatures in fall caused complete mixing of the water column allowing fish to inhabit all depths of the lake. An inverse temperature stratification occurred directly below the ice during winter months as ice cover cooled the surface water to below 4 degrees Celsius. Ice cover also blocked air – water oxygen transfer and reduced light for photosynthesizing algae. Associated with winter ice cover, DO concentrations in the hypolimnion decreased significantly, once again reducing available fish habitat. It is likely anglers will have a higher success rate catching fishing in water above 6 meters (m) (~20 feet) in a eutrophic sandpit lake during hot summer months and below ice cover in winter. Fish can utilize all depths of the lake during fall turnover and could theoretically be caught by anglers anywhere in the lake.

Table of Contents

Acknowledgments

I would first like to thank Tadd Barrow, Water Quality Specialist at the School of Natural Resources, for taking the time to be my thesis advisor. He has provided loads of guidance to help make this thesis possible. Thank you to Sara Yendra for providing encouragement as well as taking on the task of thesis reader. I would also like to thank Scott Jarecki, Tim Sutton, and Princess Baeza for their physical contributions in the field. Positioning the boat, collecting and recording data would have been tedious without them.

Introduction

Fishing is one of the oldest and most practiced activities in the world. Whether for profit, relaxation, socializing, or recreation, fishing is enjoyed by people everywhere. According to U.S. Fish and Wildlife Services, in 2006, 169,000 Nebraska residents purchased fishing permits (U.S. Census Bureau). For some, catching a fish is not necessary to enjoy a good fishing trip, but few would argue with the fact that catching a fish definitely enhances a fishing trip (Pretty et al 2005). In spite of this, there are many factors that affect fishing success. What bait to use, often followed by where the fish are located in a particular lake, are they at depth or near the surface? What about fish's ability to relate to structure (depth changes, drop-offs, points, etc) as well as cover (submerged or emergent brushpiles, macrophytes (weed beds), docks, etc. One factor often overlooked by the casual angler is dissolved oxygen concentrations within the water column. . Lake productivity is widely variable, increased productivity within the system can lead to rapid depletion of dissolved oxygen (Kodama et al 2010). Fish cannot survive without enough dissolved oxygen (Bauer and Schlott 2006). "Among the environmental factors limiting the survival and growth of fish, temperature and DO concentrations are considered the two most significant" (Stefan et al 1996). In this study, water temperature and dissolved oxygen concentrations will be monitored throughout the water column to determine how much of the lake is inhabitable to fish during different times of the year.

Jarecki Lake is a sand bottom lake formed by a gravel mining operation in the early 1960's. It is located 45 meters south of the Platte River near Columbus, Nebraska. The lake has seen home development over the last 15 years with 38 lots and cabins surrounding it, half of which are occupied year round. Many different fish species have been caught or noticed in Jarecki Lake. Sometime in the past, the Platte River is believed to have flooded allowing whatever fish inhabited the river to immigrate into the lake. Fish species caught over the last 15 years include largemouth bass, smallmouth bass, white bass, wipers (white bass / striped bass hybrid), channel and flathead catfish, drum, bullhead, bluegill, green sunfish, black crappie, common carp, bigmouth buffalo, river carpsucker, redhorse, gizzard shad, shortnose and longnose gar, northern pike, walleye, and sauger. In 1995 a 6 foot long paddle fish was found dead along the north shore of the lake. However, the most common fish species in the lake are largemouth bass, white bass, bluegill, black crappie, common carp, channel catfish, and gizzard shad. Like all animals that use aerobic respiration, fish need oxygen to survive. It is understood that most fish need a minimum of 3 milligrams per liter of dissolved oxygen to survive (Holz and Hoagland 1999). When dissolved oxygen concentrations drop below 3 mg/L, even common carp, which are known to be extremely hardy fish, "…stop feeding and search for better oxygenated water" (Bauer and Schlott 2006). Other studies have shown nearly all fish avoid DO concentrations below 4 mg/L (McDermot and Rose 2000).

During the summer months, typically May through mid October, thermal stratification occurs throughout the water column (Stefan et al. 1996). The surface depths of the lake, first few meters (epilimnion) heat up until they reach a depth known as the thermocline or (metalimnion).

This is where the temperature changes most rapidly with depth more so than it does in the epilimnion or the hypolimnion (bottom depths of the water column) (see Figure 1). Atmospheric events such as wind and rain cause water in the epilimnion to mix regularly. However, below the thermocline the water is much cooler and as a result of its density, does not mix with the epilimnion (Smith and Bella 1973). During periods of thermal stratification dissolved oxygen levels are usually greatest near the surface then drop with increasing depth. Algae in lakes provide the most dissolved oxygen near the surface during photosynthesis. The dissolved oxygen is then used up by other organisms like zooplankton, fish, and bacteria during respiration and organic matter degradation (D'Autilia et al. 2004).

Jarecki Lake has a mean depth of 7.5 meters (m), (about 25 feet), and a maximum depth of 14.6 m, (about 48 feet). Some of the lake's residents theorize bigger fish are at the bottom in the deeper parts of the lake; > 11.5 m. In a similar Nebraska sandpit lake, Holz and Hoagland (1999) discovered dissolved oxygen concentrations dropped below 3 mg/L after 4.5 m. This leads me to believe there is not enough dissolved oxygen in the deeper parts of the lake during the summer months for fish to survive. Even though the lake is 14.6 meters deep, I predict most, if not all fish in Jarecki Lake are limited to the top 4.5 meters during the warm summer months. With cooling water temperatures in the fall and winter, I believe / hypothesize fish will be able to live at all depths of the lake, including 14.6 m.

With this study we hope to gain a better understanding of what is going on below the surface of Jarecki Lake at different times of the year by relating dissolved oxygen concentrations to accessible fish habitat. This knowledge could then be applied to other lakes and potentially increase fishing success. Possible limitations of the study may include faulty readings from the

Hydrolab or fish finder and data collection when the lake ice is too thin to walk on, yet too thick to break through with a boat.

Materials and Methods

Beginning July 12, 2009, water temperature and dissolved oxygen concentrations at different depths of the lake were recorded once per month through February 13, 2010, using Hydrolab equipment borrowed from the University of Nebraska-Lincoln. An electronic depth / fish finder was used to estimate the concentration of fish at various depths throughout the water column and to confirm the depth of the data collection site.

Before sampling, air temperature, time of day, cloud cover, and relative wind speed were recorded. In order to test whether dissolved oxygen concentrations were high enough to sustain fish life in the deepest parts of Jarecki Lake, the deepest areas of the lake were located. The deepest spot in Jarecki Lake of 14.5m (roughly 48 feet), was a small area at which we had a difficult time positioning the boat over the top long enough to collect adequate data. However, we did find a larger area of the lake that was consistently 11.5 m deep or (38 feet). An Eagle (Ultra Classic edition) electronic depth / fish finder was used to find depths at various sites in the lake and also determine at what depths the majority of fish were suspended. At this locale, a digital HYDROLAB MiniSonde 4a Water Quality Multiprobe was used to retrieve data at different depths until reaching the bottom of the lake. Beginning at the surface and stopping every one half meter, the probe was lowered to the desired depth and slightly bobbed until the temperature and dissolved oxygen data stabilized. Recording water temperature and dissolved oxygen concentration data from every 0.5 m allowed us to trace rapid changes throughout the water column. Fish assemblage was also noted throughout the water column.

To acquire a better understanding of oxygen concentrations throughout Jarecki Lake, we collected temperature and DO data at 5 different sites (Figure 2). Site 1 is located along the north shore of the lake. Site 2 is the deepest spot (11.5 m) and is located roughly in the middle of the lake. Site 3 is on the northeast corner, site 4 is on the south shore, and site 5 is located on the south west shore of the lake. Site 2 will provide the primary data used to analyze water temperature and dissolved oxygen concentrations throughout the water column in this study. After analyzing results from all locations, temperature and DO concentrations were found to be relatively uniform horizontally (Smith and Bella 1973) (see Figure 3). Depth data from every site were used to assess the amount of usable fish habitat based on results acquired from site 2.

These research methods were repeated once in the middle of every month beginning in July 12, 2009 and ending February 13, 2010 which covered the climatic extremes (Celik 2002). The temperature and dissolved oxygen results throughout the water column were compared to similar research taken from different lakes around the world.

Results

Spatiotemporal patterns of dissolved oxygen and temperature during summer stratification

In the summer heat of July and August, the epilimnion warmed significantly while the hypolimnion was cold and motionless. July water temperatures ranged from 27.23 °C one half meter below the surface to 8.78 °C on the bottom at 11.5 m, a difference of 18.45 °C. Near the surface, DO concentrations reached 13.83 mg/L but decreased to 0.33 mg/L at the bottom of the lake (Figure 4). In August, surface temperatures reached 26.55 °C and dropped to 9.30 °C along the bottom (Figure 5). Dissolved Oxygen concentrations maxed out at 11.41 mg/L at the surface and decreased to 0.55 mg/L in the hypolimnion. During both months, water temperature decreased at a relatively steady pace until reaching the thermocline. Thermocline depth averaged around 6 meters (Figures 4 and 5), where water temperature decreases most rapidly with depth (Smith and Bella 1973). It was noted that the fish / depth finder reported the majority of fish suspended roughly between 2 and 6 meters.

Spatiotemporal patterns of dissolved oxygen during Fall Turnover

Beginning in October, water temperatures were relatively constant from the surface to the bottom of the lake ranging from 10.75 °C to 9.39 °C, a difference of 1.36°C. Dissolved Oxygen ranged from 9.14 mg/L near the surface to 7.30 mg/L, a difference of 1.84 mg/L throughout the water column (Figure 7). The depth / fish finder confirmed fish at all depths of the water column. November profiles continued to show isothermic conditions. Temperatures from the lake surface to the bottom only varied 0.15 °C ranging from 9.09 °C to 8.94 °C. Dissolved Oxygen concentrations only varied 1.09 mg/L throughout the water column varying from 8.75 mg/L to 7.66 mg/L (Figure 8).

Spatiotemporal patterns of dissolved oxygen during Winter with ice-cover

Through January and February, a thick layer of ice covered Jarecki Lake. January ice cover was 28 cm (roughly 11 inches). A temperature of 3.31°C was recorded near the lake surface. At 11.5 meters, the water temperature was 4.20 °C. Dissolved oxygen levels ranged from 10.45 mg/L at 0.5 m down to 1.26 mg/L near the bottom at 11.5 m (Figure 9). February showed a similar trend. Colder water of 2.60 °C was found directly below the ice at 0.5 meters and warmed significantly to 5.12 °C near the bottom. At 0.5 m, the DO concentration was 18.47 mg/L but fell to 0.03 mg/L by 11.5 m (Figure 10). The electronic fish finder did not show any fish during this time.

Discussion and Conclusion

Two representative months were displayed for each of the three seasons data was collected to sufficiently explain each of the seasonal changes including the climatic extremes for this study (Celik 2002). September data was omitted because of its similarity to July and August. December was also omitted due to lack of data for safety reasons. Ice cover was patchy on the surface of the lake with 5 cm (2 inches) of ice in some areas, 13 cm (5 inches) in others and open water near site 2.

Summer 2009 - July and August

In Jarecki Lake, July and August water temperatures averaged 26.89 °C one half meter below the surface to 9.04 °C on the bottom creating a density gradient. The differences in water densities did not allow mixing which inevitably led to summer stratification of the water column (Ellis et al 1991). Near the surface, DO concentrations reached a maximum of 13.83 mg/L. According to the U. S. Environmental Protection Agency, 27 °C water can hold 7.95 mg/L of DO before becoming saturated. High concentrations of dissolved oxygen that exceeded saturation near the surface are likely the byproduct of photosynthesizing algae (Smith and Bella 1973). Water temperature decreased at a relatively steady pace until reaching the thermocline. Thermocline depth averaged around 6 meters for both months, where water temperature decreases most rapidly with depth (Smith and Bella 1973). The degradation of dead algae and other organic matter in the hypolimnion caused the dissolved oxygen to be depleted near the bottom of the lake (Breitburg et al. 1997). Dissolved oxygen concentrations near or below the threshold for fish, 3 mg/L, directly corresponded with the depth of the thermocline (Araoye 2009).

The lack of fish displayed on the fish finder below the thermocline agrees with other research suggesting fish avoid depths where DO concentrations fall below 3 mg/L (Holz and

Hoagland 1996). Occasional fish displayed below depths of 6 m were probably the result of the electronic fish finder mistaking underwater structure (ie. trees or branches) for fish. There is also a possibility of fish living near underground springs or groundwater seeps since Jarecki Lake is groundwater fed. It is also possible fish occasionally dive into less oxygenated water for a food source or predator avoidance. In conclusion, depths below 6 m should typically be avoided by anglers fishing in relatively deep productive sand-pit lakes during summer months.

Fall 2009 – October and November

By October and November, air temperatures cooled the epilimnion causing the colder denser water to sink to depths of equal density (Smith and Bella 1973). As the surface water sinks, bottom water rises and is replaced by the more oxygenated surface water resulting in a complete mixing of the lake (Gammons et al 2009). Water temperatures varied throughout the water column an average of 0.78 °C for both months suggesting isothermic conditions with very small density differences. Wind, rain, or other disturbances at the lake surface were sufficient to cause mixing. With DO concentrations remaining above 7 mg/L at all depths, fish can inhabit every part of the lake. This could explain why fewer fish were displayed on the electronic fish finder at any given time.

Fish were sporadically distributed throughout the entire water column during the fall season. Theoretically, fish could be caught at any depth at this time. However, with more available habitat, finding and catching fish may be harder during October and November in relatively deep eutrophic sand-pit lakes.

Winter 2010 – January and February

Ice cover grew roughly 10 cm (4 inches) between January and February. January ice was 28 cm (~11 inches) and February ice was 38 cm (~15 inches). There was a temperature inversion near 4 °C where water below 4 degrees becomes less dense. Water is typically most dense at 4 °C and sinks to the bottom of the lake with warmer water being less dense. However, water temperature increased near the bottom, probably an influence of the water table below the lake. Cold water holds more DO thus the high levels near the surface next to the ice. This is largely evident at the .5 meter reading in February where the Hydrolab probe was only 12 cm (~4.5 inches) below the ice. The small increase of DO around 3 m in January is likely due to an algal colony hovering around that depth producing oxygen. Dissolved Oxygen dropped below 3 mg/L at a depth of about 9 m in January and 8.3 m in February limiting the available fish habitat. The fact no fish were seen at this time on the fish / depth finder could indicate there were no fish in the area at this time. The transducer for the fish /depth finder was localized at the hole in the ice above site 2 meaning fish would have to swim almost directly beneath it. Fish are also known to be sluggish when water temperatures are cold helping support the reason for not seeing fish on the fish finder.

This knowledge could be applied to other lakes with similar productivity and depth characteristics. The internet is a great source to find contour maps of some of the more popular public fishing areas in the United States. Knowing water temperature and dissolved oxygen concentrations related to depth could improve fishing success.

Figures and Graphs

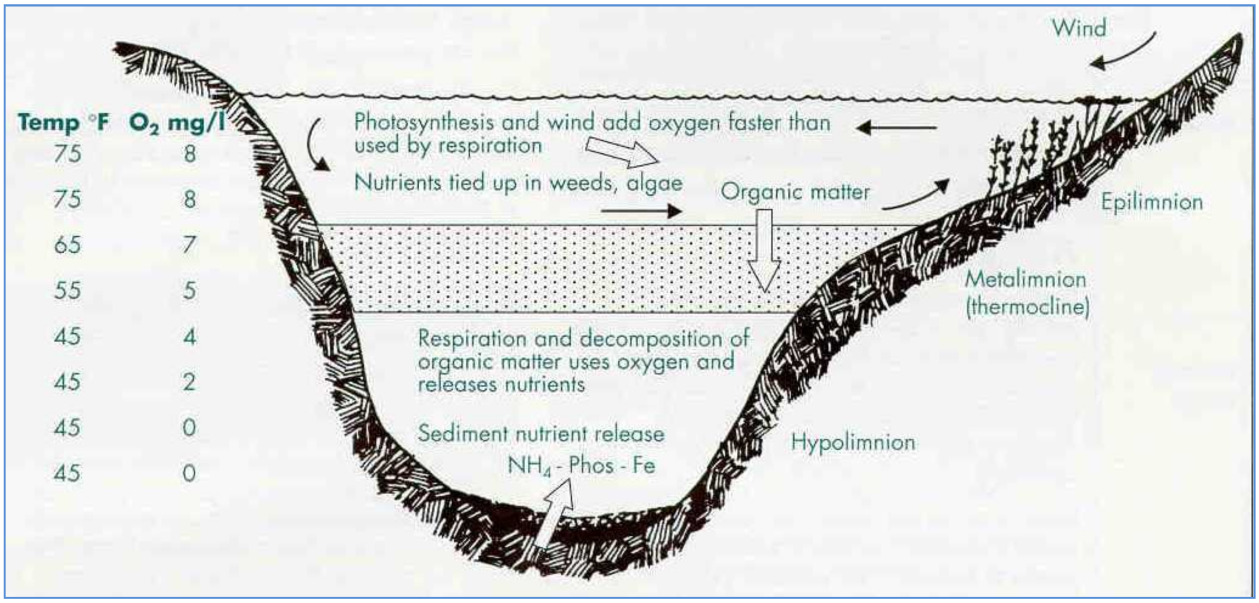

Figure 1: Typical summer stratification, provided by (Wisconsin Department of Natural Resources 2009)

Figure 2: Arial photo of Jarecki Lake data collection sites with primary site circled in blue. Provided by (Google Earth 2009).

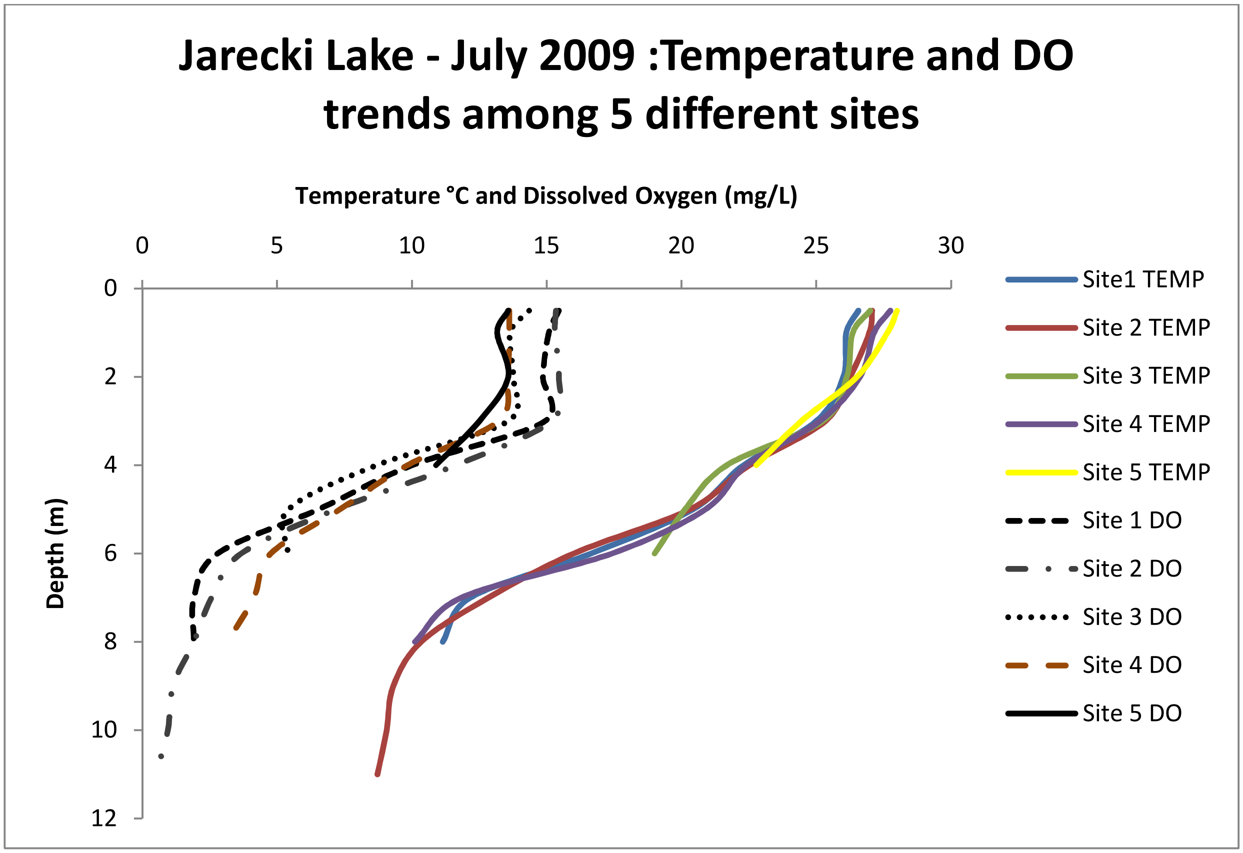

Figure 3: Temperature and DO throughout the water column at 5 different locations around the lake.

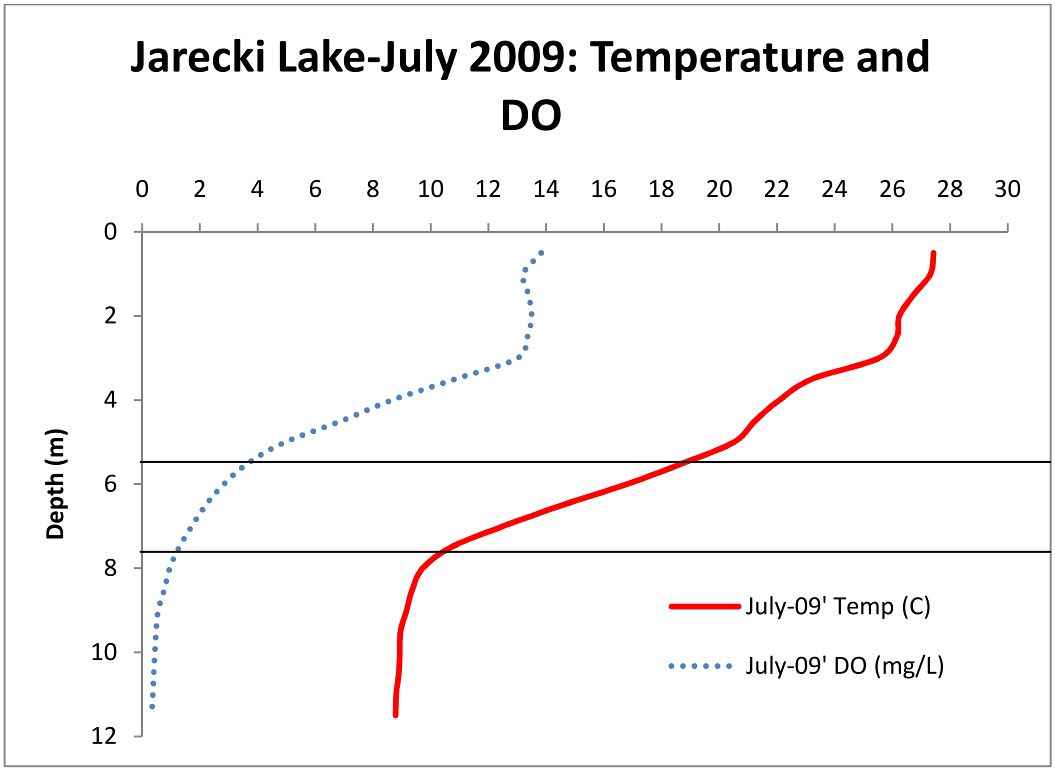

Figure 4: Temperature and DO concentrations showing stratification throughout the water column; warm temperatures and high DO concentrations in the epilimnion (0 – 5.5m), rapidly declining temperatures at the thermocline (5.5 – 7.5m), and steady cold temperatures in the hypolimnion (7.5 – 11.5m).

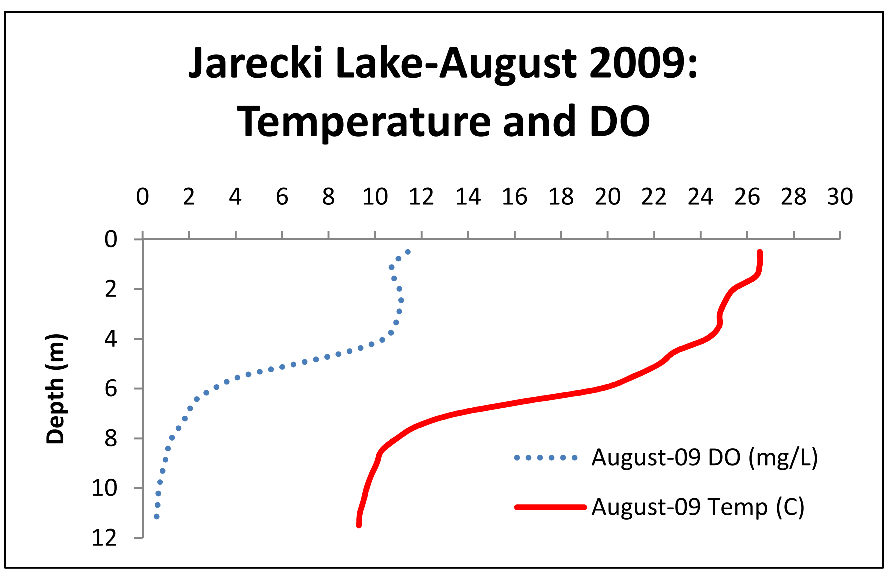

Figure 5: Temperature and DO concentrations showing summer stratification throughout the water column.

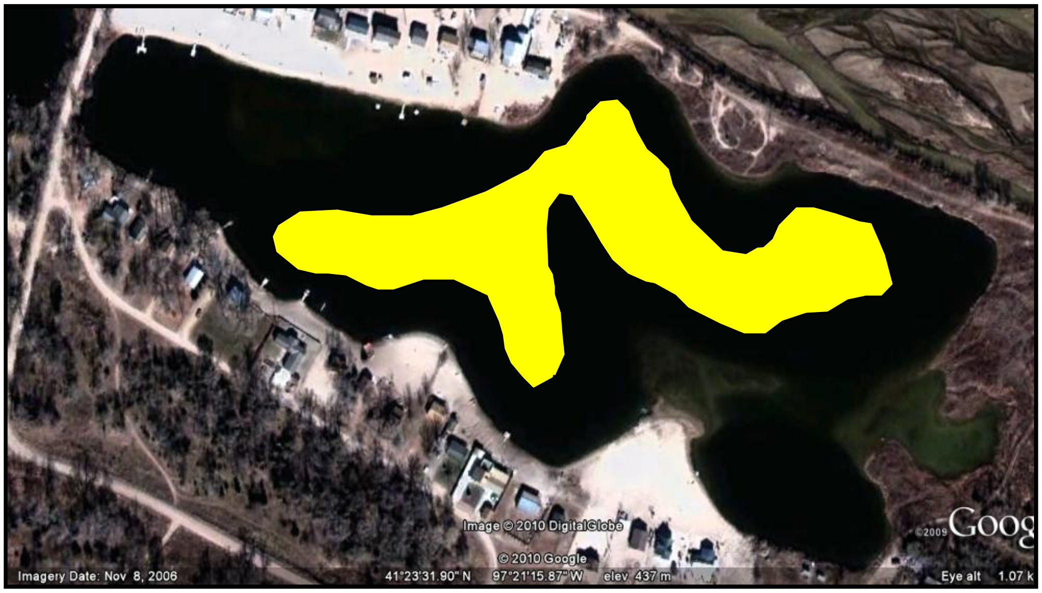

Figure 6: Yellow area denotes maximum depths of at least 6 meters where DO concentrations approach 3 mg/L.

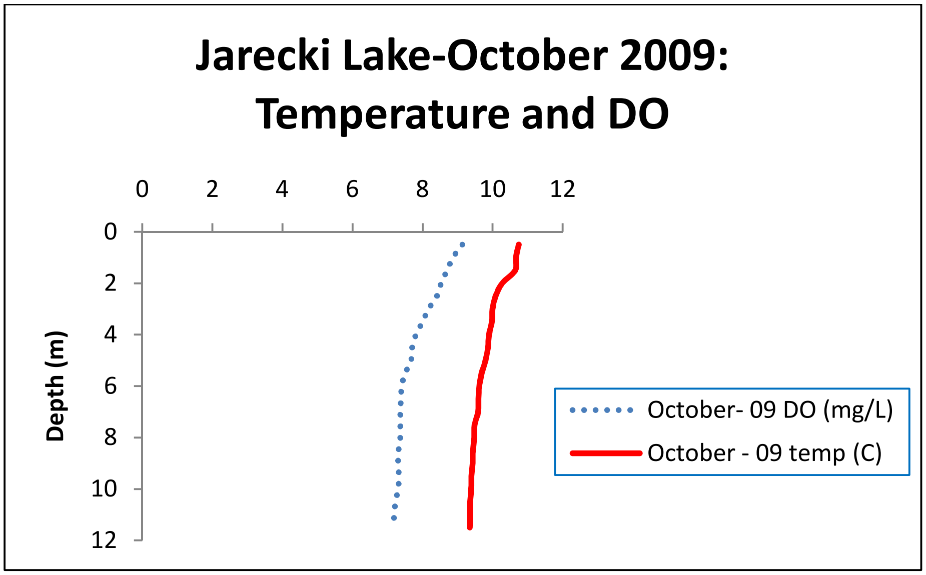

Figure 7: Temperature and DO concentrations showing complete mixing of the water column during Fall turnover.

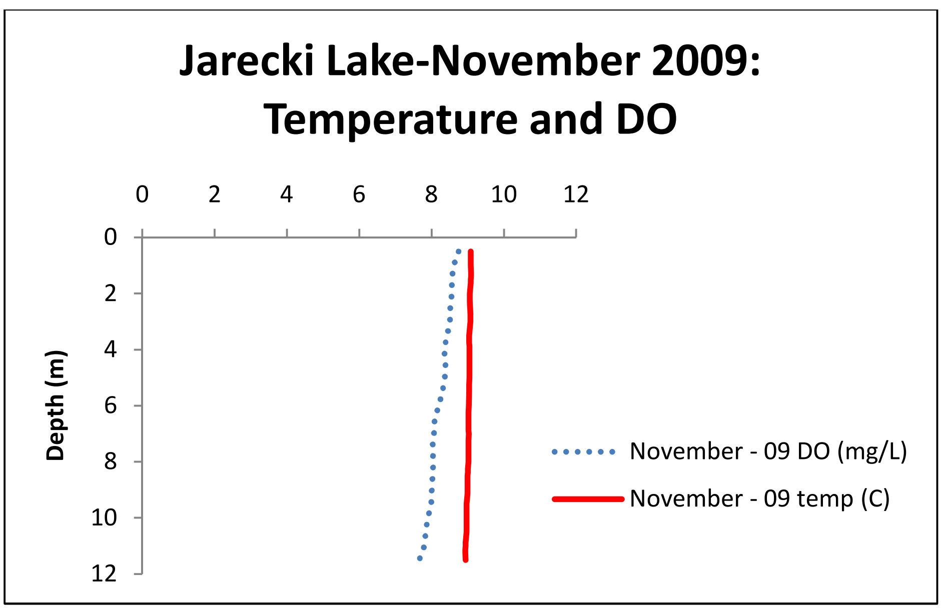

Figure 8: Temperature and DO concentrations showing isothermic conditions from complete mixing of the water column during fall turnover.

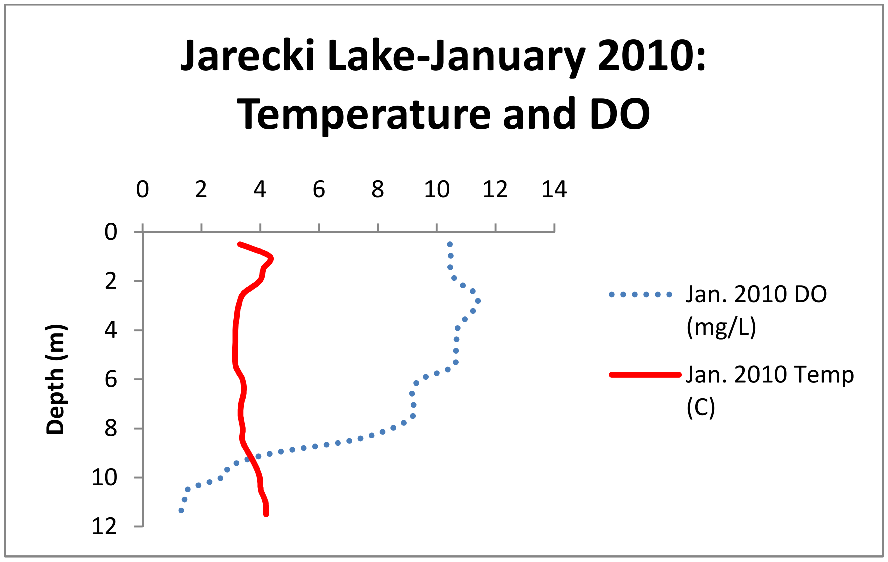

Figure 9: Temperature and DO concentrations beneath 28 cm (roughly 11 inches) of ice.

.

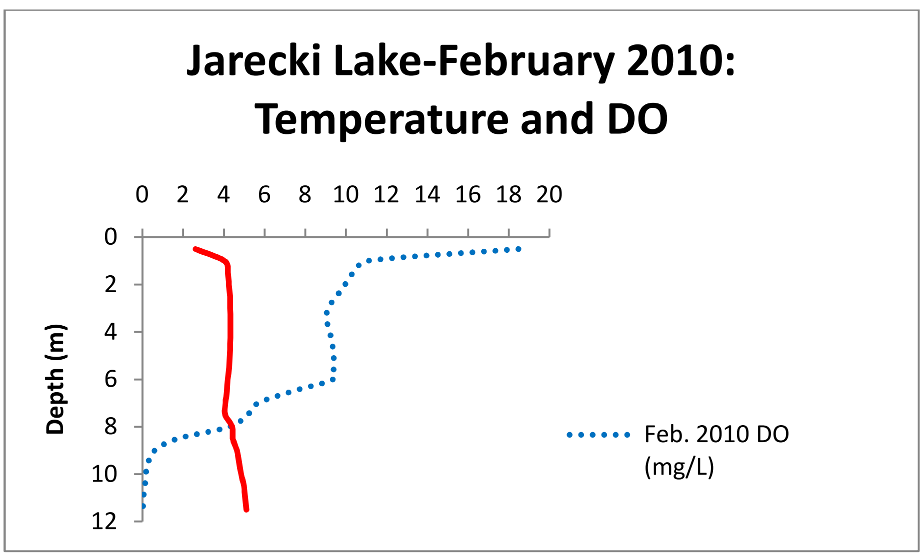

Figure 10: Temperature and DO concentrations beneath 38 cm or 15 inches of ice.

Literature Cited

Bauer, C. and G. Schlott. "*Reaction of Common Carp (Cyprinus carpio, L.) To Oxygen deficiency In Winter as an Example for the Suitability of Radio Telemetry For Monitoring the Reaction of Fish To Stress Factors In Pond Aquaculture". Aquaculture Research* (2006) **37**: 248-254. *Blackwell Publishing*. Web. 24 Sep. 2009

Breitburg, D.L., T. Loher, C. A. Pacey, and A. Gerstein. *"Varying Effects of Low Dissolved Oxygen on Trophic Interactions in an Estuarine Food Web." Ecological Monographs* (1997) **67**: 489 – 507. *JSTOR.* Web. 27 Mar. 2010.

Celik, K. *"Community Structure of Macrobenthos of a Southeast Texas Sand-Pit Lake Related to Water Temperatue, pH, and Dissolved Oxygen Concentration." Turk J Zool* (2002) **26**: 333 – 339. *Tubitak.* Web. 24 Mar. 2010.

D'Autilia, R., M. Falcucci, V. Hull, and L. Parrella. *"Short Time Dissolved Oxygen Dynamics In Shallow Water Ecosystems." Ecological Modelling* (2004) **179**: 297-306. *Science Direct*. Web. 23 Sep. 2009.

Gammons, C. H., L.N., Harris, J.M. Castro, P.A. Cott, , and B.W. Hanna, 2009. *Creating lakes from open pit mines: processes and considerations - with emphasis on northern environments*. Can. Tech. Rep. Fish. Aquat. Sci. 2826: ix + 106 p. JSTOR. Web. 28. Sep. 2009.

Holz, J.C. and K. D. Hoagland. *"Effects of Phosphorus Reduction on Water Quality: Comparison of Alum-Treated and Untreated Portions of a Hypereutrophic Lake." Journal of Lake and Reservoir management*. (1999) 15: 70-82.

Kodama, K., M. Oyama, G. Kume, S. Serizawa, H. Shiraishi, Y. Shibata, M. Shimizu, and T. Horiguchi. *"Impaired Megabenthic Community Structure Caused by Summer hypoxia in a Eutrophic Coastal Bay". Ecotoxicology* (2010)

19: 479-492. *Springer.* Web. 15 Feb. 2010.

McDermot, D. and K. A. Rose. *"An Individual-Based Model of Lake Fish Communities: application to piscivore stocking in Lake Mendota". Ecological Modeling* (2000) **125**: 67 – 102. *Elsevier Science.* Web. 28 Sep. 2009.

Pretty, J., M. Griffin, J. Peacock, R. Hine, M. Sellens, and N. South. *"A Countryside for Health and Well-Being: The Physical and Mental Health Benefits of Green Exercise." Report for the Countryside Recreation Network.* (2005). Retrieved March 31, 2010 from http://kc.csip.org.uk/upload/CRN%20Report%20FINAL%20Feb17.pdf

Smith, S. A., and D. A. Bella. "*Dissolved Oxygen and Temperature in a Stratified Lake". Journal (Water Pollution Control Federation)* (1973) **45**: 119 – 133. *JSTOR*. Web. 28 Sep. 2009.

Stefan, H.G., M. Hondzo, X. Fang, J. G. Eaton, and J. H. McCormick. *"Simulated Long-Term Temperature and Dissolved Oxygen Characteristics of Lakes in the North-Central United States and Associated Fish Habitat Limits.*" *Limnology and Oceanography* (1996) **41**: 1124-1135. *JSTOR.* Web. 28 Sep. 2009.

U.S. Census Bureau. 2006 National Survey of Fishing, Hunting, and Wildlife Associated Recreation (FHWAR). Retrieved November 3, 2009 from http://www.census.gov/prod/2008pubs/fhw06-ne.pdf

U.S. Environmental Protection Agency. Monitoring and Assessing Water Quality. Retrieved February 15, 2010 from http://www.epa.gov/volunteer/stream/vms52.html

Wisconsin Department of Natural Resources. "Oxygen – Understanding Lake Data" Retrieved December 3, 2009 from http://www.dnr.state.wi.us/lakes/publications/under/f9.jpg