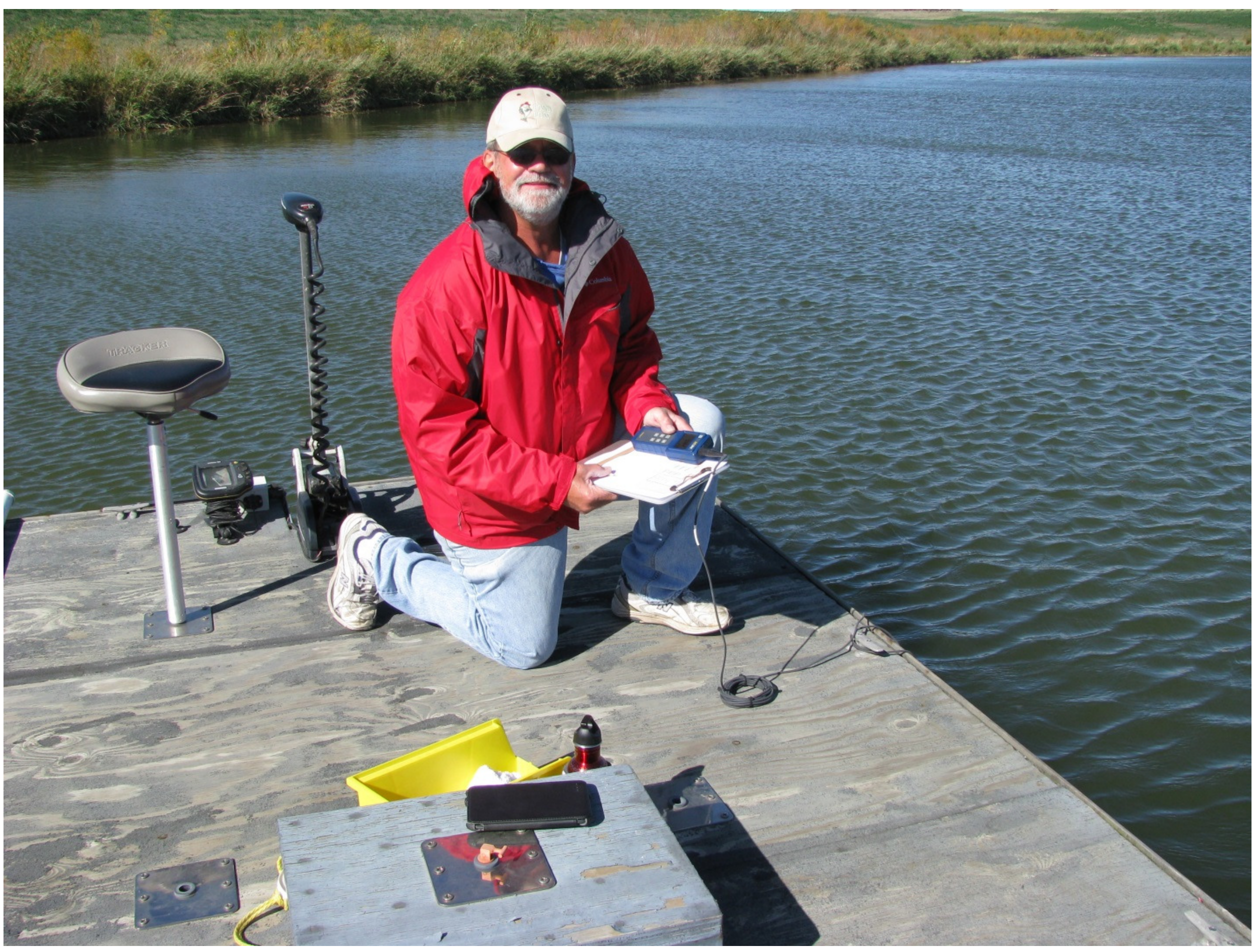
On Northern Pond

Seasonal Changes in Water Temperature and Oxygen in Northern Ponds

By Bradley Smith, Jason Augspurger, Riley Schubert, Dave Willis, and Brian Graeb

Editor's Note: *To honor Dr. David Willis since his passing, we've gone through our archives and shared some of his best articles. It's time to make a transition into new topics of interest. When Dr. Willis died, his students were working on a number of stories for Pond Boss, based on applied research. Fisheries professor Dr. Brian Graeb worked under Dr. Willis, assisting these efforts. Starting this issue, we're returning to SDSU to assist this column. To start, we have an article about data collected by long time Pond Boss subscriber, Dwight Bremer, on his Minnesota pond. This study was coordinated by Dr. Willis, with Dr. Graeb and several SDSU students at the time. There are several more articles which were in the works at the time of Dr. Willis' passing, so look forward to the next issues, as we'll publish those which fit our audience.*

Meet Dwight Bremer. He seems like a normal guy, doesn't he? Some of you may know him from the *Pond Boss* Forum, or even a *Pond Boss* Expo and Conference. Well, he's certainly not typical. Once per week for several years he has been out at his Minnesota pond measuring dissolved oxygen (DO) and water temperature from the pond bottom to surface waters with his trusty DO meter. That's summer or winter, warm or cold, windy or calm, rain or shine, during snowfall, through the ice! He's an iron man!



Dwight Bremer on his barge at his Minnesota pond. Note the hand-held meter that measures both water temperature and dissolved oxygen from pond bottom to the surface. Note also his Pond Boss cap!

What has resulted from all this hard work has been a truly amazing dataset that has been used to help educate fisheries students at South Dakota State University in Dr. Brian Graeb's advanced fisheries management class. Long-term data sets like this one are unusually rare so they provide a great learning opportunity for students of biology and fisheries science. As students, we were excited to have access to so much information and we hope to do it justice through our examination. So, what have we learned from all of Dwight's hard work and patient data collection? Well, before we get into the details let's begin by describing the pond that we shall hereafter refer to as Bremer Pond.

Bremer Pond is located in southwestern Minnesota and is five acres in size with an average depth of about 10 feet with the deepest spot about 15 feet. The pond was formed through excavation of gravel over several years. Moderate groundwater flow-through occurs year-round. A temporary channel (now closed) to a nearby river allowed fish to colonize and become established. Included in this fish assemblage are northern pike, largemouth bass, bluegill, black and white crappies, yellow perch, common carp and black bullhead. Erosion of topsoil from berms surrounding the pond during construction provided nutrients to support plant life in this otherwise poor productivity gravel pit. Dwight has installed a surface water circulator to keep ice off his barge during winter and it likely has no effect on overall circulation of water within the pond as mentioned in a previous *Pond Boss* article from September/October 2009. Overall, Bremer Pond is a pretty typical pond, set in a landscape that can be quite unforgiving.

Northern ponds are harsh environments, warm in the summer and frozen over during the winter and, as a result, temperature and dissolved oxygen levels are constantly in a state of change. During summer in northern ponds we would expect (at least in deeper ponds) to see the warmest water near the surface and the coolest water at the bottom with a sharp transition between the two somewhere in the middle of the water column. We call this situation *stratification* and it generally only lasts for a short few months during summer and during the winter under the ice in the North Country. Moving into fall, as the air temperature gets colder ponds slowly begin to cool. Cooling begins at the surface and once water temperatures reach about 39 degrees, F (the point at which water is most dense) the surface water will begin to sink, allowing thorough mixing of the water column. This process is called *turnover* and interestingly we see it in both fall and spring in northern waters. We would expect to see water temperatures continue to cool through the fall until eventually, the inevitable happens. Ice forms and covers the pond beginning in December and lasts through April in some years! Under the ice, change is still underway but now we would expect the coldest water to be at the surface just under the ice and the warmest water at the bottom of the pond, exactly the opposite of what we expect to see during summer! This condition should last until the Earth begins to tilt in favor of the northern hemisphere again and sunlight can begin to beat back the ice. The same process of mixing which happens in fall should also happen in spring as surface waters warm to 39 F and again mix the pond water. However, as summer grows nearer we should see water temperatures begin to separate by depth, with warmer water near the surface and cooler water near the bottom. Strongly related to temperature and of equal importance for fish in Bremer Pond we will next need to consider what should happen to DO through the seasons.

Dissolved oxygen levels are especially important to understand in northern waters because we tend to lose much of it under winter ice and particularly near the bottom. Depletion of DO under ice can lead to disastrous consequences for the fish community in the form of winterkill, particularly in long cold winters. So, what do we expect to see from Dwight's DO data? Well, because DO is strongly related to temperature with warm water capable of holding much less DO than cold water, we should see DO levels decline as the water warms up in late spring and through the summer. With the approach of autumn we should see as water temperatures drop, DO levels should steadily increase throughout the whole pond until ice forms and blocks direct input of oxygen from the air into the water. At that point, we expect to see DO levels steadily decline and most notably at the bottom of the pond where microorganisms will increasingly consume much of it. Because Bremer Pond is formed from a gravel pit and moderately deep (about 15 at the deepest) we would not expect DO levels to drop low enough to cause a problem for the fish. At ice off in spring, the water mixes and we expect DO levels to increase steadily until the water warms up in late spring and into summer.

Fortunately for us Dwight also measured water clarity and ice depth on Bremer Pond. Trends for both clarity and ice depth are difficult to predict but clarity in particular can be highly variable throughout a season for many reasons. Water clarity can change rapidly due to spring/fall turnover, booms in algae or zooplankton populations, or wind-driven mixing of the pond. Ice depth varies substantially depending on winter severity and the amount of snow insulating the ice. We would be hard-pressed to predict patterns in clarity or ice depth from year to year but they can still provide insight into what is happening in Bremer Pond.

So how did our expectations stand up to what actually happened in Bremer Pond? Well, thankfully our understanding of northern ponds served us well and our predictions were pretty accurate! The figure below (Figure 1) shows temperature and DO data plotted against time for the whole time period that Dwight sampled Bremer Pond. What we can easily observe is the seasonal ebb and flow of temperature and DO levels with warm water holding less DO in the summer and cold water holding much more until ice cover developed. At that point snow and ice drastically reduced light penetration into the water reducing photosynthesis and blocked gas exchange between the water and air. You can observe that in each winter the bottom DO levels plummet as the winter progresses. Also notice the difference between the long cold winter of 2010/2011 with its large decline in bottom DO in contrast with the mild winter of 2011/ 2012 with a less noticeable decline. However, there was never a large enough drop in winter DO levels to cause winterkill, even in the harshest winters recorded at Bremer Pond.

From this dataset we can also see when summer stratification and spring/fall turnovers occurred. Look at temperature data from the months of July/August in each year and observe how the top of the pond became much warmer than the bottom. This is when the pond stratified. Next, look at the months of April and October of each year and observe how temperatures at all depths of the pond converge to become practically the same because of mixing. This anomaly is the turnover that we had predicted and DO levels at all depths converge as well reflecting the mixing of the water temperatures. Clarity and ice depth values were erratic as we expected them to be but we can still glean some interesting observations. From looking at the ice depth data we easily pick out the cold harsh winters (2009/2010 and 2010/2011) and the comparatively mild winter of (2011/2012). In the water clarity data we can pick out distinct clear phases in the spring of 2009 and fall of 2010 which may be explained by a high abundance of a zooplankton called *daphnia* which graze heavily on single-celled algae, thus clearing up the water. In the summer during each year we see erratic swings in water clarity values from week to week which is likely caused by successive population explosions of different algae species that increase in number rapidly then disappear and are replaced by another algae species. Wind mixing likely has a limited role in changing water clarity due to the small size of the pond.

So what can we conclude from this data about Bremer Pond and northern ponds in general? For starters, we can see winters up North tend to be the most risky time for aquatic life in ponds. The longer and harsher the winter, the worse the DO conditions under the ice. Due to the nature of Bremer Pond's formation as a gravel pit near a river and with moderate groundwater inflow we would not expect winterkill to be a problem. However, in more productive ponds, methods of managing growth and productivity such as feeding and fertilization need to be balanced against the risk of winterkill. More productivity during the growing season means more aerobic decomposition and loss of DO under the ice in winter. Even at low to moderate levels of productivity like those seen at Bremer Pond, we can see what happens to DO levels as winter drags on. In a more productive pond or where fertilization or too much feed are used, the likelihood of winterkill would be much higher. To counter the risk of winterkill, northern pond owners typically use aeration systems to prevent over-depletion of DO, especially in productive ponds underlain by rich soil of the Midwestern states. From what we see on Bremer pond, though, there appears to be no worry of winterkill and it appears to be a fairly stable system.

From all of Dwight's persistent data collection we now have a good grasp of seasonal dynamics of some critical variables (Temperature, DO, clarity, and ice depth) relevant to the management of Bremer Pond and a better understanding of what makes ponds in the North unique and challenging. We look forward to what the future holds for Bremer Pond and hopefully we can learn a lot more as we go along!

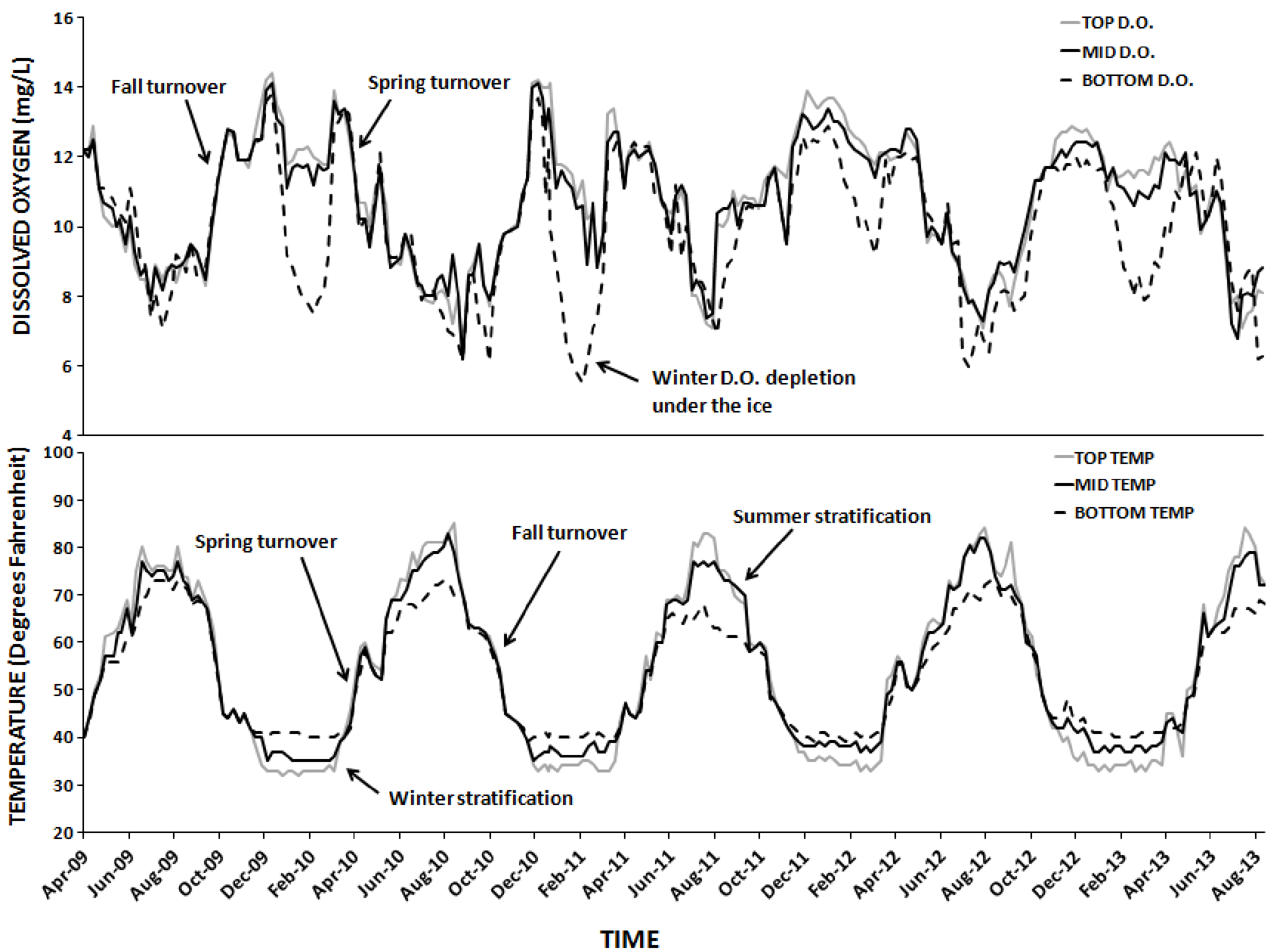


Figure 1. Dissolved oxygen (Top) and temperature (Bottom) readings from Bremer Pond collected with a hand held temperature/dissolved oxygen meter plotted by depth strata (Top, Mid, Bottom) against time (Month-Year) from April 2009 to August 2013.

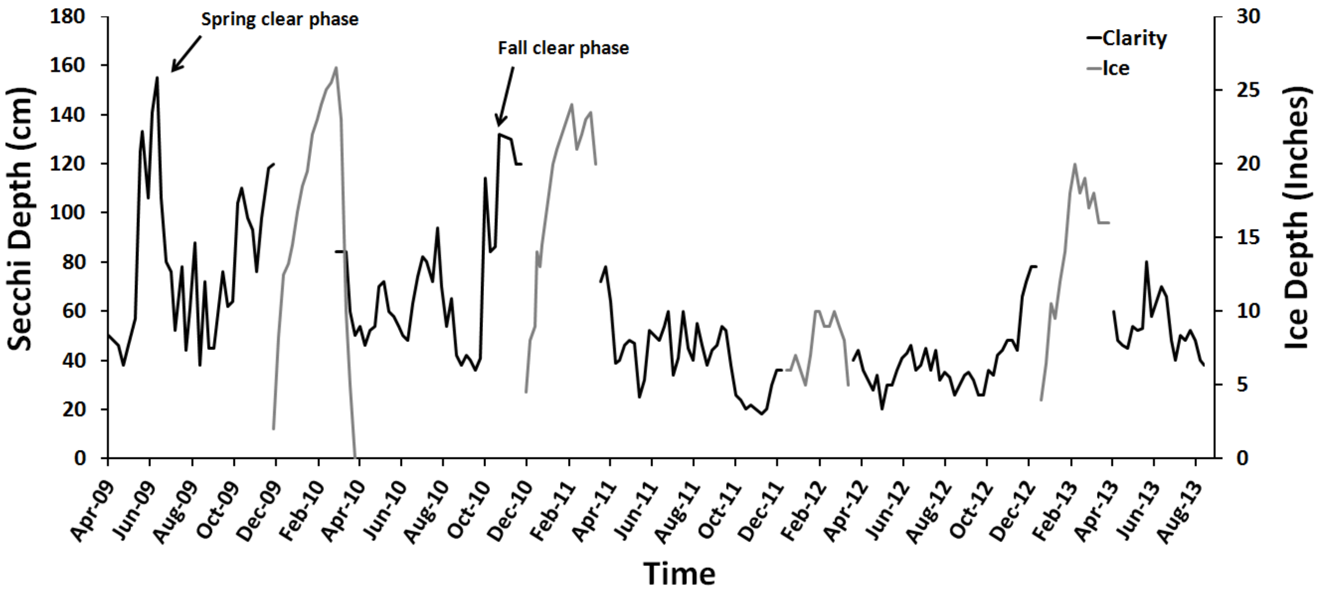


Figure 2. Secchi depth (cm) and ice depth (Inches) readings from Bremer Pond plotted against time (Month-Year) from April 2009 to August 2013.