Review of Hagerman Lake Water Quality

Prepared by:

White Water Associates, Inc.
Contact: Angie Stine
429 River Lane, P.O. Box 27
Amasa, Michigan 49903
Phone: (906) 822-7889
Email: angie.stine@white-water-associates.com

Submitted to:

Hagerman Lake Landowners Association
Contact: Pete Wedegartner
Iron River, MI 49935
906-265-2758
2weeds@fast-air.net

Date: October 21, 2013

WHITE WATER ASSOCIATES, INC.

Review of Lake Water Quality

Table of Contents

Review of Hagerman Lake Water Quality

Prepared By Angie Stine, B.S., Biologist, White Water Associates, Inc.

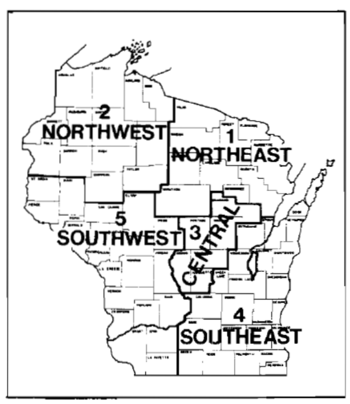
Introduction

Hagerman Lake is located in Iron County, Michigan. It is a 585 acre lake with a maximum depth of 54 feet. The purpose of this study is to develop a baseline of water quality information for Hagerman Lake. This information will provide a starting point to understanding changes in lake water quality and or biology in the future. Some water quality data was available from the USGS (2013) that was collected in May and August 2007. White Water Associates collected data from Hagerman Lake in 2010 and 2013.

Comparison of Hagerman Lake with other datasets

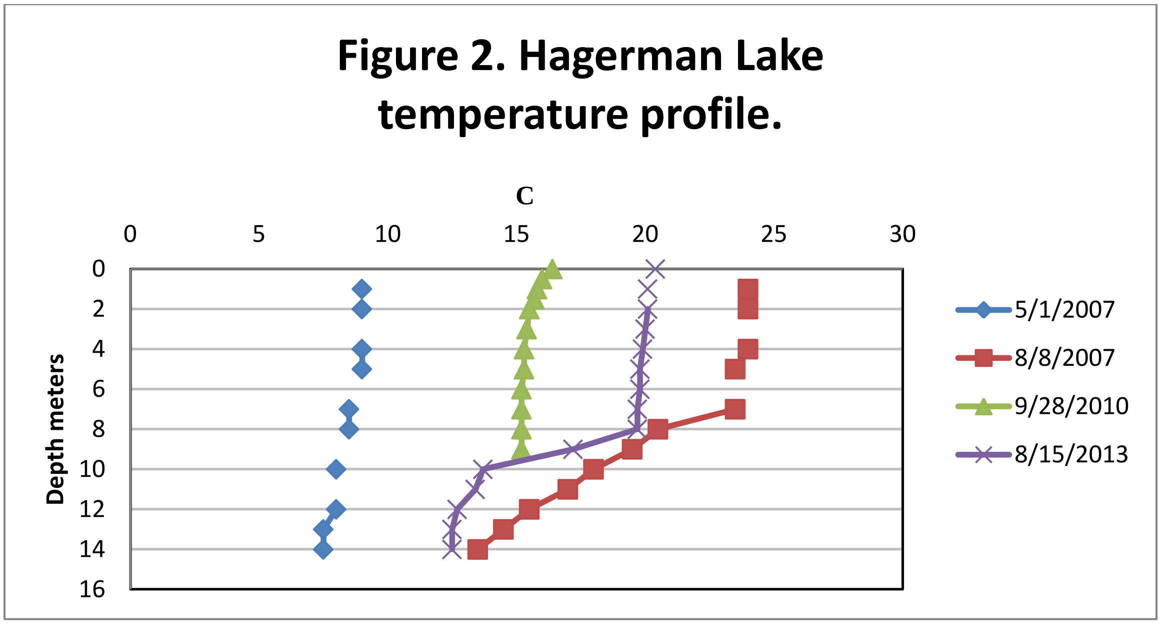
Lillie and Mason's *Limnological Characteristics of Wisconsin Lakes* (1983) is a good source to compare lakes within our region to a subset of lakes that have been sampled in Wisconsin. Wisconsin is divided into five regions of sampling lakes. Because of its proximity, Hagerman Lake can be compared to the Northeast region of Wisconsin (Figure 1).

Figure 1. Wisconsin regions in terms of water quality.



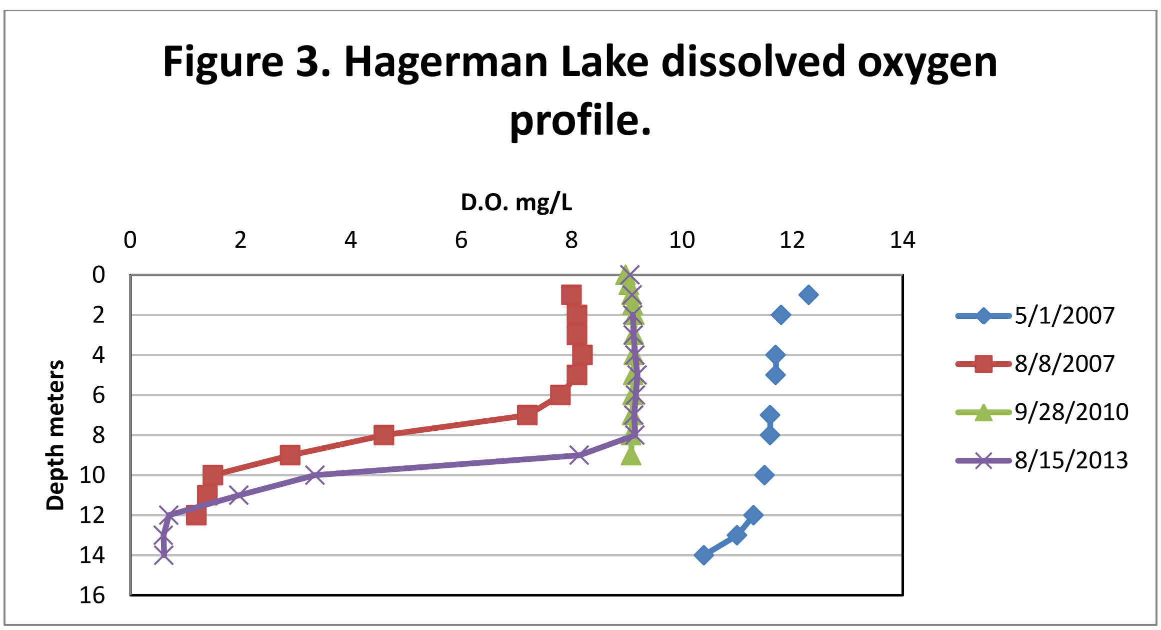
Temperature

Measuring the temperature of a lake at different depths will determine the influence it has on the physical, biological, and chemical aspects of the lake. Lake water temperature influences the rate of decomposition, nutrient recycling, lake stratification, and dissolved oxygen (D.O.) concentration. Temperature can also affect the distribution of fish species throughout a lake. Figure 2 presents several water temperature profiles for Hagerman Lake. In May, the temperature stayed constant from the surface to the bottom, which is an indication of spring overturn and thorough mixing of the lake. The August temperature levels show summer stratification. In September, the lake shows no stratification up to 10 meters, which is an indication of fall overturn.



Dissolved Oxygen

The dissolved oxygen (D.O.) content of lake water is vital in determining presence of fish species and other aquatic organisms. Dissolved oxygen also has a strong influence on the chemical and physical conditions of a lake. The amount of dissolved oxygen is dependent on the water temperature, atmospheric pressure, and biological activity. Oxygen levels are increased by aquatic plant photosynthesis, but reduced by respiration of plants, decomposer organisms, fish, and invertebrates. The amount of dissolved oxygen available in a lake, particularly in the deeper parts of a lake, is critical to overall health. D.O. levels were the highest in May of 2007, with 12.3 mg/L due to spring turnover (Figure 3). In August dissolved oxygen levels showed stratification. The D.O profiles for September 2012 and August 2013 were similar.



Water Clarity

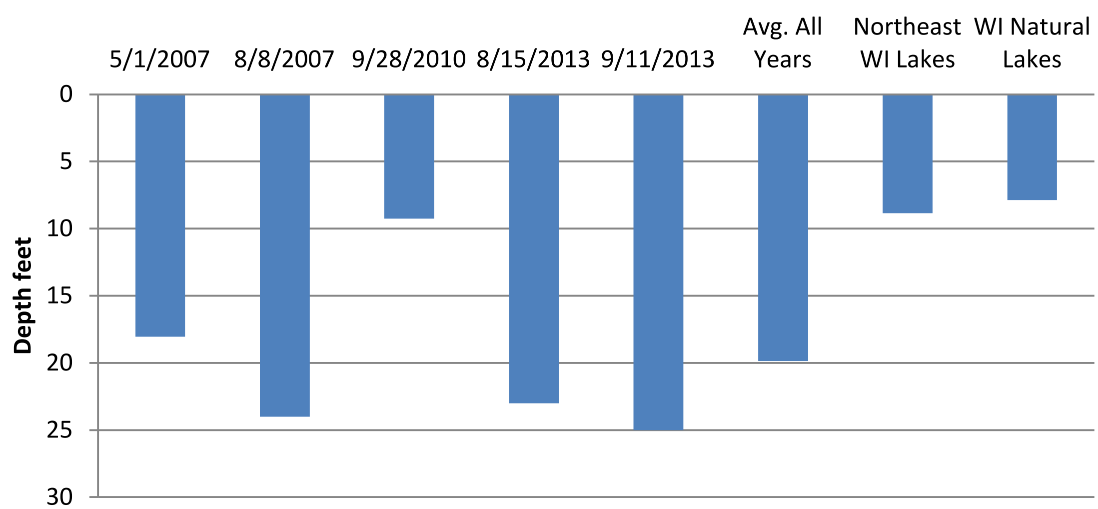
Water clarity has two main components: turbidity (suspended materials such as algae and silt) and true color (materials dissolved in the water) (Shaw et al., 2004). Water clarity gives an indication of the overall water quality in a lake. Water clarity is typically measured using a Secchi disk (black and white disk) that is lowered into the water column on a tether. In simple terms, the depth at which the disk is no longer visible is recorded as the Secchi depth.

Figure 4 shows the Secchi depths from 2007, 2010, and 2013. The shallowest Secchi depth was 9.25 feet in 2010, and the deepest reading was at 25 feet in 2013 (Figure 4). According to Table 1, Hagerman Lake is "very good" with respect to water clarity.

Table 1. Water clarity index (Shaw et al., 2004).

Water clarity	Secchi depth (ft.)
Very poor	3
Poor	5
Fair	7
Good	10
Very good	20
Excellent	32

Figure 4. Hagerman Lake Secchi depth.



Turbidity

Turbidity is another measure of water clarity, but is caused by suspended particulate matter rather than dissolved organic compounds (Shaw et al., 2004). Particles suspended in the water dissipate light and reduce the depth at which the light can penetrate. This affects the depth at which plants can grow. Turbidity also affects the aesthetic quality of water. Water that runs off the watershed into a lake can increase turbidity by introducing suspended materials. Turbidity caused by algae is the most common reason for low Secchi readings (Shaw et al., 2004). In terms of biological health of a lake ecosystem, measurements less than 10 Nephelometric Turbidity Units (NTU) represent healthy conditions for fish and other organisms. Hagerman Lake turbidity has not been tested, and could be included in future water quality sampling.

Water Color

Color of lake water is related to the type and amount of dissolved organic chemicals. Its main significance is aesthetics, although it may also influence light penetration and in turn affect aquatic plant and algal growth. Many lakes have naturally occurring color compounds from decomposition of plant material in the watershed (Shaw et al., 2004). Units of color are determined from the platinum-cobalt scale and are therefore recorded as Pt-Co units. Shaw states that a water color between 0 and 40 Pt-Co units is low. Hagerman Lake color was analyzed 8/8/2007 and was below detection level.

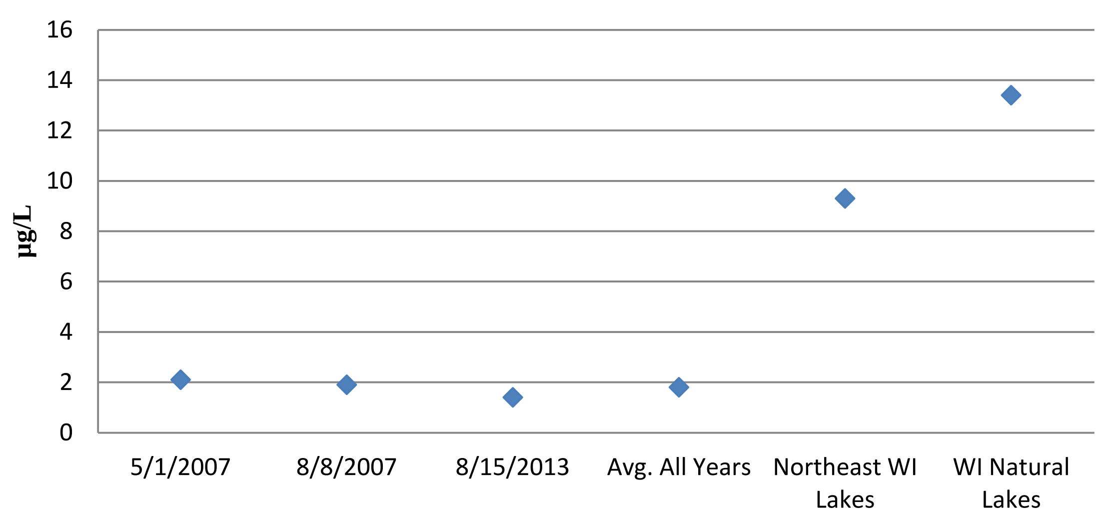
Water Level

Water levels have not been monitored on Hagerman Lake and could be included in future monitoring.

Chlorophyll *a*

Chlorophyll *a* is the photosynthetic pigment that makes plants and algae green. Chlorophyll *a* in lake water is therefore an indicator of the amount of algae. Chlorophyll *a* concentrations greater than 10 µg/L are perceived as a mild algae bloom, while concentrations greater than 20 µg/L are perceived as a nuisance. Chlorophyll *a* values were below nuisance levels and well below the average levels for Wisconsin natural lakes (Figure 5).

Figure 5. Hagerman Lake chlorophyll *a*.



Phosphorus

In more than 80% of Wisconsin's lakes, phosphorus is the key nutrient affecting the amount of algae and plant growth. If phosphorus levels are high, excessive aquatic plant growth can occur.

Phosphorus originates from a variety of sources, many of which are related to human activities. Major sources include human and animal wastes, soil erosion, detergents, septic systems and runoff from farmland or lawns (Shaw et al., 2004). Phosphorus provokes complex reactions in lakes. An analysis of phosphorus often includes both soluble reactive phosphorus and total phosphorus. Soluble reactive phosphorus dissolves in the water and directly influences plant growth (Shaw et al., 2004). Its concentration varies in most lakes over short periods of time as plants take it up and release it. Total phosphorus is considered a better indicator of a lake's nutrient status than soluble reactive phosphorus because its levels remain more stable (Shaw et al., 2004). Total phosphorus includes soluble phosphorus and the phosphorus in plant and animal fragments suspended in lake water. Ideally, soluble reactive phosphorus concentrations should be 10 µg/L or less at spring turnover to prevent summer algae blooms (Shaw et al., 2004). A concentration of total phosphorus below 20 µg/L for lakes should be maintained to prevent nuisance algal blooms (Shaw et al., 2004).

Hagerman Lake total phosphorus (Figure 6) values were considered "good to very good," and are in comparison with the Northeast region Wisconsin values. It would be beneficial for Hagerman Lake to monitor total phosphorus on a routine basis. June 2009, the total phosphorus was high correlating to an algal bloom.

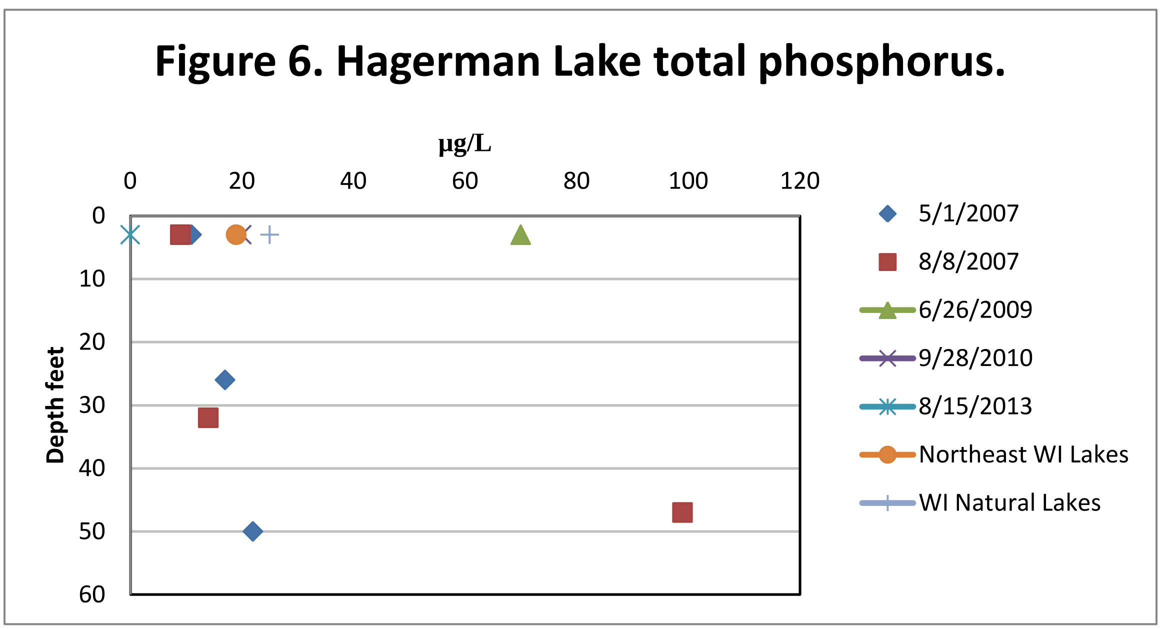
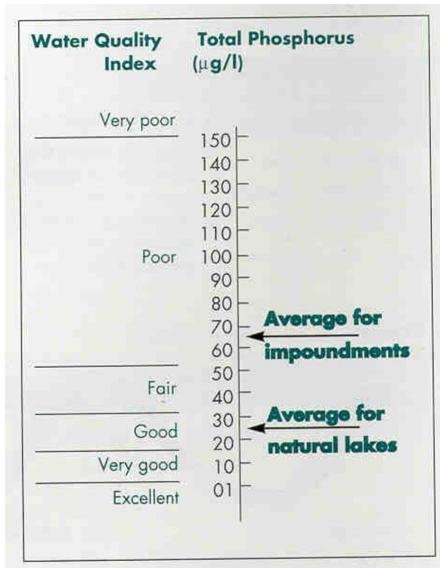


Figure 7. Total phosphorus concentrations for Wisconsin's natural lakes and impoundments (Shaw et al., 2004).



Trophic State

Trophic state is another indicator of water quality (Carlson, 1977). Lakes can be divided into three categories based on trophic state – oligotrophic, mesotrophic, and eutrophic. These categories reflect a lake's nutrient and clarity levels (Shaw et al., 2004).

Researchers use various methods to calculate the trophic state of lakes. Common characteristics used to make the determination are: total phosphorus (important for algae growth), chlorophyll *a* concentration (a measure of the amount of algae present), and Secchi disk readings (an indicator of water clarity) (Shaw et al., 2004) (Table 2).

Table 2. Trophic classification of Wisconsin Lakes based on chlorophyll *a*, water clarity measurements, and total phosphorus values (Shaw et al., 2004).

Trophic class	Total phosphorus µg/L	Chlorophyll *a* µg/L	Secchi Disk (ft.)
Oligotrophic	3	2	12
	10	5	8
Mesotrophic	18	8	6
	27	10	6
Eutrophic	30	11	5
	50	15	4

Trophic State Index (TSI) values for Hagerman Lake are presented in Figure 8. On average, Hagerman Lake is classified as "oligotrophic" based on these TSI values (Table 3). It would be beneficial to monitor

Secchi depth, chlorophyll *a*, and total phosphorus on a routine basis to see if there are any trends. On average, Hagerman Lake is classified as "oligotrophic" (Figure 9) (Table 3). It would be beneficial to monitor Secchi depth, chlorophyll *a*, and total phosphorus on a routine basis to see if there are any trends.

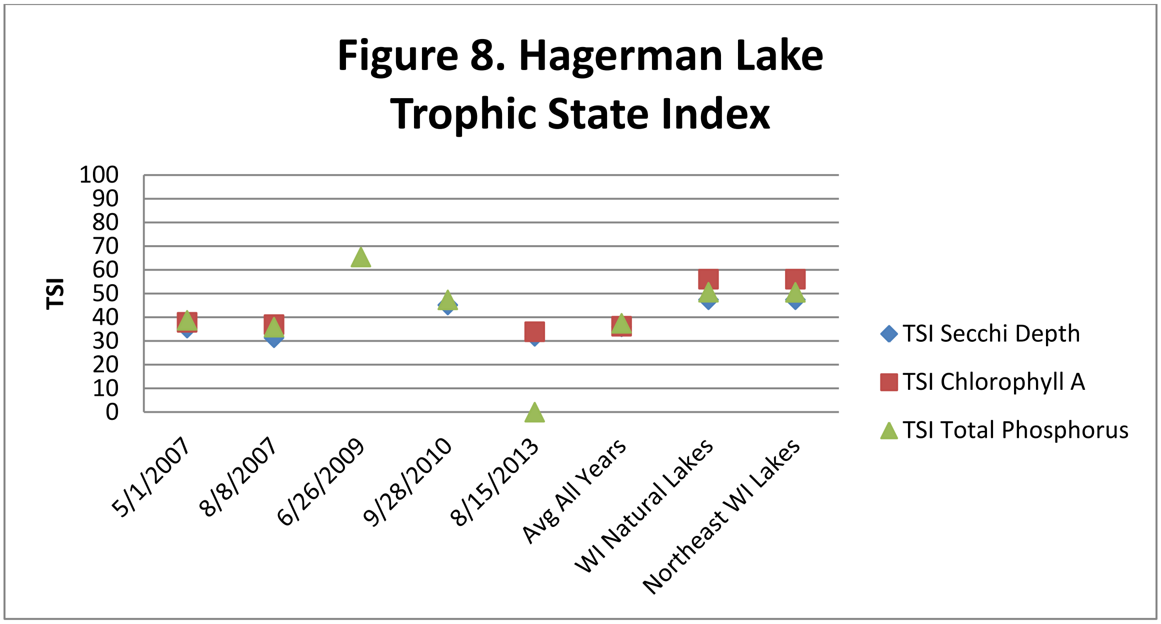


Table 3. Trophic State Index.	
30-40	**Oligotrophic:** clear, deep water; possible oxygen depletion in lower depths; few aquatic plants or algal blooms; low in nutrients; large game fish usual fishery
40-50	**Mesotrophic:** moderately clear water; mixed fishery, esp. panfish; moderate aquatic plant growth and occasional algal blooms; may have low oxygen levels near bottom in summer
50-60	**Mildly Eutrophic:** decreased water clarity; anoxic near bottom; may have heavy algal bloom and plant growth; high in nutrients; shallow eutrophic lakes may have winterkill of fish; rough fish common
60-70	**Eutrophic:** dominated by blue-green algae; algae scums common; prolific aquatic plant growth; high nutrient levels; rough fish common; susceptible to oxygen depletion and winter fishkill
70-80	**Hypereutrophic:** heavy algal blooms through most of summer; dense aquatic plant growth; poor water clarity; high nutrient levels

(WDNR, Sept 2012)

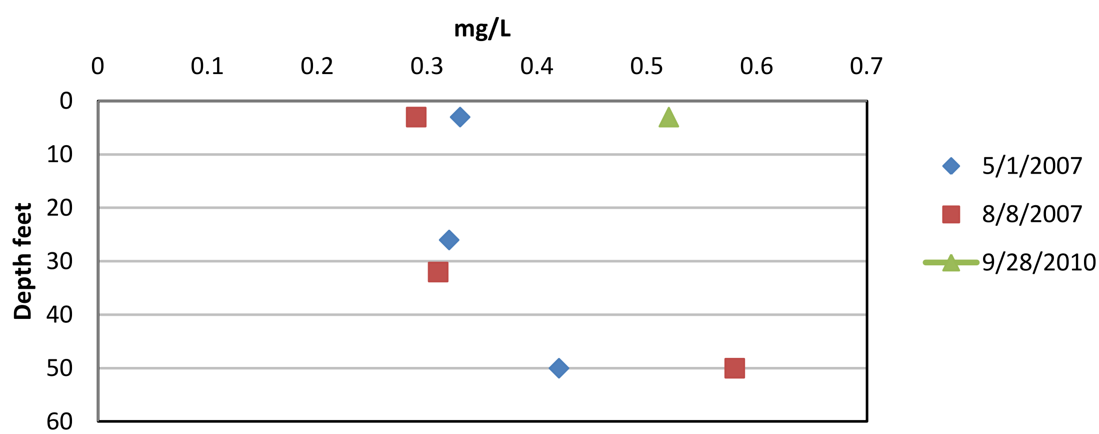
Nitrogen

Nitrogen is second only to phosphorus as an important nutrient for aquatic plant and algae growth (Shaw et al., 2004). Human activities on the landscape greatly influence the amount of nitrogen in a lake. Nitrogen may come from lawn fertilizer, septic systems near the lake, or from agricultural activities in the watershed. Nitrogen may enter a lake from surface runoff or groundwater sources.

Nitrogen exists in lakes in several forms. Hagerman Lake was analyzed for total Kjeldahl nitrogen (Figure 9), total nitrogen (Figure 10), nitrate-nitrite (Figure 11), organic nitrogen (Figure 12) and ammonium (not detected 9/28/2010). Nitrogen is a major component of all organic (plant and animal) matter.

Decomposing organic matter releases ammonia, which is converted to nitrate if oxygen if present (Shaw et al., 2004). All inorganic forms of nitrogen can be used by aquatic plants and algae (Shaw et al., 2004). If these inorganic forms of nitrogen exceed 0.3 mg/L (as N) in spring, there is sufficient nitrogen to support summer algae blooms (Shaw et al., 2004). Elevated concentrations of ammonium, nitrate, and nitrite, derived from human activities, can stimulate or enhance the development, maintenance and proliferation of primary producers (phytoplankton, benthic algae, macrophytes), contributing to the widespread phenomenon of the cultural (human-made) eutrophication of aquatic ecosystems (Camargo et al., 2007). The nutrient enrichment can cause important ecological effects on aquatic communities, since the overproduction of organic matter, and its subsequent decomposition, usually lead to low dissolved oxygen concentrations in bottom waters, and sediments of eutrophic and hypereutrophic aquatic ecosystems with low turnover rates (Camargo et al., 2007). The nitrogen level in Hagerman Lake is low and below the average Northeast Wisconsin Lakes (Figure 10 and 12).

Figure 9. Hagerman Lake total Kjeldahl nitrogen.



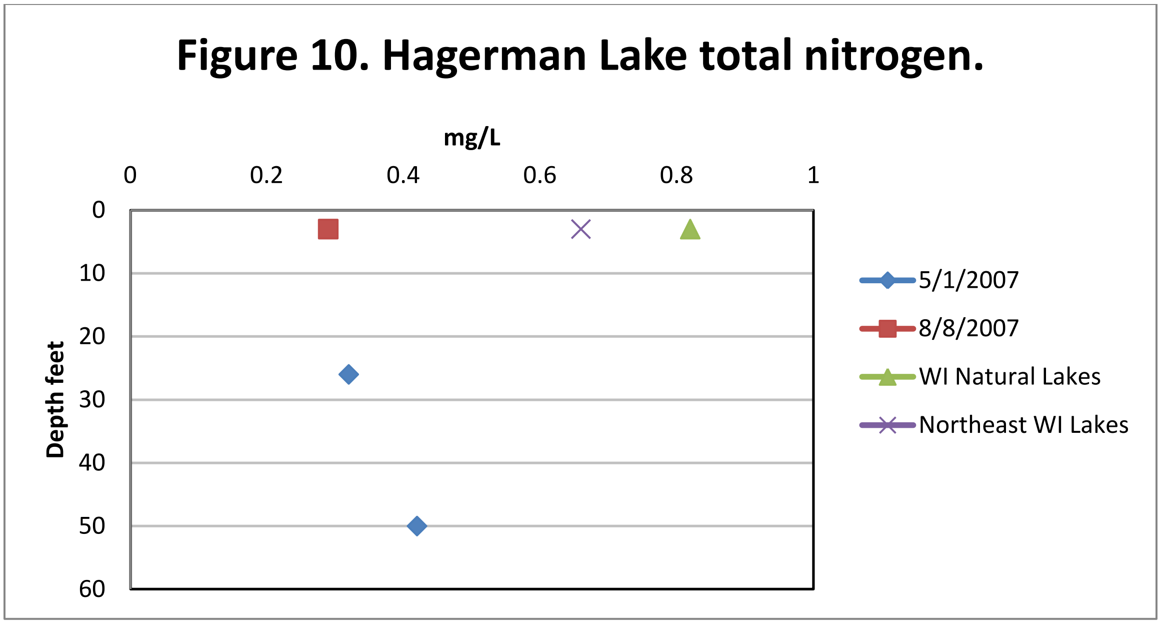


Figure 10. Hagerman Lake total nitrogen.
mg/L
0
0.2
0.4
0.6
0.8
1
Depth feet
0
10
20
30
40
50
60
5/1/2007
8/8/2007
WI Natural Lakes
Northeast WI Lakes

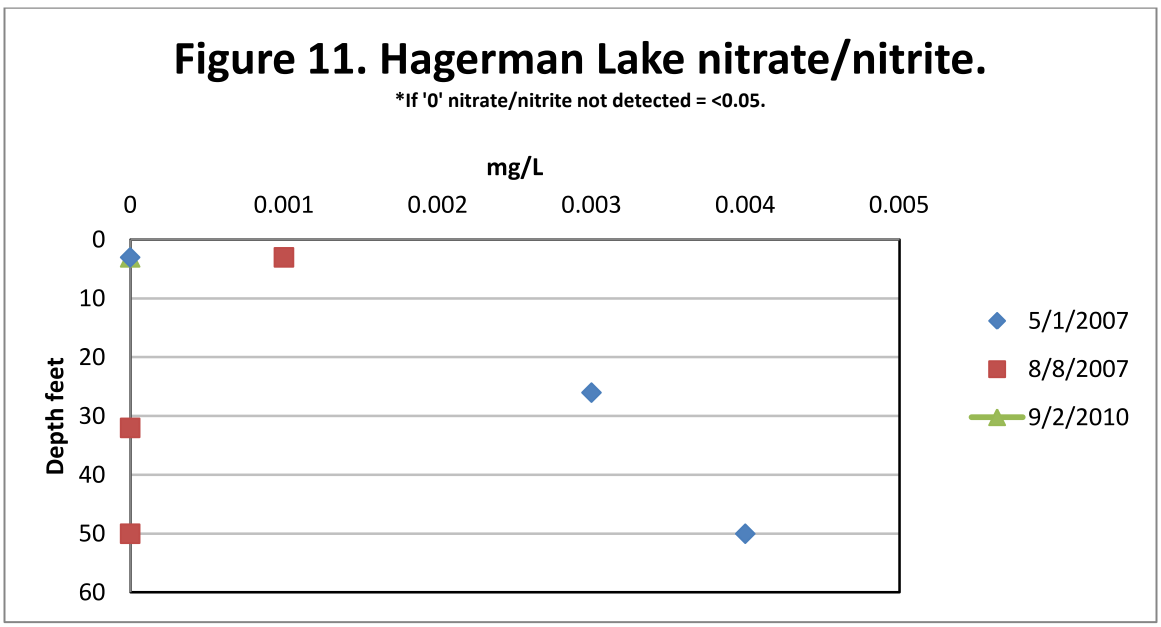
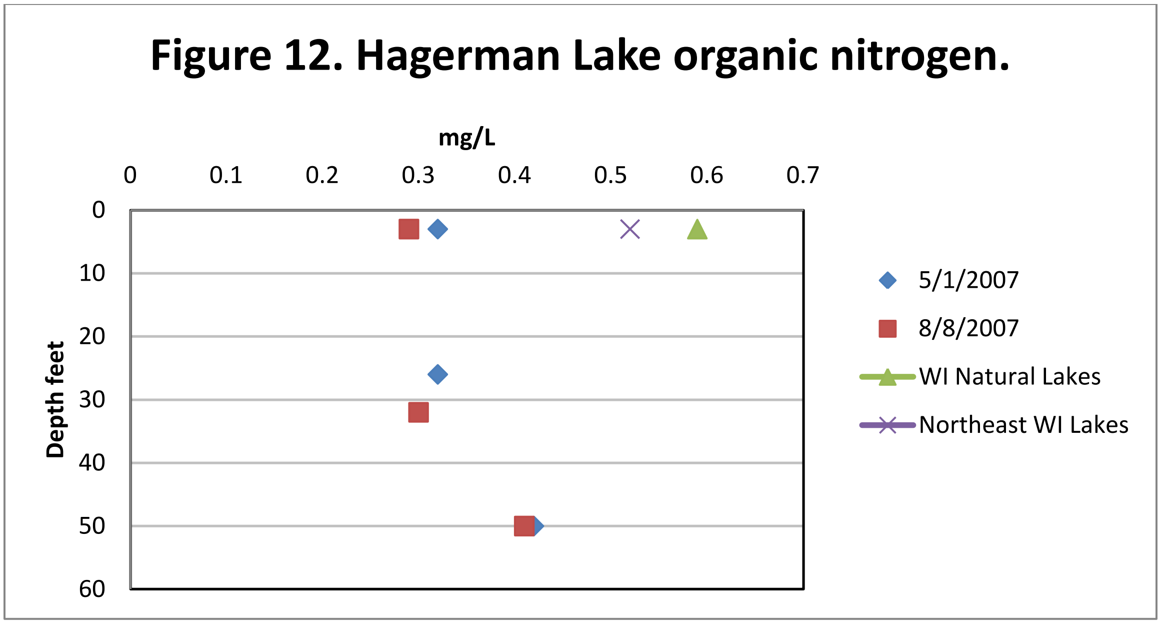


Figure 11. Hagerman Lake nitrate/nitrite.
*If '0' nitrate/nitrite not detected = <0.05.
mg/L
0
0.001
0.002
0.003
0.004
0.005
Depth feet
0
10
20
30
40
50
60
5/1/2007
8/8/2007
9/2/2010



Chloride

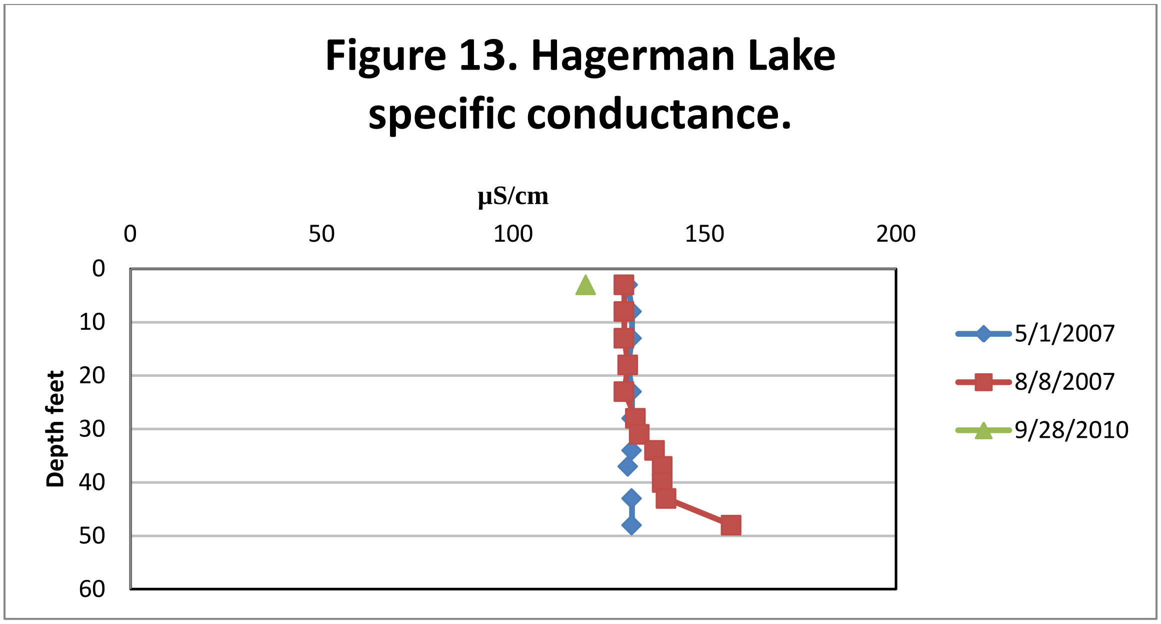
The presence of chloride (Cl^-) where it does not occur naturally indicates possible water pollution (Shaw et al., 2004). Chloride does not affect plant and algae growth and is not toxic to aquatic organisms at most of the levels found in Wisconsin (Shaw et al., 2004). Chloride concentrations in Hagerman Lake were well below the generalized distribution gradient of chloride found in surface waters in Wisconsin. Only trace amounts of chloride were found in Hagerman Lake (1 mg/L) 5/1/2007.

Sulfate

Sulfate in lake water is primarily related to the types of minerals found in the watershed, and to acid rain (Shaw et al., 2004). Sulfate concentrations are noted to be less than 10 mg/L in Northeastern region of Wisconsin (Lillie and Mason, 1983). Sulfate (5 mg/L) was analyzed in 5/1/2007 indicating concentrations were low for Hagerman Lake.

Conductivity

Conductivity is a measure of the ability of water to conduct an electric current. Conductivity is reported in micromhos per centimeter **(**µmhos/cm) and is directly related to the total dissolved inorganic chemicals in the water. Usually, values are approximately two times the water hardness, unless the water is receiving high concentrations of human-induced contaminants (Shaw et al., 2004). Hagerman Lake has average conductivity in comparison to northeast Wisconsin. We expect to see an increase in conductivity with depth during the summer (Figure 13).



pH

The acidity level of a lake's water regulates the solubility of many minerals. A pH level of 7 is considered neutral. The pH level in Wisconsin lakes ranges from 4.5 in acid, bog lakes to 8.4 in hard water, marl lakes (Shaw et al., 2004). Natural rainfall in Wisconsin averages a pH of 5.6. Some minerals become available under low pH (especially aluminum, zinc, and mercury) and can inhibit fish reproduction and/or survival. Mercury and aluminum are not only toxic to many kinds of wildlife, but also to humans (especially those that eat tainted fish). The pH scale is logarithmic, so every 1.0 unit change in pH increases the acidity tenfold. Water with a pH of 6 is 10 times more acidic than water with pH of 7. A lake's pH level is important for the release of potentially harmful substances and affects plant growth, fish reproduction and survival. A lake with neutral or slightly alkaline pH is a good lake for fish and plant survival.

The pH for Hagerman Lake appears to be alkaline (Figure 14) indicating a good lake for fish and plant survival in 2007. The pH was 7.06 in 2010 which is neutral.

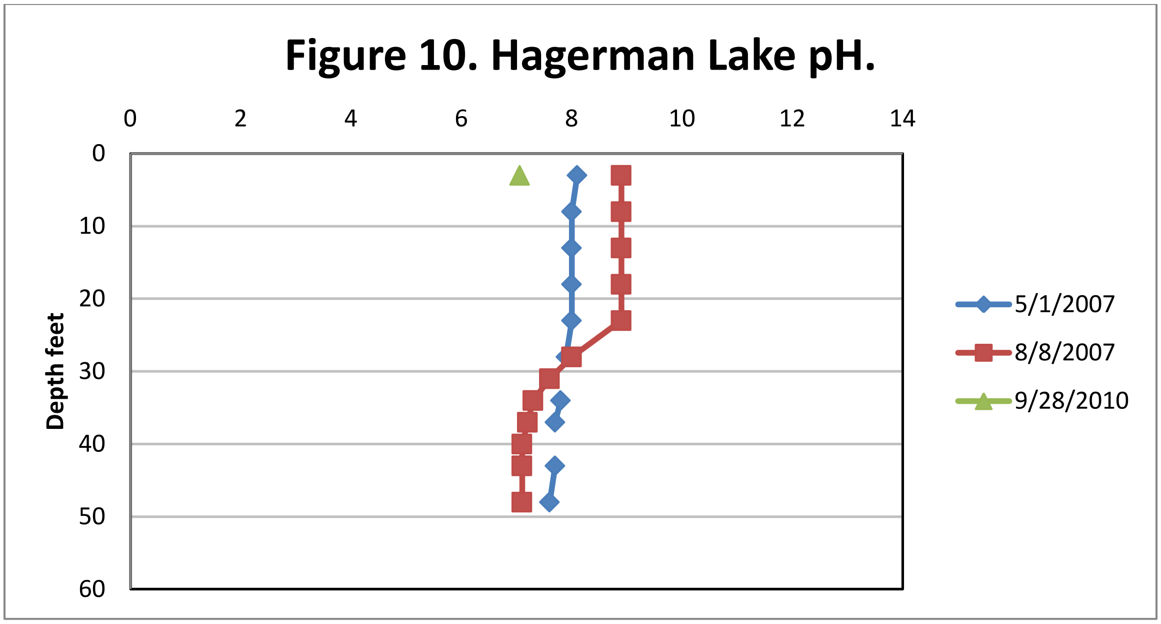


Table 4 indicates the effects pH levels less than 6.5 will have on fish. While moderately low pH does not usually harm fish, the metals that become soluble under low pH can be important. In low pH waters, aluminum, zinc, and mercury concentrations increase if they are present in lake sediment or watershed solids (Shaw et al., 2004).

Table 4. Effects of acidity on fish species (Olszyk, 1980).

Water pH	*Effects*
6.5	Walleye spawning inhibited
5.8	Lake trout spawning inhibited
5.5	Smallmouth bass disappear
5.2	Walleye & lake trout disappear
5	Spawning inhibited in most fish
4.7	Northern pike, sucker, bullhead, pumpkinseed, sunfish & rock bass disappear
4.5	Perch spawning inhibited
3.5	Perch disappear
3	Toxic to all fish

Alkalinity

Alkalinity levels in a lake are affected by the soil minerals, bedrock type in the watershed, and frequency of contact between lake water and these materials (Shaw et al., 2004). Alkalinity is important in a lake to buffer the effects of acidification from the atmosphere. Acid rain has long been a problem with lakes that have low alkalinity levels and high potential sources of acid deposition. The alkalinity was high in

Hagerman Lake 9/28/2010 (63 mg/L) in comparison to the Northeast region and other lakes in Wisconsin with an average of 5.1 mg/L $CaCO_3$. Because of this, Hagerman Lake is not sensitive to acid rain.

Hardness

Hardness levels in a lake are affected by the soil minerals, bedrock type in the watershed, and frequency of contact between lake water and these materials (Shaw et al., 2004). One method of evaluating hardness is to test for calcium carbonate ($CaCO_3$). Hagerman Lake had a total hardness of 61 mg/L (5/1/2007) and 62.1 mg/L (9/28/2010) categorizes the lake to have "moderately hard" water (Table 5).

Table 5. Categorization of hardness (mg/L of calcium carbonate ($CaCO_3$)) (from Shaw et al., 2004).

Soft water	0-60
Moderately hard water	61-120
Hard water	121-180
Very hard water	>180

Calcium and Magnesium Hardness

The carbonate system provides acid buffering through two alkaline compounds: bicarbonate and carbonate. These compounds are usually found with two hardness ions: calcium and magnesium (Shaw et al., 2004). Calcium is the most abundant cation found in Wisconsin lakes. Its abundance is related to the presence of calcium-bearing minerals in the lake watershed (Shaw et al., 2004). Aquatic organisms such as native mussels use calcium in their shells. The aquatic invasive zebra mussel tends to need calcium levels greater than 20 mg/L to maintain shell growth. Hagerman Lake had borderline calcium levels (15 mg/L) 5/1/2007 and 15.9 mg/L (9/28/2010) which is an indication that zebra mussels could establish if introduced. A magnesium level of 5.7 mg/L (5/1/2007) is comparable to lakes in the Northeast region of Wisconsin (5 mg/L).

Sodium and Potassium

Sodium and potassium are possible indicators of human pollution in a lake, since naturally occurring levels of these ions in soils and water are very low. Sodium is often associated with chloride and gets into lakes from road salting, fertilizations, and human and animal waste (Shaw et al., 2004). Potassium is the key component of commonly-used potash fertilizer, and is abundant in animal waste. Both of these elements are held by soils to a greater extent than is chloride or nitrate; therefore, they are not as useful as indicators of pollution impacts (Shaw et al., 2004). Although not normally toxic themselves, they provide a strong indication of possible contamination by more damaging compounds (Shaw et al., 2004). Hagerman Lake had low levels of sodium (1.2 mg/L) and potassium (0.6 mg/L) 5/1/2007.

Dissolved Organic Carbon

Dissolved Organic Carbon (DOC) is a food supplement, supporting growth of microorganisms, and plays an important role in global carbon cycle through the microbial loop (Kirchman et al., 1991). In general, organic carbon compounds are a result of decomposition processes from dead organic matter such as plants. When water contacts highly organic soils, these components can drain into rivers and lakes as DOC. DOC is also extremely important in the transport of metals in aquatic systems. Metals form extremely strong complexes with DOC, enhancing metal solubility while also reducing metal bioavailability. Base flow concentrations of DOC in undisturbed watersheds generally range from 1 to 20 mg/L carbon. Hagerman Lake DOC has not been tested, and could be included in future water quality sampling.

Silica

The earth's crust is abundant with silicates or other compounds of silicon. The water in lakes dissolves the silica and pH can be a key factor in regulating the amount of silica that is dissolved. Silica concentrations are usually within the range of 5 to 25 mg/L. Generally lakes that are fed by groundwater have higher levels of silica. Because silica concentration is unknown for Hagerman Lake, future water quality sampling could include measurement of this parameter.

Aluminum

Aluminum occurs naturally in soils and sediments. In low pH (acidic) environments aluminum solubility increases greatly. With a low pH and increased aluminum values, fish health can become impaired. This can have impacts on the entire food web. Aluminum also plays an important role in phosphorus cycling in lakes. When aluminum precipitates with phosphorus in lake sediments, the phosphorus will not dissolve back into the water column as readily. Because aluminum levels are unknown in Hagerman Lake, future water quality sampling could include measurement of this parameter.

Iron

Iron also forms sediment particles that store phosphorus when dissolved oxygen is present. When oxygen concentration gets low (for example, in winter or in the deep water near sediments) the iron and phosphorus dissolve in water. This phosphorus is available for algal blooms. Hagerman Lake iron levels have not been tested, and could be included in future water quality sampling.

Manganese

Manganese is a mineral that occurs naturally in rocks and soil. In lakes, manganese is usually in particulate form. When the dissolved oxygen levels decrease, manganese can convert from an insoluble form to soluble ions. Hagerman Lake manganese levels have not been tested, and could be included in future water quality sampling.

Sediment

Lake bottom sediments are sometimes analyzed for chemical constituents that they contain. This is especially true for potentially toxic metals such as mercury, chromium, selenium, and others. Lake sediments also tend to record past events as particulates settle down and become part of the sediment. Biological clues for the historic conditions in the lake can be gleaned from sediment samples. Examples include analysis of pollen or diatoms that might help understand past climate or trophic states in the lake. Sediment data was not collected for Hagerman Lake, and future sampling could include measurements of this constituent.

Total Suspended Solids

Total suspended solids are all particles suspended in lake water. Silt, plankton, and wastes are examples of these solids and can come from runoff of agricultural land, erosion, and can be produced by bottom-feeding fish. As the suspended solid levels increase, they absorb heat from sunlight which can increase the water temperature. They can also block the sunlight that plants need for photosynthesis. These events can in turn affect the amount of dissolved oxygen in the lake. Lakes with total suspended solids levels less than 20 mg/L are considered "clear," while levels between 40 and 80 mg/L are "cloudy." Because total suspended solids data has not been collected for Hagerman Lake, future water quality sampling could include measurement of this parameter.

Aquatic Invasive Species

In 2009, zebra mussels were identified on a dock in Hagerman Lake. Monitoring has been done since the observation and no zebra mussels have been detected. The University of Wisconsin-Madison's Aquatic Invasive Species Smart Prevention program classifies Hagerman Lake as "borderline suitable" for zebra mussels, based on calcium and pH levels found in the lake (UW-Madison). There are no other aquatic invasive species documented in Hagerman Lake to date.

Clean Boats Clean Waters is a program that inspects boats for aquatic invasive species and in the process educates the public on how to help stop the spread of invasive species. Volunteer monitoring would benefit educating the lake patrons on aquatic invasive species. The Hagerman boat wash was installed by the Ottawa National Forest in 2012 and should be used when entering and leaving Hagerman Lake. Early detection and rapid response is the key to aquatic invasives. When using the lake please keep your eye out for anything unusual.

Resources

Camargo, Julio A., Álvaro Alonso (Lead Author); Raphael D. Sagarin (Topic Editor). 02 April 2007. *Inorganic nitrogen pollution in aquatic ecosystems: causes and consequences.* In: Encyclopedia of Earth. Eds. Cutler J. Cleveland (Washington, D.C.: Environmental Information Coalition, National Council for Science and the Environment). Retrieved January 24, 2012. <http://www.eoearth.org/article/Inorganic_nitrogen_pollution_in_aquatic_ecosystems:_causes_and_consequences>

Carlson, R.E. 1977. *A Trophic State Index for Lakes.* Limnology and Oceanography. 22: 361-369.

Kirchman, David L.; Suzuki, Yoshimi, Garside, Christopher, Ducklow, Hugh W. (15). 1991. *High turnover rates of dissolved organic carbon during a spring phytoplankton bloom.* Nature 352 (6336): 612–614. Doi:10.1038/352612a0. Retrieved 2012. <http://www.nature.com/nature/journal/v352/n6336/abs/352612a0.html.>

Lillie, R. A. and J. W. Mason. 1983. *Limnological Characteristics of Wisconsin Lakes.* Wis. Dept. of Natural Resources Tech. Bull. Page 138. Madison, WI.

Olszyk, D. 1980. *Biological Effects of Acid Rain*. Testimony, Wis. Public Service Commission Docket No. 05-EP-2. 5 pp.

Shaw, B. Mechenich, C, and Klessig, L. 2004. *Understanding Lake Data (G3582).* Board of Regents of the University of Wisconsin System. Madison, WI.

U.S.G.S. 2013. Michigan Water Data. < http://nwis.waterdata.usgs.gov/mi/nwis/qwdata**>.** Retrieved October 11, 2013.