THE IMPACT OF WATER CLARITY ON HOME PRICES IN NORTHWEST WISCONSIN

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Executive Summary

This study estimates the property value gains associated with improvements in water clarity on 20 Northern Wisconsin lakes. Using a two stage hedonic model applied to Wisconsin DNR water studies and sales data on over 300 homes obtained from Zillow.com we estimate that a 3 foot improvement in water clarity would produce a 9 - 16% improvement in the market price of an average property on lakes with the lowest clarity.

Hedonic models are the most common method for determining the market value of specific property attributes. Hedonic modeling is a proven way to statistically account for the many differences that exist in any set of properties in order to focus on changes to one specific attribute within the set. This method has been applied to hundreds of studies including the majority of work done on the market impact of water clarity on property values.

On Lake Chetac we estimate a an additional 3 feet of water clarity would bring a 10 – 11% improvement in the value of the average property adjacent to the lake. This translates to an increase market value to $269,400 from $243,477 on the average property and an additional $10.4 million in total property valuation. Given the Sawyer County 2015 property tax rate of 1.085% the increased valuation would bring another $112,800 in annual county property taxes collected.

Picture 1: Lake Chetac

Quick Q&A

Q: Does water clarity have a significant impact on property prices?
A: Yes. Our tests show that water clarity has a statistically significant impact on property prices. Clearer water means higher property prices, all things being equal. The improvement in expected values varies by as much as 16% on the average property within the study area.

Q: How do you define water clarity?
A: This study uses annual average Secchi Disk readings as reported by the Wisconsin Department of Natural Resources. This is a scientifically valid and objective measure of water clarity.

Q: Does improving water clarity impact all properties equally?
A: No. Properties on lakes with low water clarity will experience a significantly greater benefit from improved clarity when compared to property adjacent to lakes that already have high levels of clarity.

Q: How do you account for the fact that different lakes have different types of properties?
A: A statistical picture was created for each of the lakes in the study area. This allows us to account for the great many differences that exist in the properties adjacent to lakes in the study area.

Q: Do the benefits of improving water clarity outweigh the costs?
A: Uncertain. Because both the costs and benefits differ across lakes it is impossible to make a blanket statement. However, the economic benefits associated with improved clarity on any of the 20 lakes within the study area are presented in the study. The data clearly show the economic benefits of improving water clarity, especially for lakes that currently have poor water clarity.

Q: How were the results estimated?
A: We used a hedonic pricing model to estimate the results. This model relies on actual market data (e.g. housing prices) rather than hypothetical data. Economists commonly use this type of model to estimate the market price of specific property or location attributes.

Q: Does this study take into account so-called multiplier effects?
A: No, the study did not evaluate economic multiplier effects. The results show the estimated economic impacts to the current existing property values. They do not include indirect economic impacts such as increased tourism or increased economic development associated that may or may not occur with any change water clarity.

Introduction[1] [2]

Picture 2: Butternut Lake

The Problem

There exist a significant number of lakes in Northwest Wisconsin that exhibit low levels of water clarity. It is also a well-established fact that perceptions of water quality have a significant bearing upon property values. As such it is the case that an improvement in water clarity on those lakes that currently exhibit low clarity would result in a significant improvement in property values. (Not to mention a number of other economic benefits – such as increased tourism.) Of course rising property values means increased property taxes and thus State revenue. On the other hand improving water clarity is not without costs. The matter is therefore a balancing act: In cases where the economic benefits

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[1] Funding for this study was provided by the Wisconsin Department of Natural Resources and the University of Wisconsin – Eau Claire ORSP. We would also like to thank Mr. Alex Smith of the Wisconsin DNR for his comments on a draft version of this paper. All remaining errors or omissions are the responsibility of the authors.

[2] All pictures provided by Mr. David Kemp.

exceed the costs associated with water clarity improvement there is a clear case to be made for said improvements.[3]

In this study we seek to better understand the value increment likely to be associated with improvements in water clarity. From this we are able to estimate the likely economic benefits to both the private and public sector. It is our hope that that this will produce better informed and economically sound environmental remediation and an improvement in the already impressive natural resources of the State.

Outline of the Study

This study is divided into five (5) parts. These are,

- Introduction (p. 3)
- Method/Literature (p. 13)
- The Model (p. 18)
- Analysis (p. 23)
- Conclusions (p. 27)

In the introduction we will first give an overview and brief history of the twenty (20) lakes chosen for the study area. We then cover the method of analysis used for the study. This will include a brief primer on hedonic modeling, an overview of the relevant literature, and a discussion of the sources of the data used.

Following this an entire section of the report is devoted to the specific model used to conduct the analysis. We used a two stage hedonic model similar to those used in several other similar studies. We conclude this section with a brief discussion of some of the problems encountered during the construction of the model and what steps were taken to remedy these issues.

The fourth portion of the study analyses the model output. Readers who are only interested in the study results may wish to jump right to page 23. In that section we cover the expected economic gains associated with improved water clarity to the private sector (property prices) and the public sector (property taxes). Specific numbers are given for Lake Chetac (the primary focus of this study) for all other lakes within the study area the data and formulae needed to calculate the direct economic effects are given.

In the concluding section we review the two basic factors driving the marginal economic benefits associated with improved water clarity. These are, in order of importance, the existing level of clarity and the current level of economic development. To be clear, our

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[3] While there are certainly other measures of water quality (color, odor, bacteria, etc…) this study focuses solely upon water clarity and its economic impacts. This is not to suggest that these other measures are not important but that they are merely beyond the scope of this study.

results show that property values improve with any improvement in water clarity on any of the lakes in the study area. That said the improvement in values (marginal change) is greatest on those lakes that currently have low levels of clarity and where the current level of economic development is the least. In this way we provide a clear and straightforward method for understanding the areas in which the economic benefits can be expected to be the greatest.

The Study Area

Picture 3: Round Lake

Initially, 24 lakes in Northwest Wisconsin were chosen for the study. A large number of lakes were chosen to ensure that a statistically significant number of properties could be obtained. The decision to choose the lakes were based on adherence to the following attributes including: distance away from a major city in Northwest Wisconsin (We did not choose lakes located in or adjacent to a metropolitan area), lakes that have a significant number of properties surrounding them, lakes that have at least 15 separate water quality readings conducted by the Wisconsin DNR, and lakes that are not part of a reservation or state/national parks. However, four of the lakes; Castle Rock Lake, Sand Lake, Grindstone Lake and Metonga Lake, had to be dropped from the study due to unavailability or the lack of water quality readings. The study ended up with 20 lakes with 324 home properties sold during the last year (228 properties when empty lots are excluded). The study set of lakes includes;

Chetac/Birch Lakes
Mean Annual Secchi Disk Reading – 4 Feet

Big Chetac Chain Lakes Association sponsored Curly Leaf Pond Weed Reduction Project on Lake Chetac, a 3-year project in 2013. This project focused on (1) control curly-leaf pondweed chemical; (2) monitor pre-post treatment; (3) monitor turion; (4) plant native aquatic plants; (5) AIS education.

Big Chetac Chain Lake Association sponsored a multi-phase comprehensive lake management-planning project – “Getting Rid of the Green” in 2007 on Birch Lake.

Phase 1 included (1) install and record of lake level staff gage; (2) monitor water quality or sediment of the lake during the growing season; (3) collect date of stream flow measurements and water quality sampling.

Phase 2 included (1) estimate curly leaf pondweed beds for comparison to previous mapping or survey; (2) collect internal load calculations under various conditions for cores; (3) install fourteen mini-piezometers.

Balsam Lake
Mean Annual Secchi Disk Reading – 7.63 Feet

Several projects were completed from 1994-2014. These projects were made to (1) monitor the water quality of the lake; (2) develop aquatic plan management plan; (3) update and reprint an existing guidebook for controlling runoff and erosion on waterfront property; (4) control aquatic invasive species.

There is an ongoing project, which was proposed by Balsam Lake P&R District in 2015. This project is to control giant knotweed, and pre-post treatment aquatic plant, herbicide, turion and AIS monitoring.

Red Cedar Lake
Mean Annual Secchi Disk Reading – 10.35 Feet

Projects included (1) control curly leaf and Purple Loosestrife; (2) diagnostic and feasibility study of the lake; (3) observe water quality and watershed map; (4) education, prevention and planning of the lake.

Picture 4: Red Cedar Lake

Long Lake
Mean Annual Secchi Disk Reading – 8.05 Feet

Past projects included (1) development and modification of lake management plan; (2) control or eradicate invasive species; (3) watercraft inspections; (4) aquatic plant chemical treatment; (5) conduct social survey of residents or users
FDL Long Lake Association proposes to continue to monitor and control aquatic invasive species (AIS) on a lake-wide basis in Long Lake through 2018.

Sissabagama Lake
Mean Annual Secchi Disk Reading – 9.55 Feet

Past projects in 1991 – 1997 were proposed to monitor water quality and build a quantitative database to determine changes that may occur.

Big Sissabagama Lake Association sponsored a “Clean Boats Clean Water” project in 2015, and is sponsoring the same project in 2016.

Whitefish Lake
Mean Annual Secchi Disk Reading – 13.45 Feet

Past projects in 1997 – 2012 mainly focused on (1) monitor water quality; (2) control aquatic invasion; (3) AIS education.

The Whitefish Lake Conservation Organization has been sponsoring a Clean Boats Clean Water project since 2013 and the project continues in 2016.

Petenwell Lake
Mean Annual Secchi Disk Reading – 2.42 Feet

Past projects in 1996 – 1997 were proposed to conduct water quality modeling and monitor water quality.

A restoration project in 2006 involved removal of sea walls, minor bank re-shaping, placement of rip-rap, establishment of vegetative buffers and implementation if individual storm water management plans.

Projects in 2006 – 2015 involved establishment of Clean Boats, AIS education and habitat restoration.

Lake Lucerne
Mean Annual Secchi Disk Reading – 22.18 Feet

Lake Lucerne Advancement Association has been sponsoring an AEPP grant, which will focus on increasing the awareness of AIS issue near the lake since 2008 – 2014; Clean Boats Clean Waters project is still ongoing since 2014.

Metonga Lake
Mean Annual Secchi Disk Reading – 22.94 Feet

Zebra Mussel study took part in 2002 – 2003. This study was to research the impacts of zebra mussels on Lake Metonga.

Past projects in 2005 – 2011 involved (1) AIS education; (2) control Aquatic Invasive Species; (3) comprehensive planning studies; (4) Eurasian Water Milfoil (EWM) treatment.

Lake Metonga Association Inc. has been sponsoring Clean Boats Clean Water project since 2013, and the project continues.

Shell Lake
Mean Annual Secchi Disk Reading – 14.45 Feet

A hydrologic budget and computer modeling project was proposed by The Shell Lake Inland Lake Protection and Rehabilitation District in 1997. This project was to collect data to determine hydraulic parameters and budget component.

The City of Shell Lake conducted studies to determine the feasibility of a boat washing station for the effective removal of aquatic invasive species. Most of the projects 2003 – 2011 mainly focused on controlling invasive species.

Yellow Lake

Mean Annual Secchi Disk Reading – 5.88 Feet

Burnett County Lakes & Rivers Association sponsored a two-year boat launch surveillance watercraft inspection, and public education project on five lakes in 2006.

An aquatic Plant Management Plan was carried in 2009 to monitor aquatic plant and educate lake residents.

Upper Eau Claire Lake

Mean Annual Secchi Disk Reading – 15.64 Feet

An aquatic invasive species (AIS) project was conducted for 2005 to address concerns about Eurasian Water Milfoil (EWM) and its potential to spread to other lakes in the area. A small-scale planning grant to educate 7th graders about the lake in 2010 and 2013 respectively.

A project in 2012 – 2016 involved (1) monitor pre-post treatment; (2) information and education; (3) develop aquatic plan management plan; (4) harvest aquatic plant mechanical

Middle Eau Claire Lake

Mean Annual Secchi Disk Reading – 18.80 Feet

An aquatic invasive species (AIS) project was conducted for 2005 to address concerns about Eurasian Water Milfoil (EWM) and its potential to spread to other lakes in the area. A small-scale planning grant to educate 7th graders about the lake in 2010 and 2013 respectively.

Past project in 2012 – 2016 involved (1) monitor pre-post treatment; (2) information and education; (3) develop aquatic plan management plan; (4) harvest aquatic plant mechanical

Lower Eau Claire Lake

Mean Annual Secchi Disk Reading – 16.43 Feet

Past project in 2004 was conducted to develop and modify lake management plan for the lake system that integrates with the town comprehensive land use plan.

A small-scale planning grant to educate 7th graders about the lake in 2010.

Butternut Lake

Picture 5: Butternut Lake

Mean Annual Secchi Disk Reading – 3.47 Feet

Internal Loading Assessment Project examined the internal phosphorus flux from sediments in Butternut Lake.

A project sponsored by the Price County Land Conservation Dept focused on modeling and monitoring water quality or sediment.

Picture 6: Butternut Lake

Devil's Lake

Mean Annual Secchi Disk Reading – 15.91 Feet

The Devils Lake Property Owners Association sponsored an AIS prevention and education project in 2006 and 2008.

A Clean Boats Clean Water project was conducted since 2006 – 2015.

Round Lake
Mean Annual Secchi Disk Reading – 20.05 Feet

A Eurasian Water Milfoil Inspection project was conducted on shoreline areas near boat landings on Round Lake.

Past projects 2007 – 2015 involved (1) monitor and control aquatic invasive species; (2) permit fee reimbursement for the maintenance and containment of AIS on Round Lake.

Picture 7: Round Lake

Lake Nebagamon
Mean Annual Secchi Disk Reading – 6.03 Feet

A survey was conducted to determine each septic system's compliance with state codes.

Lake Planning Grant project was done to collect and disseminate local shoreline zoning regulation information to all shoreline property owners around Lake Nebagamon.

Big Sand Lake
Mean Annual Secchi Disk Reading – 10.09 Feet

Property owners were surveyed to estimate the demand for a project that would have purchased lab equipment for phytoplankton analysis to support expanding food web monitoring.

Picture 8: Big Sand Lake

Method

Hedonic Modeling

Hedonic Modeling is a commonly used technique used to estimate the value of a specific attribute within a larger set of attributes associated with a specific commodity.[4] The most common usages include estimating the value of property improvements, the impact of public space on private property, and the value of environmental attributes associated with a given commodity on their prices. The models do this by creating a statistical picture of each attribute of a given property. These attributes can then be isolated to determine the specific value added. If desired, the additional step can be taken to create a hypothetical situation in order to determine the economic benefit of making a change to that attribute. This can then be weighed against the costs associated with making the change to test the economic feasibility of the project.

Regression analysis is used to create a statistical picture of the attributes of a sample set of properties and serves as the foundation for hedonic modeling. For studies that seek to determine the value of a specific environmental attribute such as this this basic form of the regression generally looks like;

$$P = f\,(S,L,E)$$

Where,

P = Sale Price of the Property
S = A Vector of Structural Attributes
L = A Vector of Locational Attributes
E = A Vector of Environmental Attributes

From the estimated coefficients on each of the attributes within of the vectors we can develop an idea about the marginal value of each of those attributes. This regression output is commonly referred to as the fundamental hedonic equation. In more complicated studies (such as the one presented here) this is referred to as the ‘first stage’ equation. Attributes with estimates negative coefficients have a negative impact on property prices while attributes with positive estimated coefficients have a positive effect upon property prices. Thus we would expect the estimated coefficient for water quality to have a positive coefficient. Conversely we would expect the estimated coefficient on the local tax rate to be negative. Indeed this proved to be the case.

The ‘second stage’ equation is derived from the first. This second stage creates a hypothetical ‘demand curve’ or willingness to pay for the attribute in question. By summing the estimated constant as well as the mean value of all variables times their estimated coefficients (excluding the variable we wish to focus on) we are able to create a

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[4] See Monsoon (2009) or Malpezzi (2012) for a recent, more complete overview of the uses of hedonic modeling.

statistical picture of the average property – as if the focus attribute did not exist. If we wish to create a statistical picture of the average property with the observed focus attribute we can add in the mean value of that attribute times its estimated coefficient. If we wish to test the impact of an alteration to the focus attribute we can add the altered value times the previously estimated coefficient to the 'average property created previously.

To understand how this works we might consider the decision to remodel a bathroom. The costs of doing so are not insignificant and we would reasonably wish to know if the improvements will be worth the cost and effort in terms of the change to the expected to the value of the property. Using hedonic modeling we would gather information about the sale price of a large number of houses. Some large, some small some of them with new remodeled bathrooms, some with old bathrooms and some in between – the larger our sample the better all things being equal. From this data we would run a regression analysis.[5] The regression output will show how each of the attributes of houses within the data set have impacted the sale prices of houses within the data set. This is the 'first stage' equation discussed above.

From this we can create an average house both in terms of attributes and sale price. If we remove the bathroom values from this calculation we can create the sale value of an average house – without a bathroom. We can then 'add' a bathroom back in with the attributes we are considering. From this we can determine the expected value of the property post renovation. Taking the value generated we can then subtract off the estimated value with the current attribute value to get an idea about how much value a change in the attribute (bathroom) is likely to generate.

Literature

There is a long -- but narrow -- set of literature on the economic value of water clarity stretching back to the 1960's. The issue that appears repeatedly in the early literature is the question of the best measure of water quality. That is, is it quality or clarity a better determinant of property values? If it is clarity that matters, are subjective or objective measures better?

Early papers by David (1968) and Epp and Al-Ani (1979) used subjective valuations of water clarity to measure the impacts on property prices. The earlier study by David used a simple rating of good, moderate, and poor convey water quality. These were then added to other property attributes in a simple hedonic model to determine the impact of water clarity upon property prices. David's study found that people's perceptions regarding water clarity has a significant impact upon property prices. The later study completed by Epp and Al-Ani focused on the impact of river water clarity on property prices. The authors found that although water clarity did have bearing upon property prices – but

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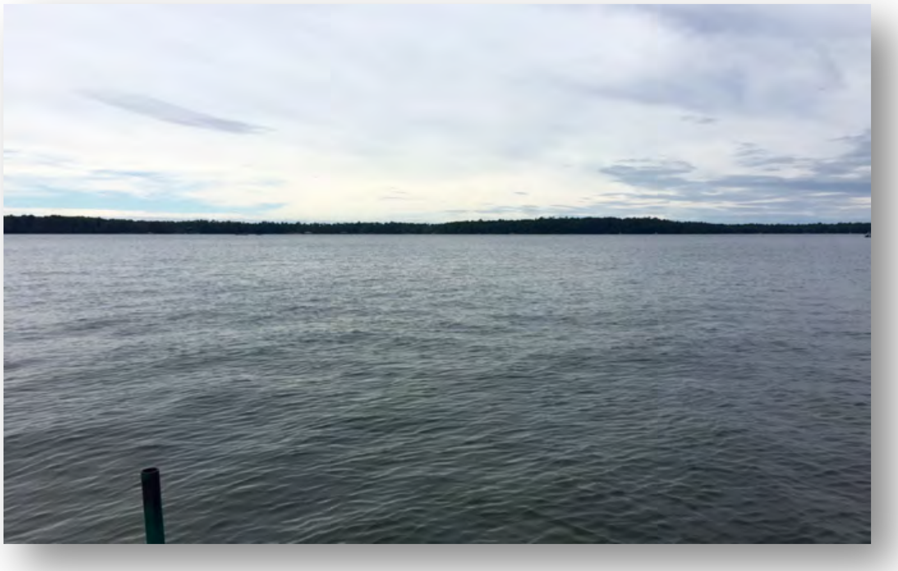
[5] The presentation here is simplified for the purposes of explanation. In the development of the specific form of the regression careful consideration must be given to a variety of factors.

only in terms of a decrease in quality. That is, a perceived decline in quality caused prices to fall but a perceived improvement in quality did not cause prices to rise. The authors did however find a consistent correlation between water acidity (as measured by pH) and property prices. Thus, raising an interesting distinction between the perception of water quality and water quality itself.

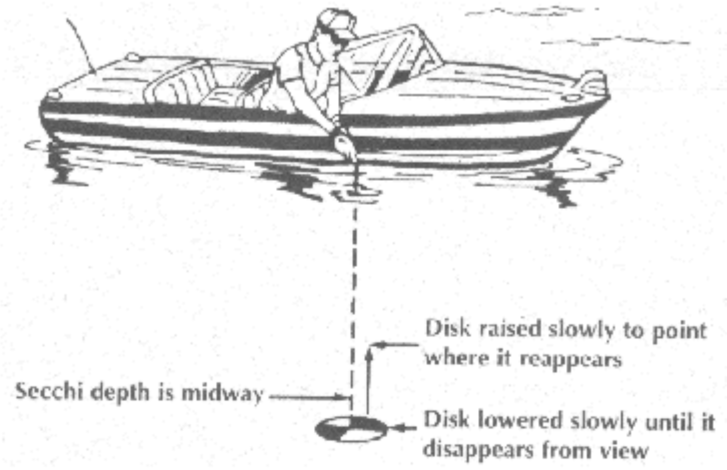


Picture 9: Round Lake

This trend in the literature continues with the study done by Brashares (1985). Using a hedonic model, this study focused on a large number of lakes in Southern Michigan and used eight different measures of water quality. The author found that only turbidity (an objective measure of clarity – similar to that used in this study) and fecal coliform had a significant impact upon property prices. The author concluded that although perception of water clarity does impact property prices these are most effectively captured with objective – rather than subjective – measures.

A number of studies have focused specifically on the question of using objective versus subjective measures of value and between perception (clarity) of quality and actual water quality in measuring water quality. A study by Steinnes (1992) found that it is the perception of water quality (clarity) rather than actual water quality that has the most significant bearing upon property values suggesting that subjectivity was an important factor. A later paper by Poor et.al. (2001) found that there existed significant differences between the economics values produced using subjective measures of water clarity when compared to using objective measures. In that study the authors found that subjective measures tended to under report water clarity when compared to objective measure (such as Secchi disk readings).

Picture 10: Lowering a Secchi



The specific model developed in this study is derived from Michael, Boyle, and Bouchard (1996). Using a hedonic model and data from a set of lakes in Maine this study demonstrated the effect of water clarity on lakefront property prices. In additional to the customary locational and structural variables the authors used Secchi disk readings as an objective measure of water clarity. In developing the model clarity data was converted into log form to in order to better represent willingness to pay for improved water. That is, to convey that individuals are likely to pay more for an improvement of 1 to 4 feet of water clarity than for an improvement of 21 to 24 feet of clarity. (Both being an improvement of 3 feet.) The authors concluded that about 15% of the property value on the lakes in the study area was the result of water quality. They further concluded that an improvement of an additional one (1) meter of clarity would roughly double the value associated with water quality on property prices. In terms of total property prices their study suggested about a 15% improvement in the sale price of property adjacent to the lake.

Subsequent studies by Boyle et.al (1998) and Krysel, Boyer, Parson, and Welle (2003) have used models very similar to the one described above. The results achieved by these studies produced similar results with a rough doubling of the value attributable to water clarity being associated with an improvement of an additional 1 meter of clarity (for those lakes with low initial water clarity. Indeed it would not be too much to say that the use of hedonic models combined with objective measures of water clarity (rather than quality) have become the ‘industry standard’ when attempting to uncover the implicit value of water clarity on property prices.

Data Sources

Water Quality data was obtained using Wisconsin DNR reports for 20 Northern Wisconsin Lakes.[6] Reported data over the last three years was used. These reports are available free to the public and, in many cases, date back several years. Reports are published several times a year at irregular intervals for most lakes and include data on water clarity. Water clarity data is collected and reported in two ways – one objective and one subjective respectively: First Secchi disks are used to measure the maximum water depth at which an object may be observed from the surface. Second the water

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[6] Reports available at http://dnr.wi.gov/lakes/waterquality/

clarity is rated on a scale from 1-5 (1 being the highest rating) on the perception of clarity. For this study statistical tests were run on both measures. (To be discussed in the next section.)

Housing prices and attributes were taken from the website Zillow.com. The prices and attributes of all houses and vacant properties sold in the last year over the study area were used. Following the attributes used by Michael, Boyle, and Bouchard (1996) data was gathered on the following structural attributes,

- Square footage of living area (zero for empty lots)
- Number of Stories
- Fireplace
- Heat
- Electric Heat
- Basement
- Deck
- Plumbing
- Septic System
- Garage
- Lot Size (Acres)

The following locational attributes,

- Public Road
- Local Tax Rate
- Distance from a City
- Lake Area

A few things about this list: First, we could develop a longer list of attributes for the given set of properties however this list has been shown in previous studies to be sufficient to generate statistically significant results. Second, where the specific attributes of a listing were unknown the site was assumed to not have said attribute. For example if no fireplace was mentioned in the listing a value of zero was assigned to that listing (binary variable) for that attribute. For properties that were simply a vacant lot all structural variables were assigned a value of zero. Finally, to these the above mentioned water quality attributes were added. In sum this produced a sample size of 373 listings.

Picture 11: Red Cedar Lake

The Model

The model used for this study is based upon one originally developed by Michael, Boyle, and Bouchard (1996) and which has been used for several other studies since that time.[7] That model was developed to determine the impact of water clarity upon real estate prices. Our model makes a few small but notable changes to take account of data availability and to test for anomalies noted in the literature.

This study uses the sale price of the property as the dependent variable rather than the sale price per square footage of lake frontage as in the Michael, Boyle, and Bouchard model. The reason for this modification is that data was not available for the vast majority of properties within the study area. That said, given the rarity of irregular shaped lots within the study area we feel that the included variable lot size and square feet of living area (both of which were significant in all regressions) capture much the same information.

Second, for our study we ran three separate linear regressions.[8] (These regression outputs were the 'first stage' equations mentioned in a previous section of this study.) The first utilized all of the variables listed in the previous section as well as one of the following: The log of mean annual water clarity in feet (Secchi Disk Reading), or Water Perception (on a scale of 1 – 5).[9] The second regression again utilized all the above-mentioned

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[7] For example see Kysel, Boyer, Parson, and Welle (2003).

[8] Regression outputs can be found in the appendix.

[9] All other studies that estimate the economic value of water quality use the log function form. This is done to reflect the fact that willingness to pay for water quality is not linear.

variables but removed the observations associated with the sale of vacant lots. The final regression removed several of the above variables and was run to test some potential unusual outcomes associated with the first two. (Discussed further in the next section.)

In each case the regression output was first used to construct a statistically average valuation for each lake – excluding and value attributable to water quality. This allows for variation between lakes in terms of the types of properties that exist on the lake.[10] One way of thinking about this would be the average value of the set of houses on a given lake within the study – if the lake was not there. This was accomplished by taking the sum of the mean value (for each lake) of each of the above variables times the estimated coefficient for that variable. To this the estimated constant term of the regression was added to complete the picture.

*a = Estimated value of c + (mean value of a * est. coefficient of a) + (mean value of b * est. coefficient of b) + …. + (mean value of x * est. coefficient of x)*

From this we add in the observed water quality. (For example: On Lake Chetac a mean annual Secchi disk reading of 4 feet). This allows us to estimate what the average house, on a given lake, should sell for – given all its attributes.

*Est. Price = a + (Log of Water Quality on Lake x * estimated coefficient for water quality)*

The table below (Table 1) gives the values for used for each lake to complete the equation above. The columns entitled ‘A’ represents the mean value of all attributes on that lake excluding water quality for each of the tested hypothesis. Column A represents the average value of a property on that lake – as though the lake did not exist. The ‘B’ columns are the estimated coefficients for water quality. The ‘A’ and ‘B’ columns on the left represent the estimated values using all the properties within the data set. The middle columns are the estimated values when the vacant lots are removed from the set of data while the columns on the right represent the estimated values with the reduced attribute set. Finally on the far right are the mean values for water clarity on any given lake in both feet and meters.

That is, people are generally willing to pay more to improve water clarity from 1 to 3 feet than they are willing to pay to improve water clarity from 22 to 24 feet. (Both being an improvement of two additional feet.)

[10] For example: Some of the lakes in the study area are highly developed with large high value properties on them. Other lakes are not nearly as developed in all aspects. Creating different statistical pictures for each lake allows us to account for these differences.

Table 1	All Properties		W.O		Limited Variable		Mean WATER Q (m)	Mean WATER Q (ft.)
	A	B	A	B	A	B		
Lake Chetac	$179,071	46459.33	$196,072	45292.89	$145,906	66046.22	1.22	12.33
Birch Lake	$181,471	46459.33	$187,721	45292.89	$158,523	66046.22	1.22	12.33
Balsam Lake	$485,299	46459.33	$492,952	45292.89	$403,674	66046.22	2.32	14.50
Red Cedar Lake	$230,689	46459.33	$262,320	45292.89	$164,657	66046.22	3.15	19.00
Long Lake	$306,743	46459.33	$293,973	45292.89	$262,086	66046.22	2.44	14.50
Sissabagama Lake	$157,429	46459.33	$191,547	45292.89	$76,723	66046.22	2.90	13.00
Stone Lake	$182,472	46459.33	$163,917	45292.89	$216,294	66046.22	7.29	31.00
Whitefish Lake	$411,802	46459.33	$416,948	45292.89	$354,273	66046.22	4.10	18.00
Petenwell Lake	$241,060	46459.33	$306,942	45292.89	$220,935	66046.22	0.74	6.00
Lake Lucerne	$262,544	46459.33	$266,131	45292.89	$199,427	66046.22	6.76	33.00
Metonga Lake	$184,561	46459.33	$202,936	45292.89	$143,617	66046.22	7.00	39.75
Shell Lake	$160,496	46459.33	$168,527	45292.89	$136,473	66046.22	4.43	32.00
Yellow Lake	$237,198	46459.33	$250,313	45292.89	$206,103	66046.22	1.78	14.00
Eau Claire (Upper)	$266,770	46459.33	$266,641	45292.89	$187,206	66046.22	4.77	20.25
Eau Claire (Middle)	$113,368	46459.33	$139,951	45292.89	$42,407	66046.22	5.73	34.75
Eau Claire (Lower)	$81,424	46459.33	$115,462	45292.89	$23,283	66046.22	5.01	39.00
Butternut Lake	$116,013	46459.33	$132,159	45292.89	$78,750	66046.22	1.06	6.50
Devil's Lake	$257,164	46459.33	$251,201	45292.89	$247,673	66046.22	4.86	24.00
Round Lake	$254,495	46459.33	$282,801	45292.89	$194,519	66046.22	6.11	30.20
Lake Nebagamon	$204,001	46459.33	$200,816	45292.89	$161,428	66046.22	1.84	9.19
Big Sand Lake	$236,274	46459.33	$246,586	45292.89	$201,429	66046.22	3.06	18.00
Combined	$218,562	46459.33	$238,142	45292.89	$175,331	66046.22	3.75	21.21

Using the values in the table above, we estimate that the average property on Lake Chetac would sell for $179,000 without the value added by the lake. (When we add in the lake with existing water quality the estimate increases to $243,400.) When we remove the vacant properties, the estimated value of the average property rises to $196,000. Finally when we remove several of the property attributes from the whole data set the estimated average property value falls to $145,000 – each as would be expected.[11]

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[11] The reasons for running this third regression are discussed below.

Using these values we can change the water quality to whatever hypothetical situation we might wish to estimate the value of the average property on a given lake with that alternative water quality. (This is the 'second stage' equation mentioned in an earlier section of the study.) In a later section we give estimates for a one (1) and three (3) foot increase in water clarity on several of the lakes in the study area.

Extensions and Concerns

As discussed in the previous section three (3) separate regressions were run to estimate the impact of water quality upon property prices. First we wished to apply a few different methods to give a range of likely outcomes based upon issues discussed in the literature. Second, the first regression output produced some unexpected results and we wanted to ensure that these results were not biasing our estimated values.

Picture 12: Round Lake

The first regression included all the variables mentioned in the above section. Several of variables had estimated coefficients that had signs opposite of what would be expected. For example: The coefficient for the variable 'Deck' was estimated to be negative and was statistically significant. Since it is unreasonable to suggest that the presence of an outdoor deck reduces the value of a property some concerns were raised.

A look through the source data reveled that there were at least a few occasions where a deck was visible in the pictures but was not mentioned in the listing. Since all variables were defaulted to zero this meant that any structural attribute not mentioned in the listing was assumed to not be present. This led to two hypotheses: First: That larger properties may not be listing all the attributes of the property, and second that the large, vacant properties may be biasing the sample. It was in order to test these that we ran two additional regressions.

The second regression removed all the vacant properties from the sample.[12] We wanted to ensure that the presence of large – and therefore expensive – vacant property was not having a significant impact upon the value of the amenities within the developed properties. From this regression output an identical set of calculations to those described in the previous section we found that this was not the case. Indeed, removing undeveloped properties had little impact upon the estimated impact of water clarity on property prices. (About a 1% change in most cases.)

The final regression removed several of the structural attributes in an attempt to test the significance of the non-reporting problem noted in the data. All locational attributes were retained. Removing several attributes puts more 'weight' on the remaining attributes in the sense that they are being asked to provide additional explanatory power.[13] As would be expected this had a larger effect upon the estimated impact of water quality on property prices. (As it did for all other remaining attributes.) However the associated r-squared fell significantly (from .59 to .48) suggesting that the explanatory power of this final model was inferior to the original one.[14] Thus, we can safely conclude that the non-reporting of certain property attributes is not reducing the effectiveness of our model.

Finally following up on Steinnes' (1992) and others work regarding subjective versus objective measures of water clarity work several regressions were run using the subjective measures of water clarity from the Wisconsin Department of Natural Resources reports. Using this data we were not able to derive statistical significance with any of the abovementioned models. As such we not feel that there was any clear connection between water perception and property prices. We speculate that this inconsistency with some studies in the literature may be due to the way this data is collected. Being a simple scale from 1 – 5, subjectively determined, may make it difficult for individuals collecting the data to make an evaluation that corresponds to the valuations being made by other data reporters in different locations. Consistent with some studies in the literature we found that the subjective measures of water clarity were unreliable in their ability to predict property prices. Indeed, to our surprise, there seemed to be a fairly low correlation between Secchi Disk readings and water perceptions.

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[12] Regression outputs can be found in the appendix

[13] To understand consider the case where all explanatory variables are removed excepting one. Our regression output would give the relationship between only those two variables. The relationship between the two might be strong but the explanatory power of one upon the other would very likely be poor.

[14] R-squared is a statistical measure of the explanatory power of the regression output. That is, the correlation between the independent and dependent variables. All things being equal a higher r-squared indicates greater explanatory power.

Analysis

Property Value Impacts

Using the output from the first regression we are able to derive estimated impacts to property values associated with changes to water clarity.[15] Using Lake Chetac as an example we estimated previously that the ***economic value of the lake to the average property***, at existing clarity, was roughly ***$64,400*** ($243,400 - $179,000). If we increase clarity by one foot we estimate that this will increase the property value associated with the lake will to $74,700 giving an average property value of roughly $253,700. If we increase clarity by three feet we estimate that the value associated with the lake will rise to roughly $90,400 giving a total average property valuation of roughly $269,400 – a little more than a 10% increase over the original valuation. A summary of the estimated changes for all lakes within the study area can be seen in the table below (Tables 2 and 3).

Moving from left to right the columns of this table give the estimated average property value with current water clarity. The second column gives the amount of that value that is attributable to the water quality. (For example, we estimate that the value of the average property (in all attributes) on Lake Chetac is $243,477 and of that $64,406 is attributable to the house being on the lake with its existing water clarity.) The third and fourth columns give the value attributed to the lake – with improved water clarity. The fifth column gives the new property value with an additional 3 feet of clarity. Mathematically this is the first column minus the second column plus the fourth column. The last column on the right gives the percentage change in property values associated with an additional 3 feet of water clarity. Using the numbers presented in table 1 above similar calculations could be made for any amount of additional clarity for any other lakes.

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[15] The numbers presented in this paragraph are derived from the output associated with the first regression output. (Full attribute list and all properties included.)

Table 2	Est Price	Value WQ	Plus 1 ft	Plus 3 ft	Increase Value	% Increase
Lake Chetac	$243,477	$64,406	$74,773	$90,406	25999.37	10.68
Birch Lake	$245,878	$64,406	$74,773	$90,406	25999.37	10.57
Balsam Lake	$579,709	$94,409	$100,131	$109,815	15405.56	2.66
Red Cedar Lake	$339,264	$108,575	$112,860	$120,400	11825.29	3.49
Long Lake	$403,642	$96,899	$102,339	$111,615	14716.38	3.65
Sissabagama Lake	$262,266	$104,837	$109,464	$117,529	12691.74	4.84
Stone Lake	$330,006	$147,534	$149,435	$153,019	5485.06	1.66
Whitefish Lake	$532,549	$120,747	$124,079	$130,101	9354.42	1.76
Petenwell Lake	$282,119	$41,059	$57,128	$78,521	37461.47	13.28
Lake Lucerne	$406,530	$143,986	$146,035	$149,880	5893.79	1.45
Metonga Lake	$330,113	$145,552	$147,534	$151,262	5710.04	1.73
Shell Lake	$284,574	$124,079	$127,187	$132,843	8764.33	3.08
Yellow Lake	$319,503	$82,305	$89,602	$101,458	19152.62	5.99
Eau Claire (Upper)	$394,526	$127,755	$130,635	$135,908	8152.59	2.07
Eau Claire (Middle)	$249,673	$136,305	$138,713	$143,183	6878.45	2.75
Eau Claire (Lower)	$211,469	$130,045	$132,790	$137,836	7791.66	3.68
Butternut Lake	$173,815	$57,803	$69,568	$86,748	28945.16	16.65
Devil's Lake	$385,714	$128,551	$131,383	$136,576	8025.53	2.08
Round Lake	$393,790	$139,045	$141,557	$145,774	6478.13	1.65
Lake Nebagamon	$287,477	$83,476	$90,604	$102,236	18760.53	6.53
Big Sand Lake	$343,667	$107,393	$111,783	$119,486	12093.54	3.52
Combined	$335,126	$116,564	$120,198	$126,710	10145.91	3.03

The changes in estimated values were similar when vacant properties were excluded from the sample data. Again using Lake Chetac as an example the table below shows that the estimated impact upon property prices changes only very slightly losing roughly $2,000 in value when compared with the previous estimates.

Table 3	Est Price	Value WQ	Plus 1 ft	Plus 3 ft	Increase Value	% Increase
Lake Chetac	$258,861	$62,789	$72,896	$88,136	25346.62	9.79
Birch Lake	$250,510	$62,789	$72,896	$88,136	25346.62	10.12
Balsam Lake	$584,991	$92,039	$97,617	$107,058	15018.78	2.57
Red Cedar Lake	$368,168	$105,849	$110,026	$117,377	11528.39	3.13
Long Lake	$388,439	$94,466	$99,770	$108,813	14346.90	3.69
Sissabagama Lake	$293,753	$102,205	$106,716	$114,578	12373.09	4.21
Stone Lake	$307,747	$143,830	$145,683	$149,177	5347.35	1.74
Whitefish Lake	$534,663	$117,715	$120,963	$126,835	9119.56	1.71
Petenwell Lake	$346,971	$40,028	$55,694	$76,549	36520.94	10.53
Lake Lucerne	$406,502	$140,371	$142,369	$146,117	5745.81	1.41
Metonga Lake	$344,833	$141,897	$143,830	$147,464	5566.68	1.61
Shell Lake	$289,491	$120,963	$123,994	$129,508	8544.29	2.95
Yellow Lake	$330,552	$80,239	$87,353	$98,911	18671.76	5.65
Eau Claire (Upper)	$391,189	$124,548	$127,355	$132,496	7947.91	2.03
Eau Claire (Middle)	$272,834	$132,883	$135,230	$139,589	6705.75	2.46
Eau Claire (Lower)	$242,242	$126,780	$129,456	$134,376	7596.04	3.14
Butternut Lake	$188,510	$56,351	$67,821	$84,570	28218.44	14.97
Devil's Lake	$376,524	$125,323	$128,084	$133,147	7824.03	2.08
Round Lake	$418,600	$135,798	$138,003	$142,114	6315.49	1.51
Lake Nebagamon	$282,196	$81,380	$88,330	$99,669	18289.51	6.48
Big Sand Lake	$351,283	$104,697	$108,977	$116,486	11789.91	3.36
Combined	$351,779	$113,637	$117,180	$123,528	9891.18	2.81

In either case the changes in value are highly dependent upon the current status of the Lake. Lakes with very poor water quality will find that improvements have a very large effect while those lakes that already exhibit high levels of water clarity will see little benefit from increased clarity. For example Butternut Lake in North Central Wisconsin would be expected to experience a nearly $30,000 increase in the value per property if it's water clarity were to improve by 3 feet. On the other hand Round Lake could expect to see only about $6,400 in increased valuation with an additional 3 feet of clarity. As a concluding note it is worth mentioning that Lake Chetac, the focus of this study, is near the bottom of the list in terms of existing water clarity. As such it would be expected that valuation gains, would be greater than average should water clarity be improved.

Using the information in tables 2 and 3 above we can determine the aggregate impact to property values associated with improved lake water clarity for any of the lakes in the study area. That is,

*Change in valuation = N * estimated change in average property valuation*

Where,

N = the number of properties adjacent to the lake.

Using the numbers for Lake Chetac, a rough count of the number of properties (400) means that for that Lake the total expected change in valuation would be in the neighborhood of 10.4 million dollars.[16] Using the 2015 average property tax rates for Sawyer County, Wisconsin (1.085%) this translates to an annual increase of $112,800 in county property taxes collected. The former number gives a rough idea of the direct private sector benefits of an additional 3 feet of water clarity while the later number gives the public sector benefits. These same methods could be applied to any of the lakes in the study area to arrive at the direct benefits associated with improvements in water clarity.

These figures give only the direct benefits associated with the change in water clarity. It is highly likely that other indirect benefits would result from the improvements. For example, several studies have pointed to the correlations between water clarity and tourism.[17] It is highly likely that should water clarity be improved on several of the study area lakes that those areas would experience increased tourism and the associated economic benefits to commercial establishments both on and near the lake.

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[16] We arrive at this figure by taking 400 properties * $26,000 – the expected average change in property valuation. This may be considered a ‘low end’ figure as uses the more conservative, estimate it also does not take account of rising property values near but not adjacent to the lake. If we use the estimated values from the third regression output we get an increased valuation of 7.4 million dollars and an $80,200 annual increase in property taxes. We feel this is a reasonable ‘high end’ estimate.

[17] For recent examples see Lee and Lee 2015 and Farr, et. Al. 2016.

Conclusions

There exists a clear economic rationale for the improvement of water clarity on several Northern Wisconsin lakes. Using a two stage hedonic model we have estimated that a 3 foot improvement in water clarity would increase property prices from 1 – 16%. The variation is largely dependent upon existing water clarity and the degree to which the lake is already economically developed.

Lakes with low water clarity – such as Lakes Chetac, Petenwell, and Butternut would see an improvement of between 9 – 16%. The figures for these lakes are much higher than for others within the study area because the willingness to pay for given improvements is likely higher on lakes where clarity is poor. That is, people are likely to pay more for a 3 foot improvement in clarity when the current level is 1 foot than they would if it were 20 feet

Picture 13: Butternut Lake

These differences in these increases (9 – 16%) are largely dependent upon the existing level of economic development on the lake. For example, Butternut would be expected to experience a greater gain in property values than Petenwell even though Butternut Lake's clarity is worse. The reason for this is the properties adjacent to Lake Petenwell are more advanced when compared to Butternut.[18] Therefore any changes to the entire property picture can be expected to have a smaller marginal component.

Thus, taken in sum we conclude that the marginal economic benefits to improvements in clarity are most significant when applied to lakes with low existing clarity and even more so when they are applied to lakes with low clarity and even more so when the surrounding areas are currently at a low levels of economic development.

Of course these improvements must be paid for. Generally speaking improvements have been undertaken by the public sector. For this reason we have estimated the local tax implications for Lake Chetac. Taken over just a few years the differences are not insubstantial and conservatively come to several hundred thousand dollars. Of course if one includes State as well as local taxes the increased tax revues rise substantially. From the results presented in this study one could easily produce similar estimates for any of the 20 lakes in the study area.

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[18] The estimated average property price on Lake Petenwell is just under $347,000 while on Butternut it is only $188,000.

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Appendix

Estimated Hedonic Coefficient			
VARIABLE	All Properties	No Empty Properties	Short Regression
INTERCEPT	72459.30	145876.7	-28437.48
	(77004.02)[b]	(227794.60)	(76891.69)
STOREY	31606.74	34496.84	26108.07
	(35969.34)	(33465.08)	(36271.27)
FIRE	29240.85	29789.45	-
	(32120.69)	(29771.28)	
HEAT	27438.92	30174.3	-
	(33092.41)	(30801.14)	
ELHEAT	115701.3[a]**	120614.2**	58451.3
	(57031.36)	(52684.37)	(57939.02)
BSMNT	-29018.8	-28806.02	-
	(33286.17)	(30878.47)	
DECK	-59158.01*	-66089.74**	-
	(32854.93)	(30758.46)	
PLUMB	-147572.6	-203013.6	-
	(51714.76)	(215674.70)	
SEPTIC	-22372.15	-24586.61	-
	(37767.73)	(36229.02)	
GARAGAE	-30330.72	-38023.3	-
	(39797.96)	(37994.19)	
LOTSZ_ACRES	1802.686	313.4863	2083.186*
	(1131.806)	(1112.975)	(1164.586)
TAXRT	-11415.32*	-13283.65**	-12186.67*
	(6198.0840)	(6561.469)	(6350.258)
DIST	1170.126*	1266.913**	733.0093
	(595.7380)	(627.9005)	(609.0434)
LKAREA_ACRES	4.209942*	5.944177**	7.343657***
	(2.474707)	(3.426787)	(2.423283)
LVAREA_SQFT	185.1292***	185.1749***	144.8257***
	(14.40669)	(13.46610)	(11.21874)
LNWQ_FT	46459.33**	45292.89*	66046.22***
	(22129.11)	(24704.45)	(22669.91)
R^2	0.529158	0.600311	0.480499
N	0.506153	0.572032	0.467263

[a] * Significant at the 90th percentile, **Significant at the 95th percentile, ***Significant at the 99th percentile.

[b] Standard errors are shown in parentheses.

	STORY	LVAREA	FIRE	HEAT	ELHEAT	BSMNT	DECK	PLUMB	SEPTIC	GARAGE	LOTSZ	RDPUB	TAXRT	DIST	LKAREA	WATERQ(FT)
Lake Chetac	0.13	1382.47	0.67	0.27	0.07	0.13	0.27	0.80	0.40	0.53	1.70	1.00	6.03	26.00	2400.00	4.00
Birch Lake	0.07	1583.86	0.50	0.21	0.00	0.36	0.29	0.79	0.57	0.57	5.70	1.00	6.03	20.00	364.00	4.00
Balsam Lake	0.67	2908.67	1.00	0.00	0.33	0.33	0.33	1.00	0.33	0.67	1.65	1.00	6.03	41.00	1901.00	7.63
Red Cedar Lake	0.25	1575.63	0.46	0.04	0.00	0.17	0.29	0.50	0.46	0.50	1.57	1.00	6.03	20.00	1897.00	10.35
Long Lake	0.40	2823.20	0.80	0.20	0.00	0.40	0.40	1.00	0.40	0.80	1.96	1.00	12.18	17.00	423.00	8.05
Sissabagama Lake	0.17	911.33	0.33	0.33	0.17	0.33	0.00	0.50	0.50	0.33	2.23	1.00	6.51	38.00	805.00	9.55
Stone Lake	0.33	1840.11	0.56	0.44	0.00	0.44	0.78	1.00	0.89	1.00	10.48	1.00	6.51	36.00	87.00	23.94
Whitefish Lake	0.38	2768.20	0.75	0.63	0.19	0.31	0.69	0.94	0.75	0.50	1.27	1.00	6.51	43.00	848.00	13.45
Petenwell Lake	0.16	1265.19	0.30	0.03	0.00	0.14	0.27	0.38	0.05	0.38	3.11	1.00	10.98	26.00	23173.00	2.42
Lake Lucerne	0.24	1617.57	0.52	0.33	0.10	0.33	0.38	0.76	0.52	0.67	9.70	1.00	9.43	94.00	1039.00	22.18
Metonga Lake	0.27	1309.80	0.53	0.27	0.07	0.40	0.47	0.73	0.67	0.67	1.23	1.00	9.43	94.00	2038.00	22.94
Shell Lake	0.38	1572.54	0.46	0.31	0.12	0.27	0.35	0.85	0.50	0.54	1.48	1.00	9.75	24.10	2513.00	14.45
Yellow Lake	0.27	1594.67	0.40	0.20	0.20	0.27	0.27	0.93	0.53	0.47	1.52	1.00	642	59.00	2283.00	5.88
Eau Claire (Upper)	0.38	1767.50	0.75	0.38	0.00	0.25	0.25	0.75	0.25	0.38	11.95	1.00	9.78	50.00	1024.00	15.64
Eau Claire (Middle)	0.08	939.17	0.25	0.42	0.08	0.08	0.33	0.50	0.42	0.42	1.85	1.00	9.78	50.00	880.00	18.80
Eau Claire (Lower)	0.13	481.00	0.25	0.13	0.00	0.13	0.13	0.50	0.25	0.25	3.10	1.00	5.93	53.00	784.00	16.43
Butternut Lake	0.28	1091.11	0.33	0.33	0.00	0.44	0.50	0.67	0.50	0.56	2.16	1.00	10.72	83.00	983.00	3.47
Devil's Lake	0.60	1828.80	0.80	0.60	0.40	0.40	0.80	1.00	0.80	0.80	6.70	1.00	6.42	40.00	975.00	15.91
Round Lake	0.30	1444.79	0.47	0.30	0.04	0.21	0.38	0.64	0.51	0.51	3.14	1.00	6.51	71.00	3294.00	20.05
Lake Nebagamon	0.43	2065.87	0.65	0.57	0.00	0.17	0.52	0.87	0.65	0.61	1.98	1.00	12.58	29.00	986.00	6.03
Big Sand Lake	0.50	1654.00	0.50	0.25	0.00	0.25	0.50	0.75	0.50	0.50	6.84	1.00	6.42	42.00	142700	10.09
Combined	0.28	1550.73	0.49	0.29	0.06	0.25	0.39	0.70	0.48	0.55	3.42	1.00	8.43	47.58	4004.53	12.29