"LAKESHORE PROPERTY VALUES AND WATER QUALITY: EVIDENCE FROM PROPERTY SALES IN THE MISSISSIPPI HEADWATERS REGION."

Submitted to the Legislative Commission on Minnesota Resources

By the Mississippi Headwaters Board

and Bemidji State University

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Forward Forward

The Legislative Commission of Minnesota Resources (LCMR) provides grants on a competitive basis to proposals that best protect the State's natural resources. The Mississippi Headwaters Board (MHB), a joint powers board of eight counties, joined in the mission under Minnesota Statute 103F. 361-377 in 1980. The mission is to protect and enhance the values of the first 400 miles of the River. This pristine stretch of River runs through eight rural counties from the Headwaters at Lake Itasca in Clearwater County to the southern border at Royalton in Morrison County. MHB is responsible for the initiation of this project

The First City on the Mississippi River is Bemidji, located on beautiful Lake Bemidji. The location, scholarly reputation of the researchers and cooperation of the lake associations made Bemidji State University (BSU) the best choice to implement MHB's proposal to the LCMR. The River runs through many lakes and is the sink into which other lakes contribute runoff. As the contributing watershed to the Mississippi River, the lakes data were included in creating this tool for wise decision-making that may aid in preserving the integrity of the Upper Mississippi River basin for posterity. "We do not own our land (or water), we borrow it from our children".

For the first time, this study defines the dollar value of water quality to the northern Minnesota economy. The State of Minnesota consists of a well-educated population, aware of the value of the State's most valuable resource, clean water. In today's political/budgetary climate, support of the environment that maintains water quality has been viewed as frivolous, anti-business, or an unnecessary expense. Through objective scientific method and hedonic modeling, this study attaches tremendous economic value to investing in a clean environment. Thank you for using the information to the best advantage for all people.

In Public Service,
Jane E. Van Hunnik-Ekholm, MS
MHB Executive Director
May 15, 2003

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EXECUTIVE SUMMARY

PURPOSE OF STUDY

The purpose of this study was to conduct research (similar in design and format to the above mentioned Maine studies) to determine if water quality of Minnesota lakes located in the Mississippi Headwaters Board jurisdiction affects lakeshore property prices. The hypothesis is that it does.

Like most environmental amenities, water quality is a non-market good that is not bought and sold outright as its own product on the marketplace. Instead, water quality is exchanged in the market, albeit implicitly, as an inherently attached characteristic or feature of some differentiated product. Differentiated products are those that consist of different or varying characteristics and exchanged on the market as a packaged good. Residential lakeshore properties are these kind of differentiated products because each one is unique in the quantity and quality of characteristics attached to it---the property, structural, locational and environmental quality variables that make it distinct.

METHOD

The price contribution of an attached environmental amenity must be determined indirectly. In the case of lakeshore property, the value of water quality is capitalized in the value of the land (Boyle et al 1998; Steinnes 1992) and its share of a property's price can be determined "through the price differentials between properties on lakes with differing levels of water quality, while controlling for other property characteristics"

(Michael et al 1996). Hedonic regression analysis is used to determine the implicit price of environmental amenities for differentiated products.

Available water quality data were obtained from the Minnesota Pollution Control Agency and data on lakeshore properties were collected from county assessors. A property site-quality rating inventory was also included. From these data, explanatory variables were selected for use in hedonic models. Lakes were assigned into groups, as a proxy for real estate market areas. From these lakes, 1205 residential lakeshore property sales that occurred in 1996 through 2001 were used. A hedonic equation was determined for each of the lake groups with a water quality variable used to explain variation in sales prices. Using these equations, the implicit prices of water quality---the effects on lakeshore property prices---are estimated for lake groups and for individual lakes. Combined data from the lake groups were then used to calculate the marginal amounts that people are willing to pay for lake water quality.

FINDINGS AND IMPLICATIONS

Water quality was shown to be a significant explanatory variable of lakeshore property prices in all lake groups in both versions of the model. Water quality has a positive relationship with property prices. Site quality, the other environmental variable used in the MN model, was found to be significant in four of the six lake groups with a positive relationship with property prices in one lake group and negative in three.

Using the estimated hedonic equations from the MN model, the implicit prices of water quality was determined and calculations were made to illustrate the changes in property prices on the study lakes if a one-meter change in water clarity would occur. Expected property price changes for these lakes are in the magnitude of tens of thousands to millions of dollars. The evidence shows that management of the quality of lakes is important to maintaining the natural and economic assets of this region.

SECTION 1

INTRODUCTION AND PURPOSE OF STUDY

Minnesota's lakes are essential to the ecological, economic and cultural health and well being of the State of Minnesota. The more than 10,000 freshwater lakes that the State is known for provide essential benefits that must be wisely managed if they are to be sustained. Aside from their ecological importance, Minnesota's lakes are extremely important to the state's recreation and tourism industry, as well as to many local economies. According to the Minnesota Department of Natural Resources (MNDNR hereafter): "High-quality water is essential for a healthy state economy" (1998). Clearly, Minnesota lakes are an extremely valuable resource, assets worthy of protection if their benefits are to continue.

The challenge to maintain and protect lake water quality will become increasingly difficult if population and development trends continue at the present rate. In the last 50 years, lakeshore development on Minnesota's lakes has increased dramatically (Minnesota Planning 1998) and during the 1990s---in much of the area where the Mississippi Headwaters Board has jurisdiction---"growth has exploded…as demand for lakefront property has increased" (Minnesota PCA 2000). Lakeshore property is in demand because of the amenities or benefits they provide its owners, such as water-based recreation possibilities, an aesthetic setting for a home, tranquility away from urban and commercial life, and perhaps the privilege or esteem of owning an increasingly scarce and valuable resource.

While the overall quality of Minnesota lakes may be good, lakeshore development has and continues to degrade lake quality. In a recent MNDNR study, it was found that “developed shorelines have two-thirds less aquatic vegetation than undeveloped shorelines” (MNDNR 2001). From an ecological and water quality perspective, this finding is startling and is even more alarming when we consider that about two-thirds of Minnesota’s lakeshore is privately owned and not all of it is developed---yet.

Lakeshore development---in combination with other land-use activities and surface-water recreation---increases sediment, nutrient and other pollutant inputs. These inputs lead to unnatural eutrophication and reduce water quality. Other undesirable effects include the loss of native plants and animals, loss of littoral habitat and increases in invasive species, including exotics. The manifestation of reduced water quality results in a reduction of a lake’s aesthetic values, decreased recreation benefits, and a lowering of the price of properties around the lake (Boyle, Lawson, Michael, Bouchard 1998).

Public policy and the activities of lakeshore property owners directly affect water quality. Protecting water quality through prudent policy and precautionary treatment of lakeshore property is more effective and less expensive than restoration of a degraded ecosystem. For these reasons, economic analysis of the benefits of protecting lake-water quality could be valuable to policy makers, lakeshore property owners and the general public. This type information could enhance our understanding of the economic arguments for protecting water quality and help in determining the optimal level of protection.

In the State of Maine, studies have shown that water clarity---an observable water quality measure---significantly affects lakeshore property prices and that there is a significant demand for it (Boyle, Lawson, Michael, Bouchard 1998; Michael, Boyle, Bouchard 1996). If a similar relationship proves true for Minnesota Lakes, lakeshore property owners, state and local governments might regard enhanced property values as a common-sense incentive for protecting water quality and most importantly, take appropriate measures.

Like most environmental amenities, water quality is a non-market good that is not bought and sold outright as its own product on the marketplace. Instead, water quality is exchanged in the market, albeit implicitly, as an inherently attached characteristic or feature of some differentiated product. Differentiated products are those that consist of different or varying characteristics and exchanged on the market as a packaged good, whereby “consumers consider them all to be members of the same product class” (Palmquist 1999). Residential lakeshore properties are these kind of differentiated products because each one is unique in the quantity and quality of characteristics attached to it---the property, structural, locational and environmental quality variables that make it different and unique from others. Each one of these variables contributes to the package price and differences in price between differentiated products are attributed to the quantities and quality of variables unique to each. The share of the package price for some of the characteristics of the differentiated product---market goods that are routinely traded, like commodities such as buildings and land---can be determined rather easily. However, the price contribution of an attached environmental amenity must be determined indirectly. In the case of lakeshore property, the value of water quality is capitalized in the value of the land (Boyle et al 1998; Steinnes 1992) and its share of a property's price can be determined "through the price differentials between properties on lakes with differing levels of water quality, while controlling for other property characteristics" (Michael et al 1996). Hedonic regression analysis is used to determine the implicit price of environmental amenities for differentiated products.

The hedonic pricing method is an economic valuation technique used to estimate implicit prices for individual characteristics of differentiated consumer products---those that vary in amount and quality of characteristics they contain (i.e., residential property)---and then used to infer the underlying demand for the characteristics. Data used in a hedonic study are analyzed using regression analysis, which relates the product price to its characteristics---making it possible to estimate the effects, the value that different characteristics have on product price (Palmquist 1991, 1999). "The main promise of hedonic methods is that it becomes theoretically possible to infer demand for non-marketed commodities from markets for related commodities" (Braden & Kolstad 1991). Some non-market environmental amenities (or disamenities if the case may be) influence the price for which a commodity sells by virtue of their inherent attachment with the commodity. For example, a residential property with a desirable environmental quality attached to it (like a scenic setting or unpolluted air or water quality) and a comparable property without it would normally sell for different amounts. Most environmental amenities are not traded on markets, yet we know people reveal their preference for them by paying more to enjoy them. “Part of the variation in property prices is due to differences in these [kind of] amenities” (Braden, Kolstad, Miltz 1991).

PURPOSE OF STUDY

The purpose of this study was to conduct research (similar in design and format to the above mentioned Maine studies) to determine if water quality of Minnesota lakes located within the Mississippi Headwaters Board jurisdiction affects lakeshore property prices. The hypothesis is that it does. A steering committee for the Mississippi Headwaters Board recommended the sample of lakes that are investigated. Available water quality data was obtained from the Minnesota Pollution Control Agency and data on lakeshore properties sold between 1996-2001 was collected from county assessors. A property site-quality rating inventory was also included. From these data, explanatory variables were selected for use in hedonic models. Lakes were assigned into groups, as a proxy for real estate market areas. A hedonic equation was determined for each of the lake groups with a water quality variable used to explain variation in sales prices. Using these equations, the implicit prices of water quality---the effects on lakeshore property prices---are estimated for lake groups and for individual lakes. Combined data from the lake groups were then used to calculate the marginal amounts that people are willing to pay for water quality.

In summary, water quality of lakes is important for Minnesota’s ecological, cultural and economic sustainability. Evidence from Maine indicates that water quality affects lakeshore property prices and that there is significant demand for it. If a similar relationship exists for Minnesota lakes, lakeshore property owners and policy makers should regard enhanced property values as important enough reason to protect water quality. This study seeks to test this hypothesis.

SECTION 2

LITERATURE REVIEW

This section provides a brief overview of literature relevant to the research purposes of this project. Hedonic studies are performed to determine if non-market environmental amenities affect the prices paid for some market goods and to estimate the implicit prices embedded therein. Estimating and knowing the value of these amenities is important information to consider for informed policy and wise benefit–cost decisions regarding their use. Others have investigated the affect that water quality has on prices paid for residential lakeshore properties. This body of work---studies that have used the hedonic pricing method for determining the affect that water quality has on prices paid for residential lakeshore properties---is briefly highlighted to inform and guide the research design and analysis for this study.

The hedonic pricing method or model is commonly used to estimate the implicit prices of environmental quality amenities that property owners pay as a portion of the overall prices of properties. Hedonic models have been used in a wide array of applications, including for example: the effect of open spaces in Portland, Oregon (Bolitzer & Netusil 2000); the effect of proximity to Lake Superior shoreline in Michigan (Orr et al 2001); urban forest amenities effect in Salo, Finland (Tyrvainen & Miettinen 2000); the effect of an ocean view in Bellingham, Washington (Benson et al 1998); and also in studies of lake-water quality.

David (1968) published a hedonic study that looked at how water quality might affect lakeshore property values on artificial lakes in Wisconsin. She found that property prices were significantly correlated with a measure of water quality that represented levels of lake pollution (an "expert opinion" rating of poor, moderate or good assigned to each lake). Although statistically significant, the "expert opinion" based rating used was subjective and it is difficult to specify how the three ratings were different.

Instead of using a subjective measure to represent water quality, Brashares (1985) used 39 objective measures of water quality. Of these he found two---fecal coliform bacteria and turbidity (visual clarity)---to be significantly correlated with property prices in his study of 78 lakes in southeast Michigan. His results also indicated that it is likely that only water quality measures that are perceivable to property owners are those capitalized in property prices. This would seem to be a reasonable assumption since few property owners would be aware of or act on water quality factors not readily recognized or known through the senses.

Steinnes (1992) also suggests that it might only be a perception (or even misperception) of water quality to which property owners implicitly apply value, rather than actual water quality. He cites the examples of acid rain and naturally stained dark water lakes; potential conditions found in the region of Minnesota where he studied 53 lakes.
The effects of acid rain will improve clarity in certain lakes (usually a visual indicator of good water quality), but in actuality will degrade water quality with its polluting effects.

Likewise, a perception of low water quality due to tannin staining might lead to a misjudgment when water quality can actually be good. In his study, Steinnes used water clarity (secchi disc readings), the percentage of littoral (shallow water), and a measure based on amount of suspended organic material in water as his objective measures of water quality.

Michael, Boyle and Bouchard (1996) surveyed purchasers of lakeshore property to determine if their perceptions of water clarity would be correlated with the actual water clarity in the lake where they purchased. Survey results indicated that purchasers were familiar with current water clarity and that water clarity history also influenced their purchase decisions. Perceptions turned out to be significantly correlated with measures of water clarity that secchi disc readings indicated. As a result, the researchers used the minimum secchi disc reading for the lake for the year the property was sold and a historical trend variable as measures of water clarity. The historical trend variable was the difference between a ten-year average of minimum secchi disc reading and the minimum reading for the lake the year the sale took place. They also chose clarity as the measure of water quality because it is the most observable manifestation of eutrophication, which was the main concern of the study: the degradation of water quality in Maine lakes resulting from cultural eutrophication. They assumed that other indicators of cultural eutrophication such as chlorophyll levels, dissolved oxygen, fish habitat, and swimmability were correlated with water clarity. Over 500 lakeshore properties on 34 Maine lakes were grouped into four separate markets to test if the estimated implicit prices for water clarity for each lake group would vary across markets and thus might minimize the effects of geographical characteristics. Limitations of the study results were reported to be: that the estimates were based on a very small percentage of Maine lakes so might not be accurate predictors for lakes outside the real estate markets used; and that the estimated implicit prices for water quality are based on all things being equal, i.e., the supply of properties would not increase due to water quality improvements in most lakes through improvement efforts.

Boyle, Lawson, Michael and Bouchard (1998) updated the Michael study to refine its estimates by adding an additional year and a half of sales data, adding a seventh lake group and two lakes, and treated the missing water clarity observations more systematically. This study went further than Michael's by combining data from lake groups to estimate a demand equation that infers the marginal amounts that people are willing to pay for improved water clarity. As did Michael's, the results of this study also showed that water clarity significantly affects property prices around Maine lakes and the same limitations apply. In addition, they showed there is a significant economic demand for water clarity by lakeshore property owners.

The preceding two studies of Maine Lakes led to further investigation of issues relevant to hedonic models and the measurement of environmental quality. The issue that lakeshore property owners might perceive water quality differently than the empirical measures used in hedonic studies was investigated by Michael, Boyle and Bouchard (2000). Purchasers of lakeshore property on twenty-two Maine lakes (that had been separated into three market groups) were surveyed to correlate perceptions of water clarity to actual measurements. Respondents rated their lakes for minimum water clarity on a scale approximating secchi disk readings for Maine Lakes. The results of the survey found respondents' perceived ratings were significantly correlated with the actual minimum water clarity conditions on the lakes. Nine different water-clarity variables were then constructed using secchi disk data and based on survey results to use in hedonic models. Results revealed that estimated implicit prices for nearly all of the water quality variables proved significant, yet, implicit prices varied between markets when the nine models were estimated for the three market groups. However, within each of the market groups, they found large enough price differences (overlapping confidence intervals) between perceived and objective water clarity variables. A concern was expressed that different conclusions, and ultimately policy recommendations could result depending on the selected variable entered into a hedonic equation. The authors recommend that the measure of the environmental variable be selected with caution to reflect the public's perceptions of environmental quality, and also be based on conceptually and theoretically sound logic.

Poor, Boyle, Taylor and Bouchard (2001) investigated the issue of using objective or subjective measures of water clarity in hedonic models. They studied four market groups in Maine, where each group contained between 4 and 13 lakes. Minimum secchi disk readings for each lake for the year of sale for each lakeshore property were used as the objective measure of water quality. Subjective measures were obtained by surveying lakeshore property purchasers for their perceived water clarity judgments that compared to the objective measures by design. Both the objective and subjective measures proved to be significant variables in the models. An interesting finding was that most respondents tended to systematically under-estimate water clarity when compared to the actual measure. This resulted in larger implicit price estimates than those estimated from the objective variable. Therefore, the authors concluded that the objective measure (data usually readily available) was superior to the subjective measure (based on perceptions obtained from surveys) and should more accurately estimate the implicit price of water clarity in hedonic models.

Boyle and Taylor (2001) were concerned that the estimated implicit price for an environmental amenity could be biased if property-characteristic data is a source of substantial error (errors-in-variables-problem). They investigated the effect of using data provided by tax assessors versus data received from a survey of lakeshore property purchasers to estimate the implicit price of lake-water clarity. Lakeshore properties sold between 1990 and 1995 on 34 Maine lakes that had been segmented into four market groups were used in the study. Convergent validity testing was performed and the authors reported that from a statistical perspective, both sources of property-characteristic data performed equally well. Results of the hedonic-price functions indicated that the water quality variable is a significant predictor of property prices for both data sources. Convergent validity testing showed that coefficient estimates for the water quality variable did not vary significantly when estimated with either source of data. However, differences in implicit prices were shown to be substantial and it was noted that in terms of the effects of property characteristic measures, the magnitudes of some of the implicit prices could affect decision-making policy outcomes. The authors conclude that their results are encouraging for the continued use of tax assessor data in hedonic studies.

Although not a study of fresh-water lakes, Leggett and Bockstael (2000) did show that water quality has a significant effect on residential property values along the Chesapeake Bay. The water quality measure used was fecal coliform bacteria levels, information that had been made widely available to market participants.

The literature reviewed here is quite relevant and closely correlated with the purposes of this study. The studies reviewed clearly provide a background for the importance, justification and methods of this study. The hedonic pricing technique, appropriately applied, using pertinent data should provide the evidence to either prove or disprove the hypothesis that water quality of Minnesota lakes located in the Mississippi Headwaters Board jurisdiction affects residential lakeshore property prices.

SECTION 3

METHODS

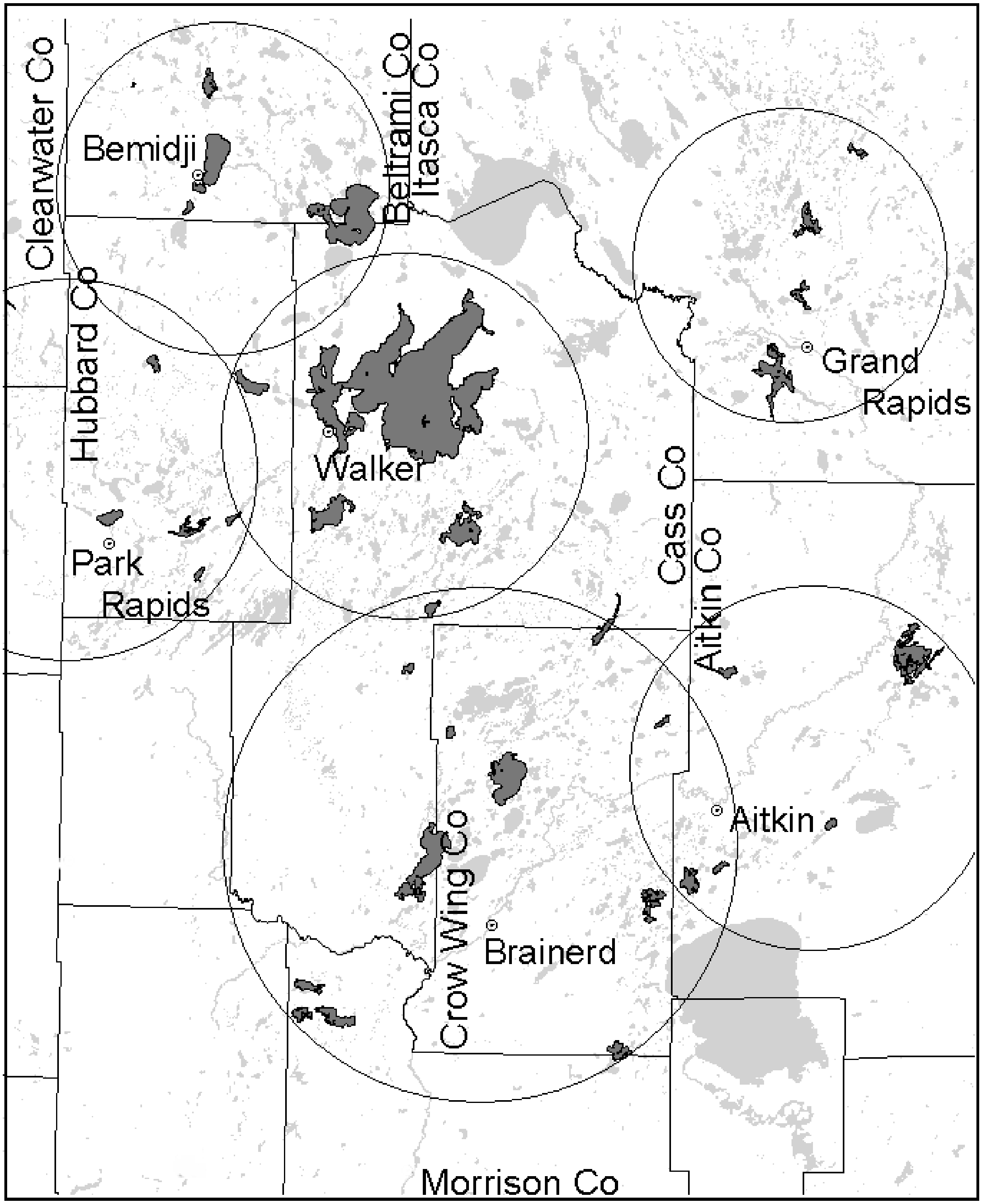
The purpose of this study is to test the hypothesis of whether or not water quality of Minnesota lakes located in the Mississippi Headwaters Board jurisdiction affects prices paid for residential lakeshore properties. As was done in the studies of Maine lakes, the implicit prices of water quality---the share of a lakeshore property's price attributed to water quality---will be identified through the price differentials between properties on lakes with differing levels of water quality, while controlling for other property characteristics. This study replicates that research that showed water clarity, a water quality measure, significantly affects property prices around Maine lakes (Boyle, Lawson, Michael, Bouchard 1998; Michael, Boyle, Bouchard 1996).

Study Sample and Data Used

Lakes

Thirty-seven lakes were selected from a pool generated by a steering committee of the Mississippi Headwaters Board. Lakes were chosen that provided a diversity of size, spatial and political representation in the jurisdiction and having water quality monitoring data available from the Minnesota Pollution Control Agency. Lakes were assigned to one of six groups that approximated real estate market areas and the nearest major community (Figure 1).

Figure 1. Location of study lakes[1] and lake groups (market areas)[2].



[1] Study lakes identified by darker shading.
[2] Lake groups identified by circle lines.

Two lakes, Cass and Leech, were included as dummy variables for lakes with special features for being situated within the Leech Lake Indian Reservation and the Chippewa National Forest. In addition, both these lakes have considerable lakeshore frontage that is publicly owned.

Lakeshore Properties

Residential lakeshore properties sold on the lakes in the years 1996 through 2001 are included in the study. A total of 1205 property sales are used. On lakes that exceeded 50 property sales (10 of the 37 lakes), 50 properties were randomly selected from each and included in the study. This limitation was applied to prevent any overwhelming influence that any one lake might have on the study results. It was also necessary to limit the sample size to meet project time and budget criteria.

Property Data

Property sales data were obtained from county assessor records. Only fair market sales were used in order to exclude relative, gift or other below market transactions that may have occurred. Only single-family residential type properties that are less than 20 acres in size were used to avoid resorts, multi-family rental units or other commercial enterprise type property sales. Lake-lot properties without dwellings as well as ones with year-round or seasonal dwellings are included to reflect the range of development stages of lakeshore properties. Of the 1205 properties included, 162 or 13.2% had been purchased without dwellings.

Data obtained for each property were its purchase price (PP), assessed values for land and structures at time of purchase, feet of frontage on the lake (FF), lot size (LOTSIZE), tax rate (TAXRATE), square footage of living area (LVAREA), if dwelling had more than one story (STORY), a fireplace (FIRE), central heating (HEAT), a full bathroom to indicate a well or municipal water source (PLUMB), septic or sewer service (SEPTIC), a garage (GARAGE), the number of adjacent properties within 1000 feet of frontage (DNSTY), and if the property access road is publicly maintained (RDPUB).

Environmental Quality Data

The water quality measure (WQ) used was the mean secchi disk reading for the lake for the year a property sold. Boyle et al (1998) used the minimum reading for the year the sale closed as its best proxy for buyer/seller perceptions of water quality at the time of sale. It was the authors' opinion that it was not possible to know the correlation between when a buyer perceives a lake's water quality and his or her purchase date without buyer provided information, which this study did not have. Therefore, it was thought that the mean reading should deliver a more conservative telling. When readings were not available for a particular year in which a property sold (7% of cases), the mean for readings for 1990-2001 was used.

As in the Boyle et al study, secchi disk readings, a measure of water clarity, was used as the all encompassing water quality variable because of the correlation it has with other lake water quality and health characteristics such as a quality fisheries, a lake's swimmability, etc. According to Boyle et al, other water quality characteristics may affect property prices in their own right, but are related and so are included in the implicit price of the WQ measure used here.

Properties were site-visited and rated for lakeshore property environmental quality features and an average rating was computed for each lake. The ratings (SQ) provided a subjective environmental quality measure to the study.

River Properties

Data were also collected in selected counties pertaining to sales of riparian property on the Mississippi River. Purchase price was recorded as well as the other variables contained in the lake data. Preliminary analysis, including multivariate statistics on the relation between purchase price and property characteristics, provided compelling evidence that the model used for lakeshore analysis would apply very differently to river property. The variability of purchase price is far less predictable among riparian property sales in the MHB region based on the data collected. Even the collection of water quality measures is different. The data available from the State as well as from the River Watch Program does not contain secchi disc readings. The closest indicator of clarity that is available is turbidity. In consultation with MHB staff and the Steering Committee, it was deemed appropriate to summarize the results of this preliminary analysis on riparian property sales. But it would not be worthwhile to pursue further application of the hedonic model to river property. While techniques exist to transform turbidity data to serve as a proxy for water clarity, the Steering Committee determined that the hedonic analysis would be so different as to not merit the additional effort. Summary results on river data are provided in Appendix E.

Method of Analysis

Hedonic pricing is a 'revealed preference' method commonly applied for valuing environmental amenities---such as environmental quality---that is actually being traded in residential property markets. Another economic technique used to value non-market environmental amenities is the contingent valuation 'stated preference' method. Unlike the hedonic pricing method that has the advantage of using actual market transaction evidence for its calculations, contingent valuation is used where market transactions are not available and must resort to hypothetical, willingness-to-pay estimates obtained from surveys. Like hedonic pricing, there is another revealed preference method used to value non-market environmental amenities; the travel cost method. It however, is designed specifically to estimate the value of benefits or costs for recreation sites or activities.

The hedonic pricing method (also referred to as hedonic property value model or hedonic model) is an econometric valuation technique used to reveal the portion of purchase price that is attributed to environmental amenities, such as water quality. The hedonic model is a devised relationship between market goods and the characteristics, including complimentary environmental characteristics that contribute to its product price (Freeman 1993), for the purpose of estimating the value of the implicit, non-market environmental characteristic (amenity) contained. Data used in a hedonic model are analyzed using regression analysis, which relates the product price to its characteristics---making it possible to estimate the effects, the value that different characteristics have on product price (Palmquist 1991, 1999). In addition, “the main promise of hedonic methods is that it becomes theoretically possible to infer demand for non-marketed commodities from markets for related commodities” (Braden & Kolstad 1991). Some non-market environmental amenities (or disamenities if the case may be) influence the price for which a commodity sells by virtue of their inherent attachment with the commodity. For example, a residential property with a desirable environmental quality attached to it (like a scenic setting, unpolluted air or lake water quality) and a comparable property without it would normally sell for different amounts in a market where they co-reside. Most environmental amenities are not traded on markets, yet we know people reveal their preference for them by paying more to enjoy them. “Part of the variation in property prices is due to differences in these [kind of] amenities” (Braden, Kolstad, Miltz 1991). “The share of a property’s price that is attributable to water quality is identified through the price differentials between properties on lakes with differing levels of water quality, while controlling for other property characteristics” (Michael, Boyle & Bouchard 1996).

To determine if water quality has an effect on the prices paid for lakeshore properties, hedonic models were devised for this study to estimate the value of water quality capitalized in the sales---the implicit price of water quality. The value of an environmental amenity such as the quality of lake water is capitalized in the value of the land and not in the value of structures or other improvements (Boyle et al 1998). Hedonic price equations were used to net out the structure and other improvement influences in property prices to isolate environmental amenity values. The equations represent the sales prices of properties as a function of the characteristics of the property for a real estate market.

Procedure

A separate equation is estimated for each of the six lake groups used in the study. The importance of using different groups of lakes representing separate markets is to minimize the effects of geographical differences and to see if the estimated implicit prices for water quality differ across markets.

The hedonic model used by Boyle et al and also in this study:

$$PP = f\,(P, S, L, \ln WATERC*SA$$

expresses its dependent variable, purchase price (PP), as a function of property characteristics (P), characteristics of structures (S), locational characteristics L), and the natural log of water clarity (WATERC) multiplied by the size of the lake (SA).

Because the assessed values for land and structures were available for this study, it was thought that a different dependent variable could be constructed to enhance understanding. Therefore, this study uses a hedonic model in parallel (MN model hereafter) that expresses the portion of the purchase price attributed to the land

(PPLand) as a function of structural characteristics (S), land characteristics (L), and the natural log of water quality (WQ), multiplied by the size of the lake (LA):

PPLand = *f* (S, L, lnWQ*LA).

The dependent variable PPLand is used to make easier the extrapolation of estimated implicit prices for changes in property prices for an entire lake. PPLand was derived for each property by dividing the assessed valve for land (AVL) by the sum of the assessed values of land and structures (AVL + AVS), multiplied by PP:

(AVL / AVL + AVS)*PP.

In Minnesota, both developed and undeveloped lake-lot properties are often priced in terms of lake frontage, a common unit used for comparison and assessing values. The structural characteristics describe the improvements that exist on the property and land characteristics describe site condition---including the neighborhood or other locational---influences on purchase price. The natural log of water quality, again, is used to reflect the anticipated nonlinear relationship between water quality and purchase price due to the effect of diminishing returns. Multiplying WQ by size of the lake is done to recognize the assumption Boyle made that lake size may be more important than WQ to buyers who prefer smaller, less congested lakes.

Another reason that a MN model is used in this study was to utilize additional, available explanatory variables and for comparison purposes between models. The Boyle et al model was adapted to fit common explanatory variables. Explanatory variables used in the models are shown in Table 1 and Table 2.

Table 1. Explanatory variables used in the Boyle (adapted) model.

Variable Type	Name	Description
Property:	FF	feet of frontage on the lake
Structural:	LVAREA	square feet of living area
	PLUMB	1 = having a full bathroom, 0 otherwise
	HEAT	1 = having a central heating system, 0 otherwise
Locational:	DNSTY	number of lots/1000 ft of frontage adjacent to property
	DIST	distance to lake group community (miles)
Environmental:	WQ	mean secchi disk readings for the lake for the year property was sold (feet)*LKAREA

Table 2. Explanatory variables used in the MN model.

Variable Type	*Name*	*Description*
Structural:	LVAREA	square feet of living area
	STORY	1 = more than one story, 0 otherwise
	FIRE	1 = having a fireplace, 0 otherwise
	HEAT	1 = having a central heating system, 0 otherwise
	BSMNT	1 = having a basement, 0 otherwise
	DECK	1 = having a deck, 0 otherwise
	PLUMB	1 = having a full bathroom, 0 otherwise
	SEPTIC	1 = having septic or sewer service, 0 otherwise
	GARAGE	1 = having a garage, 0 otherwise
Land-Locational:	LOTSIZE	in acres
	FF	feet of frontage on the lake
	DNSTY	number of lots/1000 ft of frontage adjacent to property
	RDPUB	1 = access road publicly maintained, 0 otherwise
	TAXRT	local tax rate for the year property sold
	DIST	distance to lake group community (miles)
Environmental:	WQ	mean secchi disk readings for the lake for the year property was sold (feet)*LKAREA
	SQ	site quality rating of property

Unlike the Boyle et al study that had gathered socioeconomic attributes of the lakeshore property consumers through a survey that had been conducted, this research did not do so. Therefore estimated demand for lake water quality is not performed, by use of what is known as a second-stage demand equation, as was done in the Boyle et al study. However, “the hedonic equation yields information on the *marginal* willingness to pay for the environmental improvement because the consumers optimize by equating their marginal rate of substitution between the characteristic and the numeraire to the marginal rate which is estimated by the hedonic price equation” (Palmquist 1999).

As was done in Boyle et al study, the hedonic price equations estimated for each lake group is used to derive what Boyle et al refers to as “reduced equations that include a grand constant (a) and the water quality effect (b):

$$PP = \alpha + \beta \ \ln(WATERC)*LKAREA$$

for calculating implicit prices for individual lakes. This approach is described in Boyle et al (1998). The data calculated from the reduced equations will be useful for a making a number of estimates for any lake in the study using the appropriate equation. A set of estimates is provided to illustrate the kinds of questions that the information can answer.

Summary

Thirty-seven lakes located in the Mississippi Headwaters Board jurisdiction were placed into one of six lake groups, approximating real estate market areas and having a main community at their centers. Data obtained from county assessor offices for lakeshore properties sold on the lakes in 1996 through 2001 were collected and used along with Minnesota Pollution Control Agency lake water quality data and with a site quality variable for use in hedonic models. Hedonic pricing equations were estimated for each of the six lake groups Two sets were estimated: one that used an adapted Boyle et al model and another that used the MN model as described above. Water quality and site quality were two of the explanatory variables used to identify the effects of water quality and site quality---while controlling for other property characteristics---and the implicit prices of water quality and site quality embedded in the prices paid for lakeshore properties will be revealed.

CHAPTER 4

RESULTS

Introduction to Findings

Water quality was shown to be a significant explanatory variable of lakeshore property prices in all lake groups in both the Boyle et al and MN models. Site quality, the other environmental variable used in the MN model, was found to be significant in four of the six lake groups. Water quality had a positive relationship with property prices and site quality's relationship with property prices was positive in one lake group and negative in three.

Using the estimated hedonic equations from the MN model, the implicit prices of water quality were determined and calculations were made to illustrate the changes in property prices on the study lakes if a one-meter change in water clarity would occur. Expected property price changes for these lakes are in the magnitude of tens of thousands to millions of dollars.

Analysis of Findings

Summary Statistics

Mean values for variables by lake group and for each study lake are reported in Appendix A.

Mean lakeshore property sales prices in 1996-2001 were highest in the Walker Lake Group ($179,621) and lowest in the Aitkin Lake Group ($100,313). The highest mean value per frontage foot (PPLAND/FF) was in the Brainerd Lake Group at $959 and lowest in the Grand Rapids Lake Group at $434. The mean water clarity was highest in the Walker Lake Group and lowest in the Aitkin Lake Group, 4.29 and 2.78 meters respectively.

Hedonic Model Results

Hedonic equations were estimated for each of the six lake groups and for each of the models used. The coefficients are reported in Appendices B and C.

The Boyle et al model used property purchase price (land and structures) as its dependent variable, whereas, the MN model used the purchase price of the land only (structure values having been netted out). The MN model included more explanatory variables, including one that described a subjective site quality characteristic.

Water Quality Variable

Both models revealed that the coefficients for water quality (WQ) were significant in each of the lake groups and that its relationship with property prices is positive.

Site Quality Variable

The coefficients for site quality (SQ) were significant in four of the six lake groups. For the Aitkin Lake Group the sign was positive and negative signs occurred in the Brainerd, Walker and Bemidji Lake Groups. See Appendix E for further description of the development of this index.

Other Significant Variables

Other significant variables are as shown in Appendices B and C for each model, and will not be reported here.

Expected Property Prices for Changes in Water Clarity

The table shown in appendix D shows the input used for calculating the implicit prices of water clarity for the study lakes. (Note: The table includes the estimated coefficients for WQ from the MN model regression results only.) The implicit prices of water quality were computed to determine the change in property prices for the lakes if water clarity were to improve or decrease by a one-meter increment.

Table 3 shows the results for changes in price for a lake's frontage foot and the total change in property prices for each lake. In addition, Table 4 shows the implicit prices of water clarity for each lake by frontage foot (WQ/FF), by mean property on the lake (WQ/Lot), and the expected purchase price for a mean sized lot on the lake without structures (PPLAND).

Table 3. Changes in property prices on study lakes for a one-meter (1m) change in water clarity.

Lake	Mean clarity (m)	Price change/FF for 1m		Total Lake FF	Total change in property prices for lake[3] for 1m	
		Increase	Decrease		Increase	Decrease
Big Sandy	1.38	$218.00	$516.23	324057	$63,579,983	$150,560,122
Dam	3.56	$6.32	$8.41	19196	$109,104	$145,347
Esquagamah	1.39	$17.60	$41.26	28313	$448,369	$1,051,391
Farm Island	4.22	$24.95	$31.72	63660	$1,429,485	$1,817,365
Ross	1.43	$12.29	$27.87	26575	$294,062	$666,581
Spirit	4.28	$7.01	$8.89	24390	$153,846	$195,099
Alexander	4.89	$8.99	$11.06	78055	$631,660	$776,842
Bay	4.14	$10.46	$13.36	106969	$1,006,845	$1,286,636
Fish Trap	3.74	$5.55	$7.29	57319	$286,117	$375,917
Gull	3.42	$39.23	$52.91	185179	$6,538,349	$8,817,887
Norway	2.83	$3.36	$4.85	19433	$58,829	$84,864
Pelican	4.95	$30.37	$37.25	115165	$3,147,922	$3,860,639
Platte	2.01	$6.48	$11.05	57652	$336,493	$573,580
Roosevelt	3.88	$38.80	$50.43	82052	$2,865,342	$3,724,297
Shamineau	5.11	$6.69	$8.16	49413	$297,500	$362,930
Upper Hay	2.62	$3.40	$5.06	18232	$55,820	$83,117
Balsam	3.60	$1.08	$1.43	6500	$35,478	$46,975
Pokegama	4.90	$29.53	$36.29	184460	$4,902,393	$6,024,648
Prairie	1.79	$4.20	$7.75	64774	$244,845	$451,798
Wabana	4.70	$3.73	$4.62	104751	$351,649	$435,554
Ada	4.34	$3.14	$3.97	8117	$79,458	$100,462
Kabekona	3.86	$6.00	$7.82	48238	$260,485	$339,499
Leech	3.04	$423.58	$594.16	882248	$93,425,651	$131,049,117
Ten Mile	6.61	$9.32	$10.85	108720	$911,943	$1,061,650
Woman	4.12	$13.59	$17.39	144781	$1,770,816	$2,265,967
4thCrowWing	2.80	$15.84	$22.92	20725	$295,455	$427,515
8thCrowWing	2.76	$18.73	$27.26	23900	$402,882	$586,362
Belle Taine	6.38	$28.91	$33.85	108594	$2,825,507	$3,308,316
Fish Hook	3.36	$61.02	$82.75	34282	$1,882,698	$2,553,152
George	2.71	$26.60	$38.99	26550	$635,607	$931,666
Long	5.80	$2.26	$2.69	14979	$30,467	$36,264
Bemidji	2.85	$193.48	$278.00	69399	$10,070,488	$14,469,691
Cass	4.02	$326.36	$420.20	195396	$15,942,278	$20,526,244
Irving	1.51	$34.02	$72.67	21966	$672,555	$1,436,642
Marquette	3.01	$9.97	$14.03	21384	$191,878	$270,015
Big Turtle	3.00	$20.70	$29.17	53394	$994,730	$1,401,752
Big Wolf	3.13	$17.16	$23.83	35511	$548,431	$761,604

Table 4. Equations for calculating implicit prices for study lakes.

Lake	Implicit Price WQ/FF	Implicit Price of WQ/Lot	α	Est. PPLAND	β	Mean FF	Mean WQ	Lake Size (ac.)
Big Sandy	$129	$15,471	56,099	$71,570	7.31	120	1.38	6571
Dam	$32	$5,959	53,569	$59,528	7.31	184	3.56	642
Esquagamah	$11	$2,010	33,708	$35,718	7.31	188	1.39	835
Farm Island	$576	$21,619	52,124	$73,743	7.31	128	4.22	2054
Ross	$8	$1,294	20,055	$21,349	7.31	156	1.43	495
Spirit	$52	$6,077	43,451	$49,528	7.31	116	4.28	530
Alexander	*$77*	$9,207	73,511	$82,718	1.94	120	4.89	2990
Bay	$69	$6,593	130,640	$137,233	1.94	96	4.14	2392
Fish Trap	$31	$3,334	46,545	$49,879	1.94	108	3.74	1303
Gull	$188	$22,760	159,614	$182,374	1.94	121	3.42	9541
Norway	$12	$1019	36,570	$37,589	1.94	88	2.83	505
Pelican	$264	$25,607	97,668	$123,275	1.94	97	4.95	8253
Platte	$11	$2,266	113,902	$116,168	1.94	202	2.01	1673
Roosevelt	$229	$39,231	32,694	$71,925	1.94	171	3.88	14915
Shamineau	$61	$5,320	49,096	$54,416	1.94	87	5.11	1681
Upper Hay	$10	$1,086	77,804	$78,890	1.94	107	2.62	581
Balsam	$6	$1,449	49,436	$50,885	1.73	257	3.60	654
Pokegama	$253	$43,715	51,769	$95,484	1.73	173	4.90	15900
Prairie	$6	$998	51,382	$52,380	1.73	181	1.79	991
Wabana	$30	$5,711	64,997	$70,708	1.73	191	4.70	2133
Ada	*$22*	$2,756	68,196	$70,952	1.91	124	4.34	983
Kabekona	$35	$5,810	83,275	$89,085	1.91	165	3.86	2252
Leech	$1656	$231,849	-122,023	$109,826	1.91	140	3.04	109175
Ten Mile	$125	$16,737	88,446	$105,183	1.91	134	6.61	4640
Woman	$89	$12,932	83,404	$96,336	1.91	146	4.12	4782
4th CrowWing	*$53*	$12,016	65,857	$77,873	19.95	225	2.80	585
8th CrowWing	$62	$9,965	53,082	$63,047	19.95	162	2.76	492
Belle Taine	$368	$53,718	39,341	$93,059	19.95	146	6.38	1453
Fish Hook	$284	$39,459	36,445	$75,904	19.95	139	3.36	1632
George	$84	$15,872	57,131	$73,003	19.95	188	2.71	798
Long	$35	$5,050	51,430	$56,480	19.95	202	5.80	144
Bemidji	$674	$65,355	23,670	$89,025	9.72	97	2.85	6420
Cass	$2044	$402,655	-360,060	$42,595	9.72	197	4.02	29775
Irving	$28	$2,455	28,673	$31,128	9.72	89	1.51	613
Marquette	$38	$5,398	32,719	$38,117	9.72	141	3.01	504
Big Turtle	$79	$15,334	23,007	$38,341	9.72	194	3.00	1436
Big Wolf	$71	$11,656	40,719	$52,375	9.72	165	3.13	1051

[3] Assuming 90 percent of the total lake frontage is developed or developable with three exceptions: 25 percent was

CHAPTER 5

DISCUSSION, CONCLUSION, and RECOMMENDATIONS

Statement of the Problem

Sustaining and improving the water quality in Minnesota's lakes is important to the State's ecological, economic and cultural future. The purpose of this study was to conduct research to determine if the water quality in Minnesota lakes---located within the Mississippi Headwaters Board jurisdiction---affects lakeshore property prices.

Evidence from Maine indicates that water quality affects lakeshore property prices and that there is significant demand for it. If a similar relationship exists for Minnesota lakes, lakeshore property owners and policy makers should regard enhanced property values as important enough reason to protect water quality. This study tested a hypothesis that lake water quality affects lakeshore property prices of Minnesota lakes, and that it would be a positive relationship---like was found in the State of Maine.

Discussion of Findings

Thirty-seven lakes of various sizes, water clarity, and geographical location in the eight county Mississippi Headwaters Board jurisdiction were studied. Lakes were assigned to

used for Leech and Cass Lakes due to large public land holdings and 75% was used for Lake Bemidji.

one of six lake groups that represented realistic market areas having a main economic and social community center, mainly the county seats.

From these lakes, 1205 residential lakeshore property sales that occurred in 1996 through 2001 were used. Property sales information was collected from county assessor records and water clarity data were obtained from the Minnesota Pollution Control Agency. A site quality variable was also included that ranked properties based on site characteristics from pristine and natural to manipulated and developed. The site quality information was provided to this study by the Geography Department at Bemidji State University, which had ranked the properties following on-site analyses.
Hedonic models were constructed and performed; one that followed the model Boyle et al used in their study of Maine lakes and one developed for this study, the MN model.

The major finding of the analysis was that lake water clarity---the water quality variable used---proved a significant explanatory variable of lakeshore property prices in all lake groups and in both models. The relationship between water clarity and property prices is positive, that is, all else being equal, property prices paid are higher on lakes having higher water clarity. In other words, buyers of lakeshore properties prefer and will pay more for properties on lakes with better water quality. Therefore, sustaining and/or improving lake water quality will protect and/or improve lakeshore property values. On the other hand, if water quality is degraded, lower property values will result, which in turn will increase demand and development pressures on remaining lakes with the better water quality and ultimately lowering their water quality as well.

Another finding from the MN model was that site quality was a significant explanatory variable in four of the six lake groups. In the Aitkin Lake Group, site quality was shown to have a positive relationship with property prices, whereas in the Brainerd, Walker and Bemidji Lake Groups, the relationship was negative. An inference that can be made---for the three lake groups having a negative site quality to property price relationship---is that buyers of lakeshore properties prefer and pay more for the more developed and urbanized properties. This tendency seems to reveal that buyers prefer a condition that has and can contribute to degrading lake water quality---a contradiction of their preference for locating on lakes with higher water quality. The value of educating lakeshore property buyers and owners to understand this contradiction---changing their thinking and ultimately their behavior---is clearly evidenced here if water quality is to be protected. Ideally, as was seen in the Aitkin Lake Group, preference for site quality conditions that are more ecologically healthy is the wisest mindset to promote and establish in consumers of Minnesota's lakeshore properties.

The estimated changes in property prices calculated in this study provide a rationale for appealing to economic incentives to bolster educational messages on lakeshore-water quality. Perhaps as important---from the perspective of state and local governmental concerns for protecting property values for tax base---additional and more progressive lakeshore property regulations will be important. In addition to improved lake water clarity, a future measure of success of education efforts will be a change in consumer demand for less developed site quality conditions and evidenced by higher prices paid for it.

The results shown in Table 3 illustrate that millions of dollars in lakeshore property values on Minnesota's lakes could be lost or gained upon a one-meter change in water clarity. Property owners, as will local and state property tax recipients, either gain or lose dollars as water clarity improves or degrades.

The changes in lakeshore property prices for a one-meter change in water clarity varies from lake to lake. Price variations between lakes are due to different water clarity levels, lake size, mean lake purchase prices and the different effects of water quality in the lake groups. The effect across lake groups is due to the different water quality coefficients estimated for each lake group. The Park Rapids Lake Group had the highest estimated water quality effect on property prices and the lowest effect was found in the Walker Lake group. Due to the nonlinear relationship between water clarity and property prices, the effect of a one-meter decline or improvement on lakes is not identical. The price effect for improved water clarity is always smaller than for a reduction in water clarity.

The two lakes showing the greatest effects were Leech and Cass lakes. These lakes were also used as dummy variables in the models due to their unique situation of being located in the Leech Lake Indian Reservation and the Chippewa National Forest, and due to having considerable publicly-owned lakeshore property. Because of this situation, other variables not accounted for in the modeling may have caused the higher price effects. The results for Leech and Cass Lakes might be best considered higher than what is likely a more probable lower effect. However, Leech and Cass Lake results could possibly be accurate for the unique situation they present.

The next two lakes with the highest effects were Big Sandy and Bemidji. Although not treated as dummy variables, they appear to be somewhat different from the remaining lakes. Big Sandy is a large and very popular lake that is relatively isolated from other lakes in the Aitkin and other lake groups. Lake Bemidji is partially located within the City of Bemidji and likely influenced by an urban real estate market situation. In addition, Lake Bemidji State Park is located on Lake Bemidji. The high effects that Big Sandy and Bemidji Lakes achieve seem reasonable when their individual situations are considered.

Conclusions

The major finding of this research shows that water clarity---the environmental quality variable used---significantly affects prices paid for lakeshore properties located on Minnesota Lakes within the Mississippi Headwaters Board jurisdiction, and that the relationship is positive. This finding supports the hypothesis explored in this study and the similar results found in the Michael et al and Boyle et al studies of Maine Lakes.

The implicit prices of water clarity estimated in this study were based on a sample of lakeshore property transactions that took place on only 37 lakes--a mere fraction of

Minnesota’s lakes. However, the hedonic equations may be used to estimate changes in lakeshore property prices for other lakes---having similar characteristics as the 37 lakes studied---located within the study area’s six lake groups. In order to do the calculations it would be necessary to have mean values for the variables on these other lakes to be plugged into the equations. For lakes located outside the area of study, new hedonic equations will have to be made.

Recommendations

For lakes located in the Mississippi Headwaters Region, the relationship between lakeshore property values and lake water quality is demonstrated by this research. Collectively, changes in lake water clarity will result in millions of dollars in property values---lost or gained---in this lake region of Minnesota. Clearly, for economic reasons alone---not to mention the ecological health and social benefits at stake---it is important to protect the water quality of all Minnesota’s lakes. The relationship between lake water quality and lakeshore property values is likely for other lakes outside the area of study, but additional research could be done to verify, as well as to further support this study’s findings.

Enlightened citizens and progressive regulatory policy are the key to protecting Minnesota’s valuable lakes from further degradation. Education to the importance of sustaining and/or improving the quality of Minnesota’s lakes is critical and must occur if current detrimental practices affecting water quality is to be averted. The results of this study provides compelling evidence for an educational initiative.

Appendix A. Mean Values for Variables by Lake Group and Study Lake.

AITKIN LAKE GROUP

LAKE	N	WQ	SQ	PP	AVL	AVS	pplandff	FF
Big Sandy	50	1.38	260.02	117,073	44,546	40,285	612	120
Dam	15	3.56	228.73	88,607	27,067	38,587	276	184
Esquagamah	29	1.39		81,990	23,652	23,549	230	188
Farm Island	39	4.22	268.72	129,195	50,204	43,792	613	128
Ross	7	1.43	278.00	53,571	23,600	28,200	165	156
Spirit	34	4.28	273.59	72,954	29,612	26,209	360	116
Group Total	174	2.78	263.24	100,313	37,064	34,899	452	139

	LOTSZ	TAXRT	LVAREA	STORY	FIRE	HEAT	BSMNT	DECK
Big Sandy	0.95	127.82	782.06	0.18	0.24	0.26	0.28	0.66
Dam	1.54	123.81	705.67	0.13	0.33	0.13	0.07	0.47
Esquagamah	2.22	118.49	588.21	0.14	0.14	0.28	0.10	0.45
Farm Island	0.83	119.25	804.38	0.13	0.21	0.44	0.33	0.49
Ross	1.36	89.67	528.00	0.00	0.43	0.14	0.43	0.43
Spirit	1.03	115.66	601.24	0.00	0.06	0.24	0.15	0.47
Group Total	1.22	120.09	702.61	0.11	0.20	0.28	0.22	0.52

	PLUMB	SEPTIC	GARAGE	RDPUB	DNSTY	DIST
Big Sandy	0.50	0.68	0.50	0.98	10.34	32.98
Dam	0.53	0.53	0.47	1.00	7.93	13.51
Esquagamah	0.62	0.59	0.34	1.00	7.21	14.00
Farm Island	0.69	0.69	0.49	1.00	11.00	9.92
Ross	0.43	0.43	0.29	0.57	6.43	15.26
Spirit	0.38	0.38	0.35	1.00	10.65	7.68
Group Total	0.54	0.59	0.43	0.98	9.66	17.31

Appendix A (cont). Mean Values for Variables by Lake Group and Study Lake.

BRAINERD LAKE GROUP

LAKE	N	WQ	SQ	PP	AVL	AVS	ppland/ff	FF
Alexander	50	4.89	207.87	163,622	64,778	60,048	794	120
Bay	39	4.14	220.26	228,859	110,654	73,431	1,545	96
Fish Trap	50	3.74	213.95	154,169	55,138	59,282	833	108
Gull	50	3.42	247.24	326,789	167,312	113,341	1,681	121
Norway	29	2.83	259.15	86,452	24,898	40,998	398	88
Pelican	50	4.95	250.03	217,324	98,560	65,270	1,406	97
Platte	26	2.01	234.91	105,358	34,777	62,346	377	202
Roosevelt	24	3.88	290.67	130,879	34,650	57,508	334	171
Shamineau	50	5.11	217.89	112,390	35,260	43,563	663	87
Upper Hay	19	2.62	235.36	119,089	56,158	36,958	669	107
Group Total	387	3.99	235.26	176,461	74,658	64,164	959	115

	LOTSZ	TAXRT	LVAREA	STORY	FIRE	HEAT	BSMNT	DECK
Alexander	0.83	135.44	1085.28	0.20	0.44	0.60	0.44	0.66
Bay	0.58	90.57	968.61	0.15	0.58	0.61	0.24	0.85
Fish Trap	1.21	119.09	1046.30	0.20	0.46	0.68	0.36	0.70
Gull	1.11	103.13	1324.62	0.54	0.66	0.28	0.34	0.78
Norway	0.45	98.49	922.41	0.00	0.38	0.14	0.10	0.45
Pelican	0.88	92.74	791.50	0.14	0.49	0.51	0.29	0.51
Platte	1.11	116.81	975.12	0.13	0.33	0.54	0.25	0.58
Roosevelt	1.87	90.98	909.33	0.04	0.38	0.04	0.25	0.54
Shamineau	0.50	117.73	892.48	0.14	0.34	0.48	0.46	0.66
Upper Hay	1.02	106.06	645.58	0.05	0.26	0.32	0.16	0.47
Group Total	0.92	108.61	985.76	0.19	0.45	0.45	0.32	0.64

	PLUMB	SEPTIC	GARAGE	RDPUB	DNSTY	DIST
Alexander	0.88	0.88	0.64	1.00	10.06	26.47
Bay	1.00	0.97	0.73	1.00	10.87	16.30
Fish Trap	0.96	0.96	0.68	1.00	9.74	30.02
Gull	0.94	0.94	0.86	1.00	9.16	14.77
Norway	0.83	0.83	0.62	1.00	9.14	28.67
Pelican	0.61	0.61	0.57	0.98	12.40	18.35
Platte	0.67	0.75	0.54	1.00	9.96	22.21
Roosevelt	0.75	0.75	0.50	0.96	7.17	33.00
Shamineau	0.98	0.98	0.64	1.00	14.46	26.99

Upper Hay	0.74	0.74	0.61	1.00	7.16	24.74
Group Total	0.85	0.86	0.66	0.99	10.46	23.61

Appendix A (cont). Mean Values for Variables by Lake Group and Study Lake.

GRAND RAPIDS LAKE GROUP

LAKE	N	WQ	SQ	PP	AVL	AVS	ppland/ff	FF
Balsam	21	3.60	252.80	72,444	29,024	23,710	221	257
Pokegama	50	4.90	259.79	182,156	62,368	71,392	583	173
Prairie	36	1.79	295.34	100,286	33,967	45,036	267	181
Wabana	27	4.70	279.04	147,104	74,426	38,215	547	191
Group Total	134	3.82	272.33	135,905	51,942	50,154	434	192

	LOTSZ	TAXRT	LVAREA	STORY	FIRE	HEAT	BSMNT	DECK
Balsam	2.16	117.16	561.19	0.00	0.05	0.05	0.14	0.19
Pokegama	1.48	120.28	1005.84	0.06	0.52	0.68	0.42	0.62
Prairie	1.87	111.31	873.94	0.06	0.14	0.22	0.22	0.39
Wabana	2.15	113.22	765.33	0.04	0.26	0.37	0.15	0.48
Group Total	1.82	115.96	852.26	0.04	0.29	0.40	0.27	0.46

	PLUMB	SEPTIC	GARAGE	RDPUB	DNSTY	DIST
Balsam	0.76	0.76	0.19	1.00	9.33	28.67
Pokegama	0.76	0.74	0.56	0.96	11.42	7.22
Prairie	0.86	0.86	0.69	0.81	8.31	6.91
Wabana	0.63	0.63	0.52	0.63	6.22	15.31
Group Total	0.76	0.75	0.53	0.86	9.21	12.13

Appendix A (cont). Mean Values for Variables by Lake Group and Study Lake.

WALKER LAKE GROUP

LAKE	N	WQ	SQ	PP	AVL	AVS	ppland/ff	FF
Ada	33	4.34	240.88	151,929	60,566	58,013	658	124
Kabekona	45	3.86	286.22	153,858	60,129	67,001	482	165
Leech	50	3.04	270.74	203,416	88,423	89,259	793	140
Ten Mile	38	6.61	249.65	214,635	89,481	69,332	1,000	134
Woman	50	4.12	249.04	170,680	67,096	60,208	688	146
Group Total	216	4.29	260.33	179,621	73,522	69,618	720	143

	LOTSZ	TAXRT	LVAREA	STORY	FIRE	HEAT	BSMNT	DECK
Ada	1.27	96.62	959.18	0.09	0.33	0.06	0.64	0.70
Kabekona	1.82	99.25	971.00	0.18	0.33	0.67	0.47	0.53
Leech	1.32	100.54	1157.47	0.27	0.55	0.10	0.39	0.69
Ten Mile	0.99	92.02	1119.45	0.11	0.82	0.08	0.21	0.55
Woman	1.09	90.53	944.96	0.00	0.44	0.10	0.28	0.64
Group Total	1.31	95.86	1031.87	0.13	0.49	0.21	0.39	0.62

	PLUMB	SEPTIC	GARAGE	RDPUB	DNSTY	DIST
Ada	0.82	0.82	0.55	1.00	8.70	29.29
Kabekona	0.76	0.76	0.56	1.00	7.36	10.00
Leech	0.86	0.86	0.80	0.94	7.36	14.83
Ten Mile	0.87	0.87	0.63	1.00	7.58	12.79
Woman	0.88	0.90	0.66	1.00	7.50	24.48
Group Total	0.84	0.84	0.65	0.99	7.63	17.91

Appendix A (cont). Mean Values for Variables by Lake Group and Study Lake.

PARK RAPIDS LAKE GROUP

LAKE	N	WQ	SQ	PP	AVL	AVS	ppland/ff	FF
4thCrowWing	18	2.80	359.39	52,729	25,572	13,355	189	225
8thCrowWing	25	2.76	294.16	77,604	39,745	19,930	330	162
Belle Taine	50	6.38	232.57	162,769	66,678	56,649	663	146
Fish Hook	49	3.36	225.35	164,859	55,989	81,225	560	139
George	19	2.71	351.63	87,147	35,334	31,175	281	188
Long	12	5.80	293.75	63,163	17,233	23,367	137	202
Group Total	173	4.19	270.87	124,390	48,609	48,693	458	163

	LOTSZ	TAXRT	LVAREA	STORY	FIRE	HEAT	BSMNT	DECK
4thCrowWing	3.43	105.93	268.11	0.06	0.22	0.22	0.06	0.17
8thCrowWing	1.83	115.93	521.76	0.04	0.12	0.04	0.20	0.44
Belle Taine	1.19	109.74	1166.72	0.08	0.48	0.24	0.52	0.52
Fish Hook	1.42	95.99	1212.78	0.08	0.57	0.65	0.59	0.65
George	1.83	108.56	537.26	0.00	0.05	0.05	0.11	0.37
Long	5.71	141.09	575.33	0.00	0.17	0.00	0.08	0.25
Group Total	1.97	108.39	882.91	0.06	0.36	0.29	0.37	0.47

	PLUMB	SEPTIC	GARAGE	RDPUB	DNSTY	DIST
4thCrowWing	0.17	0.33	0.06	1.00	6.78	9.84
8thCrowWing	0.04	0.60	0.32	0.96	6.68	13.04
Belle Taine	0.50	0.90	0.80	1.00	7.80	8.19
Fish Hook	0.59	0.84	0.78	1.00	8.76	2.37
George	0.21	0.37	0.32	0.95	7.21	19.19
Long	0.50	0.50	0.25	1.00	5.00	26.61
Group Total	0.39	0.69	0.55	0.99	7.54	9.90

Appendix A (cont). Mean Values for Variables by Lake Group and Study Lake.

BEMIDJI LAKE GROUP

LAKE	N	WQ	SQ	PP	AVL	AVS	ppland/ff	FF
Bemidji	44	2.85	224.02	181,172	63,964	64,993	1,156	97
Cass	12	4.02	320.50	110,850	42,867	32,592	315	197
Irving	16	1.51	220.20	135,847	25,694	87,806	377	89
Marquette	6	3.01	214.40	178,967	33,617	105,750	329	141
Big Turtle	38	3.00	312.32	114,267	41,618	52,432	308	194
Big Wolf	5	3.13	285.00	78,200	27,020	32,320	239	165
Group Total	121	2.85	263.55	142,829	46,762	61,522	624	141

	LOTSZ	TAXRT	LVAREA	STORY	FIRE	HEAT	BSMNT	DECK
Bemidji	0.65	144.56	1345.83	0.29	0.43	0.64	0.19	0.48
Cass	1.86	131.02	329.00	0.00	0.00	0.10	0.00	0.20
Irving	0.44	161.63	1257.00	0.94	0.50	0.88	0.50	0.56
Marquette	0.87	139.86	1381.17	0.67	0.50	1.00	0.50	0.67
Big Turtle	1.56	146.59	905.61	0.19	0.42	0.56	0.47	0.44
Big Wolf	1.13	162.83	1171.20	0.00	0.20	0.00	0.40	0.20
Group Total	1.06	146.63	1101.50	0.33	0.39	0.59	0.33	0.45

	PLUMB	SEPTIC	GARAGE	RDPUB	DNSTY	DIST
Bemidji	0.76	0.76	0.81	1.00	10.64	4.50
Cass	0.36	0.36	0.09	0.92	5.33	17.97
Irving	0.94	0.87	0.94	1.00	10.44	2.08
Marquette	1.00	1.00	1.00	1.00	8.33	5.65
Big Turtle	0.61	0.61	0.58	0.98	6.66	11.01
Big Wolf	0.20	0.20	0.80	1.00	5.60	11.84
Group Total	0.69	0.68	0.70	0.99	8.51	7.92

Appendix B. Estimated Hedonic Coefficients Obtained Following the Boyle et al Model.

LAKE GROUP

	Aitkin	Brainerd	Grand Rapids	Walker	Park Rapids
intercept	-17805.70	210441.10***	6363.65	-22281.91	14095.43
	(17450.91)	(29040.65)	(28417.15)	(40815.95)	(36588.82)
ln(lvarea)	8503.51***	7575.37**	12003.94**	10926.32***	10920.16***
	(1630.76)	(3272.42)	(6795.93)	(4271.00)	(2189.03)
heat	45788.22***	11853.95	68644.89***	25022.71*	12844.98
	(9328.30)	(9746.27)	(19413.80)	(16153.82)	(14698.62)
plumb	6124.27	68961.78***	-44064.00	41475.59**	44448.52***
	(9249.74)	(19681.07)	(44869.46)	(21724.31)	(13807.53)
ff	239.16***	403.46***	148.38***	430.50***	207.95***
	(44.80)	(72.21)	(44.56)	(87.82)	(67.94)
dist	742.67**	-8407.21***	-913.84	-1250.36**	-1311.49
	(354.68)	(739.37)	(1014.07)	(700.62)	(1143.91)
dnsty	-1115.87	-2062.68**	4554.88**	4605.34*	-2728.13
	(1258.90)	(1145.62)	(2026.98)	(3377.01)	(2631.28)
Leech	---	---	---	-219206.07	---
				(189121.25)	
Cass	---	---	---	---	---
ln(watrq)	13.23***	4.72***	1.10*	2.15*	21.75***
*lkarea	(3.49)	(.82)	(.82)	(1.63)	(8.24)
R-Square	.52	.47	.40	.29	.51
F-Statistic	25.61***	47.53***	11.84***	10.68***	24.76***
d.f.	173	376	133	214	172

Significance levels: ***= 1%, **= 5%, *=10%. Standard errors are shown in parentheses.

Appendix C. Estimated Hedonic Coefficients Using the MN Model by Lake Group.

	Aitkin	Brainerd	Grand Rapids	Walker	Park Rapids	Bemidji
intercept	-116081.55***	277726.42***	175360.99**	89827.83*	-18158.82	-9307.08
	(32414.78)	(56107.57)	(84480.04)	(63055.74)	(39773.51)	(67352.50)
lnlvarea	-772.84	-3954.41*	-320.16	-588.59	8772.74***	-4919.31*
	(1179.99)	(2790.25)	(3861.00)	(2641.16)	(2573.05)	(3214.14)
story	4744.45	6300.58	-15746.63	6254.47	-1644.43	-1380.76
	(7141.76)	(9145.46)	(20197.61)	(11573.49)	(9595.76)	(10723.34)
fire	1858.54	9150.41	11880.85	7546.39	2555.65	3846.22
	(6059.04)	(7554.15)	(11445.07)	(8116.01)	(6213.37)	(9334.61)
heat	10212.07**	-19519.52**	19477.47**	3109.56	-1630.57	-30442.83**
	(5540.04)	(8054.20)	(11335.93)	(10048.20)	(6502.01)	(14725.99)
bsmnt	6932.40	-8754.55	-16011.77*	-8191.00	-1906.43	-10365.19
	(5644.31)	(8351.59)	(10893.68)	(8101.09)	(6456.23)	(9997.41)
deck	2503.22	-4005.63	6035.95	-9625.27	-3802.47	7805.03
	(5375.39)	(8335.36)	(10575.96)	(8559.83)	(5894.04)	(9344.14)
fullbath	5137.57	39087.93	-22561.95	-3402.37	-9038.31*	13054.10
	(9692.63)	(34822.74)	(47462.55)	(49623.70)	(6749.67)	(43520.48)
septic	-3269.96	-12261.90	7494.83	5577.83	-32606.25**	24890.76
	(10584.13)	(35881.90)	(45092.18)	(50638.55)	(17316.24)	(39461.04)
garage	11901.01**	22895.21***	-5297.35	3817.09	-5376.87	33363.43*
	(5101.94)	(8759.68)	(11092.77)	(8242.17)	(7059.53)	(21004.45)
rdpub	-8133.28	-14725.64	-17397.75*	37149.96	-27738.75*	-4974.65
	(15865.51)	(42594.11)	(11957.54)	(30943.77)	(20341.03)	(30701.33)
dnsty	-650.35	-1523.83**	-401.52	1921.28	-1067.51	-1864.95*
	(769.06)	(904.81)	(1132.50)	(2042.61)	(1070.07)	(1408.44)
dist	-193.74	-6974.22***	4.34	-480.66	-959.68*	1089.55
	(247.11)	(602.72)	(616.88)	(446.11)	(624.96)	(1463.02)
lotsz	5482.74**	7752.56**	-510.03	-4158.03**	-2456.50**	-5115.03
	(2646.84)	(3424.39)	(1649.37)	(2331.93)	(1258.13)	(6097.99)
taxrt	1178.55***	177.70	-973.84*	-461.26	421.33**	432.60
	(302.59)	(251.92)	(709.37)	(391.06)	(253.01)	(361.72)
ff	-11.90	311.38***	86.89***	420.62***	204.87***	80.03*
	(34.87)	(62.04)	(25.92)	(61.61)	(34.08)	(58.53)
leech lk	---	---	---	-196017.72*	---	-379506.65***
cass lk				(126349.88)		(74678.72)
sq	76.34**	-264.61***	7.03	-228.51***	28.85	-80.76*
	(44.22)	(69.00)	(77.20)	(65.66)	(40.40)	(63.08)
wq	7.31***	1.94***	1.73***	1.91**	19.95***	9.72***
	(2.08)	(.66)	(.55)	(1.09)	(3.66)	(1.79)
Rsquare	.45	.53	.33	.33	.53	.43
Fstatistic	5.86***	19.00***	3.14***	5.14***	9.88***	3.82***
d.f.	141	307	127	205	168	110

Significance levels: ***= 1%, **= 5%, *= 10%. Standard errors are in parentheses.

Appendix D. Equations Used for Calculating Implicit Prices.

Lake Group	*Lake*	α	β	*Mean WATERQ*	*Lake Size (acres)*	*Total FF/Lake*
Aitkin	Big Sandy	56,099	7.31	1.38	6571	324057
	Dam	53,569	7.31	3.56	642	19196
	Esquagamah	33,708	7.31	1.39	835	28313
	Farm Island	52,124	7.31	4.22	2054	63660
	Ross	20,055	7.31	1.43	495	26575
	Spirit	43,451	7.31	4.28	530	24390
Brainerd	Alexander	73,511	1.94	4.89	2990	78055
	Bay	130,640	1.94	4.14	2392	106969
	Fish Trap	46,545	1.94	3.74	1303	57319
	Gull	159,614	1.94	3.42	9541	185179
	Norway	36,570	1.94	2.83	505	19433
	Pelican	97,668	1.94	4.95	8253	115165
	Platte	113,902	1.94	2.01	1673	57652
	Roosevelt	32,694	1.94	3.88	14915	82052
	Shamineau	49,096	1.94	5.11	1681	49413
	Upper Hay	77,804	1.94	2.62	581	18232
G. Rapids	Balsam	49,436	1.73	3.60	654	36500
	Pokegama	51,769	1.73	4.90	15900	184460
	Prairie	51,382	1.73	1.79	991	64774
	Wabana	64,997	1.73	4.70	2133	104751
Walker	Ada	68,196	1.91	4.34	983	28117
	Kabekona	83,275	1.91	3.86	2252	48238
	Leech	-122,023	1.91	3.04	109175	882248
	Ten Mile	88,446	1.91	6.61	4640	108720
	Woman	83,404	1.91	4.12	4782	144781
P. Rapids	4thCrowWing	65,857	19.95	2.80	585	20725
	8thCrowWing	53,082	19.95	2.76	492	23900
	Belle Taine	39,341	19.95	6.38	1453	108594
	Fish Hook	36,445	19.95	3.36	1632	34282
	George	57,131	19.95	2.71	798	26550
	Long	51,430	19.95	5.80	144	14979
Bemidji	Bemidji	23,670	9.72	2.85	6420	69399
	Cass	-360,060	9.72	4.02	29775	195395
	Irving	28,673	9.72	1.51	613	21966
	Marquette	32,719	9.72	3.01	504	21384
	Big Turtle	23,007	9.72	3.00	1436	53394
	Big Wolf	40,719	9.72	3.13	1051	35511

Appendix E. Description of Method on Site Quality Index

Shoreland Parcel Site Visitation

In order to verify our data and to collect additional information that might also impact shoreline values, we determined to visit up to seventy parcels on each lake. If the number was under seventy, we wanted to visit all of them and if the number on a given lake was greater than that, we would select a stratified sample of at least fifty parcels.

Locating the parcels with assurance from the water was made possible in most cases by recent advances in parcel mapping at the county level. The counties that had such mapping done or in progress were willing to share their parcel data by simply removing the personal data. Other counties had challenges for us to find the precise point on the lakeshore. In Clearwater County, we had to rectify an assessor's map to fit the lakeshore. Fortunately there was only one lake in that county and it had a sufficiently distinct shoreline that we could feel confident in our positions. In Beltrami, our lakes outside Bemidji were all parcel mapped, however within the city, the parcel data had been lost, so again we had to work from an assessor's map. In Morrison County, only E911 locations were available. In most cases, we were confident that the point, which was on the parcel's driveway, was perpendicular to the shore and when we were at our minimum distance from the point, we were in front of the parcel. On a few peninsulas, it was difficult to be sure which parcel matched the point and we asked residents when we could, to verify which parcel had been sold recently.

Of perhaps 30 cases where someone was present on shore when we pulled up to do our assessment, only one time were we on the wrong lot, and that one was very narrow. We are quite confident, therefore, that our site visits are very nearly precisely on the correct parcel in every case. The GPS equipment that we used generally gave us locations to within less than ten feet using the newly installed beacon at Pine River for our Differential Corrections. All parcels and locations were plotted into Universal Transverse Mercator Coordinates using North American Datum 1983. In a few cases this required us to convert from Minnesota County Coordinates.

Shoreland Quality Indicators

To arrive at data on shoreland management in a timely manner, we created a data set which could be completed quickly during our site visit to each parcel while on the boat. The following attributes were assessed, each with an ordinal value that we connected with better or poorer shoreland management in terms of impacts on lake water quality.
View (Pristine 3, Some Development 2, Heavily Developed 1)
Shore Landscaping (Deep Indigenous Buffer 4,Deep Buffer>15' 3, Thin Buffer 2, Mowed to Water 1)
Texture of Riparian Bank (Naturally Rocky 4, Sand 3, Mud 2, RipRap 1)
Vegetation in Riparian Zone (Wooded 5, Emergent 4, Submergent 3, Nothing 2, Artificially Cleared 1)
Parcel Ground Cover (Brush 3, Grassland 2, Mowed Lawn 1)
Tree Cover (Coniferous 4, Deciduous 3, Mixed 2, Nothing 1)
Tree Frequency (Many 3, Several 2, Few 1)

Built Shore Structures (None 4, Dock 3, Boat Lift(s) 2, Boat House etc. 1)

- Admittedly, these are crude measures, but overall they tend to reflect whether a parcel is likely to impact a lake, with the “view” variable giving a sense of the lake overall. We adjusted the ordinal values so that each measure had the potential to score sixty points. Adding them together gave us an index with values ranging from 420 to 117. We arbitrarily grouped the lakes based on the score thusly:
- 117-218 poor
- 219-320 medium – 219-252 low medium
253-286 medium
287-320 high medium
- 321-420 best

As examples, Big Sandy came in at 261,
We summarized them for each lake and combined them for each county and combined them all for an overall average.

Appendix F. Summary Results on River Properties.

Data were collected for riparian property sales on 155 properties during the study period, 1996-2001. Preliminary data analysis indicated that these data were far less suitable for application of the hedonic pricing technique. Mean values for selected variables are shown below in Table E on the five counties that were included before the evidence was sufficient to determine that no further analysis on riparian property sales was warranted for this study.

Table E. Mean Values for Variables from Riparian Properties in Five Counties

RIPARIAN PROPERTIES

AREA	N	PP	AVL	AVS	pplandff	FF
Aitkin	46	45,983	10,161	15,589	67	521
Beltrami	33	44,173	32,222	6,940	284	212
Cass	6	97,267	35,350	39,083	207	669
Itasca	17	64,878	16,971	48,788	33	696
Morrison	53	119,142	30,121	67,762	235	207
5 County Total	155	74,670	23,405	36,520	171	373

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