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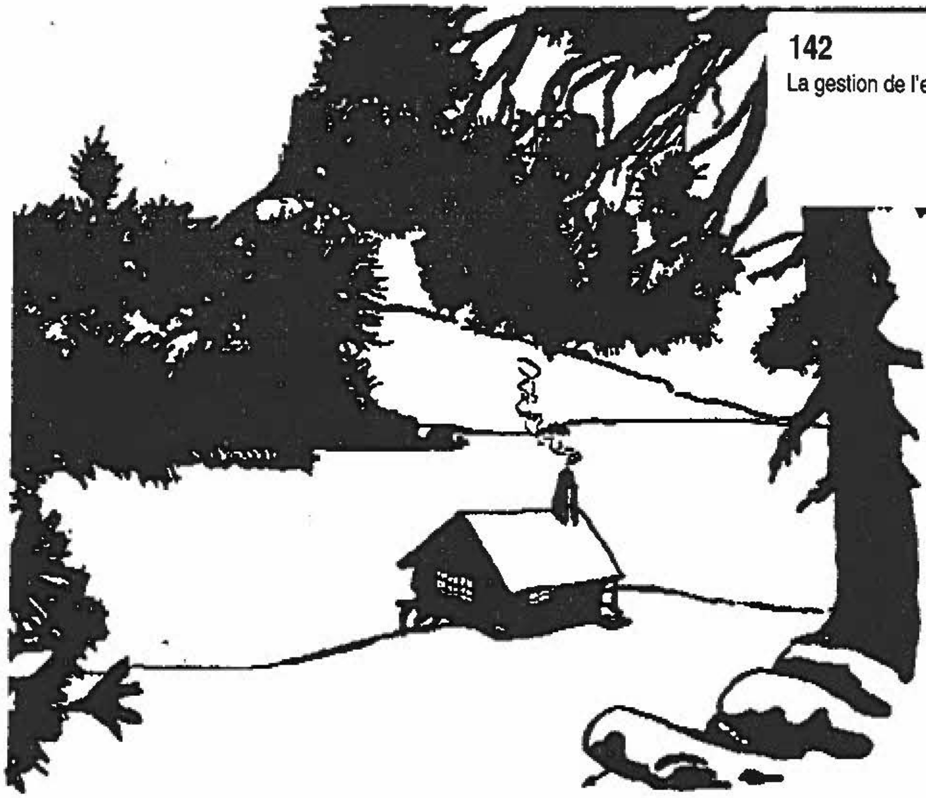

Water Quality Affects Property Prices: A Case Study of Selected Maine Lakes

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INTRODUCTION

Maine is a state that takes great pride in the quality and abundance of its natural resources. Maine's freshwater lakes and ponds, covering close to a million acres, play a key role in defining the landscape character. These freshwater bodies provide recreational and economic opportunities to the people of Maine as well as aesthetic beauty and habitat for many fish and wildlife species.

While Maine is known for clear, high-quality lakes, lake-water quality is threatened by organic enrichment (DEP 1990). Currently, 260 lakes and ponds totaling over 238,188 acres do not meet federal-state standards for swimming, aquatic life support, or increasing trophic trend.[1] There are 44,004 additional acres considered to be unimpaired but threatened (DEP 1994). The threat to Maine's lake-water quality is due mostly to nonpoint source pollution originating from excess runoff from development, silviculture, and agriculture (DEP 1989, 1994). The general symptom of increased nutrient loading, eutrophication, is increased photosynthetic productivity, primarily in the form of algal growth. Excess algal growth leads to decreased water transparency and reduced oxygen content in the water, and it often causes changes in a lake's biological community such as in the distribution of fish species (Monson 1992; Cooke et al. 1993). Eutrophication that does not occur naturally, but is induced by human activity, is known as cultural eutrophication and is the most important cause of poor water quality in Maine's lakes. Eutrophication results in decreased recreational benefits, reduces a lake's aesthetic benefits, and lowers the prices of properties around the lake.

Protecting lake water is not without costs, and lake protection monies are allocated with no information about the economic effects of lake-water quality protection. Over the last decade, $80,000 to $250,000 a year has been allocated by the state for lake protection and restoration. Information about the economic effects of lake-water quality protection would be useful in prioritizing lake management efforts and in public education programs.

Lake-front property owners are potentially the recipients of the greatest economic gains from improved lake-water quality because the benefits of water quality can be capitalized in the price of lake-front properties. These same lake-front owners may also directly affect lake-water quality through the actions they take on their properties. The objective of this study is to estimate the effect of water clarity on lake-front property prices for selected Maine lakes using a hedonic property-price model. Hedonic models are used to estimate the share of property prices that are attributable to characteristics of the properties. The word hedonic comes from individuals acting in their own self interests to select the property with the most desirable set of characteristics. Thus, people will pay more, all other characteristics being equal, for a property on a lake with high water quality than they would for a property on a lake with lower water quality. 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.

LAKE MANAGEMENT IN MAINE

The water quality standards of the Clean Water Act (1977) and related state standards require lakes to support uses for fishing, swimming, aquatic life support, and human fish consumption. The Maine Department of Environmental Protection (DEP) uses various indices to monitor changes in water quality and the potential for change in the future.

A major management goal for Maine's lakes and ponds is to maintain a stable or decreasing trophic state (DEP 1994). Lakes may be categorized as eutrophic, high nutrient levels and high plant growth, mesotrophic, or oligotrophic, low nutrient concentrations and low plant growth. Of the 695 lakes greater than 10 acres in size for which DEP has monitoring data, 79% are mesotrophic, with 12% and 9% rated as eutrophic and oligotrophic, respectively. The trophic status of a lake is affected by the age and shape of the lake, geology of the watershed, ratio of watershed area to lake area, flushing rate of water through the lake, human impact, and other factors. Therefore, lakes that are lumped into one category such as eutrophic, may each have a unique set of attributes that contribute to their trophic status (Monson 1992).

[1]Trophic means nutrition or growth. The trophic state of a freshwater pond or lake indicates the level of photosynthetic activity in the lake (algae and aquatic plant growth).

To prevent the degradation of Maine's lakes, the Maine DEP sets lake protection policies and undertakes lake restoration projects. Regulation, education, technical assistance, and restoration are all components of a comprehensive lake management plan for the state. Although the DEP utilizes all of these tactics, preventative management strategies are emphasized. The agency states "the future of Maine lake-water quality will depend in great measure on how well DEP promotes evolving guidance for protection and on efforts in education of Maine citizens. Restoration of lake-water quality, with its great expense and technical difficulty, will continue to be pursued, but emphasis will remain on planning for protection and the inevitable growth of development in lakes watersheds" (DEP 1990:42). Large-scale restoration projects can cost from $100 to well in excess of $2,000 per acre (Cooke et al. 1993), while education programs are less costly in terms of direct expenditures. The more informed property owners are of the causes of nonpoint source pollution and the benefits they enjoy by protecting lakes from cultural eutrophication, the more incentives they will have to take voluntary action to prevent nonpoint source pollution and to support lake protection regulations. One piece of the information that can provide substantial incentive is the effect of water quality on the price of lake-front properties.

HEDONIC MODELS

Lake-front properties can be viewed as heterogeneous goods; they have a number of different characteristics and are differentiated from each other by the quantity and quality of these characteristics. When consumers purchase differentiated goods, they are purchasing the characteristics that make up that good (Lancaster 1966). If the quality of one characteristic changes, we expect the price of the good to change. If consumers have a choice in the quantity and quality of characteristics of a market good, and an environmental good is a characteristic of the market good, then the implicit price of a nonmarket characteristic, such as water quality, can be observed through consumers' purchases in the market. If two lake-front properties are exactly the same and only differ by the level of water quality for their respective lakes, the price differential between the two properties is the implicit price paid for the property on the lake with higher water quality. Most comparisons are not this simple and a hedonic model can be used to control for other characteristics of properties when estimating the effect of water clarity on the overall property price.

Hedonic pricing techniques have been used in a wide variety of applications to estimate prices of nonmarket amenities that may be capitalized in the price of a housing unit, ranging from earthquake risk perception (Brookshire et al. 1988) to countryside attributes (Garrod and Willis 1992). The most common application has been the measurement of the effect of air pollution on property prices (Anderson and Crocker 1971; Murdoch and Thayer 1988; Graves et al. 1988; Brucato et al. 1990; Smith and Huang 1995). Hedonic property models have been used to measure the implicit price that property owners pay for water quality as a portion of the overall prices of properties in a number of studies (David 1968; Epp and Al-Ani 1979; Feenberg and Mills 1980; Young and Teti 1984; Brashares 1985; Mendelsohn et al. 1992).

The earliest study that used a hedonic model to estimate the implicit price of water quality was done for artificial lakes in Wisconsin, using a subjective water quality rating of poor, moderate, or good (David 1968). David (1968) found that water quality significantly affected property prices.

Epp and Al-Ani (1979) examined the effect of water quality on rural nonfarm-residential property prices. A subjective variable developed from property owners' impressions of the quality of the water, and acidity and several other physical measures of water quality were tried in this study. The investigators found that owners' perceptions of water quality and acidity had significant effects on the property prices, but only measures of acidity had a consistently significant negative effect. Therefore, acidity was used as the physical indicator of water quality in the model.

Feenberg and Mills (1980) built upon an air pollution study done by Harrison and Rubinfeld (1978) in the Boston area by adding water quality into the hedonic equation. Thirteen physical measures of water quality were considered. Of the thirteen water quality variables, oil and turbidity showed the strongest correlation with property prices and were included in the final model.

Young and Teti (1984) estimated a hedonic model to determine the impact of water quality on the price of seasonal homes adjacent to St. Albans Bay on Lake Champlain in northern Vermont. Properties outside the bay were compared with properties around the bay. They found that degraded water quality significantly depressed property prices around the bay relative to properties outside the bay.

Brashares (1985) estimated the implicit price of lake-water quality for 78 lakes in southeast Michigan. Brashares considered eight different measures of water quality and found that only turbidity (which is comparable to secchi disk measurements of clarity used in the current study) and fecal coliform were significantly correlated with property prices. Turbidity is a water quality measure that is visible. Fecal coliform levels, although not visually perceptible, were monitored by the state board of health and were reported to potential property buyers.

These studies show that water quality can significantly affect property prices and provide insight for the design of the Maine study. Water quality variables not perceivable to the public, although important to water quality managers, are not likely to be capitalized into property prices (Brashares 1985). Subjective measures of water quality, although statistically significant, may only be applicable to the individual case study for which they are developed, and may be problematic for policy-makers because questions arise concerning how to equate changes in subjective perceptions with biological changes in the lake (Young 1984). Therefore, a nonsubjective measure of water quality that is readily perceivable to property buyers and sellers is most likely to affect property prices.

The choice of the physical measure of water quality depends upon the water quality aspect of interest. Our study is concerned with poor water quality resulting from eutrophication. Although eutrophication manifests itself in several water quality measurements such as dissolved oxygen levels, chlorophyll levels, and secchi disk measurements of water clarity, clarity measurements are most observable to the public.[2] Secchi disk readings are also readily available through the DEP lake-monitoring program. Transparency is highly correlated with other indicators of cultural eutrophication such as dissolved oxygen, chlorophyll levels, fish habitat, and swimmability.

MODEL

The form of the hedonic price model for this study is an equation with the house price, divided by the foot frontage on the lake (FTPRICE), as a function of structural characteristics (S), locational characteristics (L), and the natural log of water clarity (W).

$$\text{FTPRICE} = f(\text{S, L, ln[W]}).$$

The model is estimated with house price divided by foot frontage on the lake as the dependent variable to facilitate the extrapolation of estimated implicit prices for changes in property prices for an entire lake. Structural characteristics describe the size and quality of the property itself, and locational characteristics describe the neighborhood and other locational influences on property prices. Water clarity is expressed as the natural log in the equation to reflect the nonlinear relationship between price per foot frontage and water clarity. It is assumed that at lower levels of water clarity property owners are willing to pay more for a one meter improvement in clarity than are owners who live on a lake that is very clear (Figure 1). In fact, changes in clarity occurring above four meters are not as visibly noticeable as are changes in clarity below this threshold (Smeltzer and Heiskary 1990), supporting the assumption that the relationship between property prices and water clarity is nonlinear.

A time-series, or repeat-sales model, is sometimes used to estimate hedonic price models. Most often these models will be used when an event has occurred, such as the announcement of a leaking toxic waste dump, to investigate how property prices change over time.

Cross-sectional data is used in this study for a number of reasons. First, trends in water clarity change slowly so a long period of time is required to capture the change in the market for lake-front properties. Second, when using time-series data, market trends must be accounted for in the model. In the 1980s, there was a dramatic increase in lake-front property prices, which rapidly disappeared at the end of the decade. Third, transfer tax records were required by law to be held as public records after 1986. Records of transfers occurring before that date are not generally available. Finally, accurate property characteristics for historical sales are not available. Property records are updated with each new assessment and only reveal the most recent data.

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[2]Secchi disks are round disks that are white and black on alternating quadrants. The disks are lowered into the water on a metered line. The point where the disk disappears from sight is a measure of water clarity (transparency).

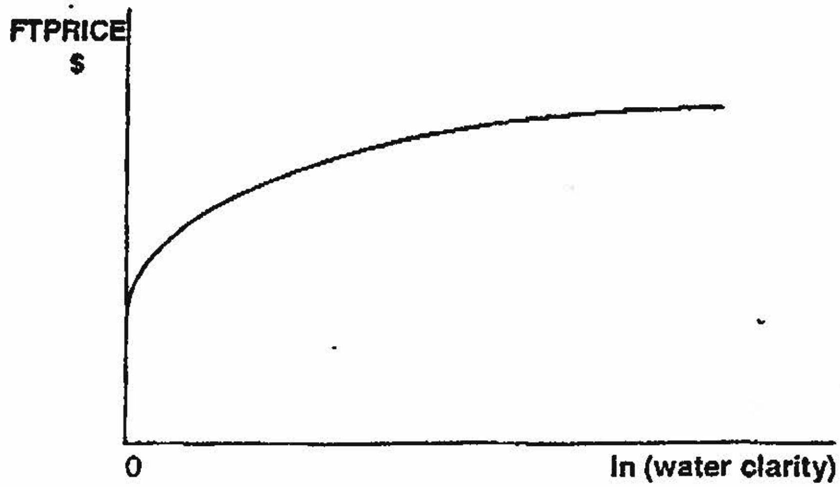

Figure 1. Expected relationship between property price and water clarity.

The structural and locational variables included in the model were based on a review of previous studies, unique characteristics of the properties in this study, and availability of property data (Table 1). Structural characteristics were chosen to reflect the size and quality of the property. Variables indicating the size of the structure include number of stories (STORY), square feet of living area (LVAREA), and characteristics such as fireplaces (FIRE) and decks and porches (DECK). For recreational homes, characteristics that distinguish camp style construction from year-round residential living also need to be included, so information about the type of heating system (HEAT) and (ELHEAT), full basement (BSMNT), full bath (PLUMB), septic system (SEPTIC), and garage (GARAGE) were collected from property records. The presence of, or increase in size of, all of these variables except ELHEAT are expected to increase the price of a house so the coefficients on these variables are expected to be positive.

In addition to structures, the land that the structures are located on affects property prices. The only land characteristics available from the property records are the size of the lot (LOTSZ), and feet of frontage on the water and on the road (not included in the model). FRONT, a measure of the feet of frontage on the lake, is used as part of the dependent variable (FTPRICE = PRICE/FRONT) and is not included as an explanatory variable.

Locational characteristics or neighborhood characteristics are included to control for local amenities that contribute to the price of a property. The locational variables incorporated into the model are location on a private or publicly maintained road (RDPUB), housing density along the lake within 500 feet on both sides of the property (DNSTY), the mil rate for the town the year the property was sold (TAXRT), distance to the largest city in the vicinity (DIST), and size of the lake (LKAREA). The type of road, private versus public, is indicated on the tax maps. The housing density variable was constructed by counting the number of lots that fell within one thousand feet of shore frontage around the sale property. The DIST variable was constructed by measuring the distance to a common city for each lake group, which would be the business/shopping center for the area. For example, all of the properties in Lake Group 1 were measured to Auburn.

To select a measure of water clarity that best reflects the perceptions of property sellers and purchasers a telephone survey was conducted. At least one property purchaser on each lake was randomly selected to participate in the survey, providing a usable sample of 52 properties.[3] The effective response rate was 72% (52/72). Of the 52 respondents, 11 were from out of state and 41 resided in Maine. Property purchasers were surveyed in the evening hours during April 1995.

[3]The sample for the survey was limited because of a modest study budget, and in the next phase of the research, all property purchasers will be surveyed. It was important to avoid contacting too many property owners in the current study because it is desirable to survey each property owner once and contacting property owners now may affect their responses to the future survey.

Table 1. Explanatory variables included in hedonic model.

Name	Description
Structural Variables	
STORY	1= more than one story in the main part of the house, 0 if one story
LVAREA	total square feet of living area
FIRE	number of fireplaces
HEAT	1= central heating system (oil or electric), 0 otherwise
ELHEAT	1= electric central heating system, 0 otherwise
BSMNT	1= full basement, 0 otherwise
DECK	1= one or more decks, 0 otherwise
PLUMB	1= full bath facilities, 0 otherwise
SEPTIC	1= septic system or town sewer, 0 otherwise
GARAGE	1= one or two car garage present, 0 otherwise
LOTSZ	size of lot in acres
Locational Variables	
RDPUB	1= road publicly maintained, 0 otherwise
DNSTY	lots/1000 ft of frontage adjacent to property
TAXRT	mil rate for the year the property was sold
DIST	distance to nearest city (miles)
LKAREA	area of the lake (acres)
Environmental Quality Variable	
WATERQ	secchi disk readings (meters) of the minimum clarity in the lake for the year the property was sold
TREND	difference between the minimum water clarity the year the property was sold and a ten year average of clarity minimum in the lake

The survey asked questions to determine how familiar purchasers were with the lake and its water clarity before they bought the property, how much water clarity influenced their purchasing decision, and how their perceptions of the water clarity match up with the actual water clarity in the lake (James 1995). The survey results indicate people were most familiar with the current water clarity in the lakes, but the history of water clarity also influenced purchase decisions. Perceptions of water clarity in the lakes were significantly correlated with secchi disk readings of clarity taken on the lakes (Pearson's correlation coefficient, $r= 0.44$, $p=0.01$). Based on these results, secchi disk readings of the minimum water clarity in the lake for the year the property was sold (WATERQ) were used as the environmental variable with a variable to control for the historical trend in lake-water clarity. A continuous variable indicating the difference between WATERQ and a ten-year average of water clarity on the lake (TREND) was computed.[4] If water clarity in the lake were increasing, TREND would be positive, and the converse would hold if water clarity were decreasing. It is expected the signs of the coefficients on WATERQ and TREND will be positive.

DATA

Thirty-four Maine lakes were selected for the study. These lakes were grouped into six separate markets. A market was defined as a group of lakes in close proximity to each other and near a large community. The purpose of selecting groups of lakes representing separate markets is to test whether estimated implicit prices for water clarity vary across markets and minimize the effects of geographical characteristics. We are assuming that there may be differences in preferences for clear water in different parts of the state and these differences would affect the implicit price of lake-water clarity. The six markets selected for the study are Lewiston/Auburn, Augusta, Waterville, Newport, Ellsworth, and northern Aroostook County. The lakes within each group are listed in Table 2.

[4]Ten different measurements of water clarity were tried in the hedonic model before selecting WATERQ and TREND; measurements reflecting the current, historical, and the change in water clarity over the summer season (James, 1995). The water clarity variable selected for the final model was based on the performance of each of the various measures in the estimated hedonic equations and the results of the telephone survey.

Table 2. Department of Environmental Protection lake monitoring data for study lakes (1992).

		Water Clarity			Lake Size	
		Min	Mean[a] (meters)	Max	Lake area (acres)	Average depth (meters)
Group 1:	Lewiston/Auburn Area					
	Sabattus Lake (1989)[b]	1.0	2.3	3.5	1,962	14
	Taylor Pond	3.7	4.7	5.5	625	17
	Thompson Lake	5.8	8.2	9.9	4,426	35
	Tripp Pond	4.3	5.7	7.3	768	11
Group 2:	Augusta Area					
	Anabessacook	1.4	3.2	5.3	1,420	21
	Androscoggin Lake	3.1	3.8	4.4	3,980	15
	Cobbossecontee	1.4	2.5	3.2	5,543	37
	Echo Lake	5.0	6.3	6.8	1,155	21
	Maranacook	5.0	5.4	6.0	1,673	30
	Togus Pond	4.0	5.4	7.0	660	20
Group 3:	Waterville Area					
	China Lake	1.6	2.9	4.4	3,845	28
	East Pond	3.4	4.4	5.8	1,823	18
	Great Pond	4.9	6.0	6.8	8,239	21
	Messalonskee Lake (1991)[b]	4.0	5.6	6.9	3,510	33
	North Pond	2.5	4.0	6.3	2,873	13
	Threemile Pond	1.5	3.7	4.9	1,162	17
	Webber Pond	1.4	3.0	4.4	1,201	18
Group 4:	Newport/Dexter Area					
	Big Indian Lake	5.8	5.9	6.2	990	15
	Great Moose Lake (1989)[b]	4.5	4.5	4.5	3,584	18
	Lake Wassookeag	5.0	8.9	11.0	1,062	27
	Sebasticook Lake	0.3	1.1	2.1	4,288	20
	Unity Pond	1.1	2.3	3.4	2,528	22
Group 5:	Ellsworth Area					
	Alamoosook Lake	5.0	5.7	6.9	1,133	16
	Beach Hill Pond (1990)[b]	5.0	5.7	8.7	1,351	44
	Branch Lake (1991)[b]	6.5	7.4	7.7	2,703	39
	Graham Lake (1979)[b]	2.0	2.6	3.0	7,865	17
	Green Lake (1991)[b]	4.4	5.8	7.5	2,989	44
	Phillips Lake	7.5	8.3	8.5	828	40
	Toddy Pond	4.0	5.2	6.8	1,987	27
Group 6:	Northern Maine					
	Cross Lake	2.3	3.2	3.5	2,515	20
	Eagle Lake (1989)[b]	4.6	4.6	4.6	5,581	44
	Long Lake	2.5	3.8	5.0	6,000	46
	Madawaska Lake	1.9	2.8	4.0	1,526	16
	Square Lake	3.0	3.5	4.9	8,150	36

[a]The secchi disk measurements represent the mean for the measurements taken between May and October 1992.
[b]If 1992 measurements were not available, data are reported for the most recent preceding year for which measurements were available, year denoted in parenthases after the lake name in the left column.

Data on lake-front property sales were collected for sales occurring between January 1, 1990, and June 1, 1994. This time period was selected for two reasons. The real estate boom of the 1980s was over, and house prices were rising very little during the early 1990s in Maine (Institute for Real Estate Research and Education, University of Southern Maine). Second, the DEP possessed extensive water clarity records for this time period. Data for several years were used because of the small number of sales that occur in any given year.

Property sales were obtained from transfer tax records. Property characteristics were transcribed from property tax records held in the town offices. The 34 lakes in the sample encompassed 53 organized towns and unorganized territories. Property sales information for unorganized territories is held in the state office of the Bureau of Taxation in Augusta. The property records reveal information structure characteristics and lot size. Only residential or recreational single family homes with lake frontage or unimproved land sales of less than twenty acres with lake frontage were included in the sample. Condominiums or any property purchased with common property rights were not included in the sample. Properties purchased with multiple single family housing units, not including sleep camps, were also excluded. These exceptional properties are not well enough represented in the data to statistically control for their unique characteristics.

Secchi disk readings have been recorded for hundreds of Maine lakes from May through October of each year since the late 1970s by DEP employees and volunteers. Most of the lakes in the study had readings taken every two weeks. Some clear lakes that are not experiencing algae blooms are not monitored as closely because water clarity is relatively constant in these lakes. If the minimum water clarity measurement was not available for the year that the property was sold, the minimum for the closest previous year was used. The closest measurements in time to the sale dates of the properties are assumed to provide adequate proxies for the missing data.

Water clarity varies among lakes within each of these groups, ranging from minimum clarity measurements above four meters (m) to two meters or less. Table 2 documents the water clarity for each of the study lakes using 1992 transparency data for illustrative purposes. Except Ellsworth, all groups contain one or more lakes that have undergone restoration projects that involved substantial media coverage of water quality problems and causes (Table 3).

Not all of the eutrophic lakes selected for the study are the result of human activity, some of these lakes are naturally eutrophic due to their geological features and some have natural coloration. If people have preferences for clear water, the price of properties on naturally eutrophic lakes will be less than on clear lakes in the same way that culturally eutrophic lakes depress property prices. Including naturally eutrophic lakes in the model along with culturally eutrophic lakes expands the data base and enhances the precision with which the hedonic price equation can be estimated. However, it would not be appropriate to apply the estimated implicit prices for changes in water clarity to lakes that are naturally eutrophic or colored and can not easily be manipulated by management when making policy decisions regarding lake-water quality.

In addition to water clarity, other lake characteristics may influence the price of a property. Some of these characteristics might be the size of the lake, the type of fishery that it supports, fish stocking in the lake, and the potability of the water. Many of these variables are correlated with water clarity because as water clarity improves fishing, swimming, and potability also improve. By not including these variables in the model that may be correlated with water quality and may affect property prices, the estimated implicit prices for improved water clarity include the effects of these related water quality variables.

The area of the lake was also correlated with water clarity and was included in the model as an interaction term with water clarity. In the case where the correlation between FTPRICE and LKAREA is positive (Group 1), LKAREA is multiplied by WATERQ. When the correlation is negative (Groups 2 and 6), WATERQ is divided by LKAREA. In Group 3 LKAREA was not significantly related to the property price so it was not included in the model. It was important to identify the effect of lake area from water clarity because changes in water clarity do not result in changes in lake size.

After collecting the property data, it became evident that the Newport group would not have sufficient property characteristic information to estimate the model due to inconsistent record keeping in these towns. This group was eliminated from the study. The Ellsworth group also presented a problem in estimating the hedonic model. Unlike the other lake groups selected for the study, the Ellsworth group had only one lake with poor water clarity (Graham Lake), which had only one property sale with a structure. Because all of the other lakes in the group have relatively high water clarity, greater than 4 m (meters) (Table 2), there was not enough variation in water clarity in this group to estimate the marginal effect of water clarity on property prices. The final number of observations, used in estimating the models, consisted of 543 property sales, 90 in Group 1, 84 in Group 2, 214 in Group 3, and 155 in Group 6.[5]

[5]The data were also screened for outliers. The reported sample sizes exclude three observations that were removed as a result of this screen.

Table 3. Lake restoration projects (DEP 1993).

Group 1: Auburn

Sabattus Pond

The Sabattus Pond Restoration project included enhanced seasonal flushing and installation of Best Management Practices on farms in the watershed in 1987. Seasonal drawdown continues.

Group 2: Augusta

Anabessacook Lake

Restoration in 1976–1979 involved control of agricultural sources of phosphorus in the watershed and an alum treatment in 1978.

Cobbossee Lake

Restoration in 1976–1979 involved control of agricultural sources of phosphorus in the Watershed.

Togus Pond

Shorefront homeowners have independently and voluntarily cooperated by correcting problems with septic systems since 1983.

Group 3: Waterville

China Lake

This project, as designed in 1988, consisted of reduction of major nonpoint sources of erosion and adoption of a long-term lake protection strategy. This program is still being implemented.

Threemile Pond

This restoration project involved control of nonpoint sources of phosphorus and an alum treatment (1988). Watershed management work continues.

Webber Pond

Restoration project included control of agricultural nonpoint sources of phosphorus, reduction of shoreline erosion problems and seasonal drawdown. Seasonal drawdown continues.

Group 4: Newport

Sebasticook Lake

Restoration project, 1979–1990, addressed (1) elimination of point sources at Dexter, (2) reduction of point sources at Corinna, (3) reduction of agricultural nonpoint sources of phosphorus, (4) enhanced seasonal drawdown. Annual drawdown continues.

Group 6: Northern Maine

Long Lake and Cross Lake

Problem agricultural sites were targeted for installation of innovative nutrient control wetland/pond systems. To date, ten of these have been constructed. An aggressive educational campaign by the area lakes association has been conducted over the last three years.

Madawaska Lake

A diagnostic/feasibility study was completed in a coordinated effort between DEP, the Soil and Water Conservation District, major landowners and volunteers. Several land-based recommendations were made for the major land uses including forestry, agriculture, camp and home lots, shoreline erosion, commercial property, public property, and roads and associated ditches.

RESULTS

The final data set indicates that property sales prices are highest in the Auburn area and lowest in northern Maine, with averages ranging from $96,304 to $35,160 per property. Price per foot frontage was $870/ft for the Auburn group and $317/ft for northern Maine. Average minimum water clarity was also highest for the Auburn group (5.7 m) and lowest for the northern Maine group (3.1 m). Summary statistics for all variables by lake group and by lake are reported in Appendix I.

Separate hedonic equations were estimated for each lake group. This allows the implicit price of water quality to vary across lake groups to reflect differences in water quality preferences of lake-front property owners and other differences in market conditions. The full equation estimates are not reported in the text because the focus here is on the effect of water quality on property prices, not the other property characteristics included in the equations. The full equations are documented in Appendix II.

Within the text we report what we refer to as reduced equations that include a grand constant (α) and the water quality effect (β):

$$FTPRICE = \alpha + \beta \ln (WATERQ).$$

The grand constant varies from lake to lake. For each lake, all variables in the equation, except WATERQ, are evaluated at their means for that lake (Appendix I). The means are multiplied by their respective coefficients for the lake group (Appendix II) and the products are summed, including the lake-group intercept terms. Thus, the grand constant varies across lakes according to the variable means for each specific lake and the different equation coefficients for each lake group. The coefficient on WATERQ (β) varies across lake groups, but not across lakes within a group. The results of these computations are reported in Table 4. The mean WATERQ in Table 4 is the mean minimum water clarity for the property sales observations from each lake that were used in the estimation of the hedonic price equations.

The data in Table 4 provides the basis for developing a number of interesting estimates. Take China Lake as an example. The China Lake equation can be used to predict that the average property sells for $830 per foot of frontage on the lake [706.5 + 193ln(1.9)], and the share (implicit price) that is attributable to water clarity is $124 per foot of frontage [193ln(1.9)]. Or, the percentage of the purchase price that is attributable to the water clarity at the time of sale was 15% ($124/$830). Using the average foot frontage per property on China Lake, the average property sold for $107,070 ($830 × 129), which includes an implicit price for water clarity of $15,996 ($124 × 129). These calculations can be done for any lake in the study using the appropriate equation. These estimates are averages for developed and undeveloped lots.

Policy questions most often consider incremental changes in water clarity, not marginal changes. For example, how much would property prices increase on China Lake if water clarity increased to 4 m of transparency. This figure is computed by subtracting the current implicit price of $124 per foot of frontage from what the implicit price would be if water clarity improved to 4 m, $268 per foot of frontage [193 ln(4.0)].

Table 4. Equations with grand constant for calculating implicit prices for individual lakes.

Group	Lake	α	β	mean WATERQ (mean minimum water clarity)	Mean Foot Frontage/Lot	Total Foot Frontage of Lake
1	Sabattus Lake	1213.6	288.6	1.0	81.6	NA*
	Taylor Pond	498.3	288.6	4.1	102	29,040
	Thompson Lake	300.0	288.6	8.4	149	163,680
	Tripp Pond	-26.5	288.6	5.0	170	36,544
2	Anabessacook Lake	808.4	74.9	1.1	115	NA
	Androscoggin Lake	250.0	74.9	3.5	136	NA
	Cobbosseecontee Lake	597.4	74.9	1.7	162	192,000
	Echo Lake	400.3	74.9	6.2	191	63,888
	Maranacook Lake	678.5	74.9	5.0	117	92,664
	Togus Pond	780.6	74.9	4.6	106	40,656
3	China Lake	706.5	193.0	2.9	129	114,048
	East Pond	427.1	193.0	3.0	160	NA
	Great Pond	335.4	193.0	5.8	169	194,832
	Messalonskee Lake	371.1	193.0	5.0	140	110,000
	North Pond	330.4	193.0	2.7	97.4	NA
	Threemile Pond	406.6	193.0	2.8	126	43,290
	Webber Pond	387.1	193.0	1.0	110	36,500
6	Cross Lake	165.4	168.3	1.9	159	88,735
	Eagle Lake	158.4	168.3	4.6	136	178,719
	Long Lake	49.1	168.3	2.8	168	180,114
	Madawaska Lake	421.3	168.3	2.1	87	53,730
	Square Lake	-170.1	168.3	3.2	167	11,451

*NA indicates this data is not available.

Table 5. Aggregate changes in property prices on selected lakes for a one meter (1m) change in water clarity.

	China Lake	Cobbossee Lake	Long Lake
Av. min. clarity	1.9m	1.7m	2.8m
Improving price for 1m	$81/ft	$34/ft	$52/ft
Degrading price for 1m	$141/ft	$65/ft	$75/ft
Total Lake Frontage	114,048 ft	192,000 ft	180,114 ft
Total change in property prices			
Improving	$9,237,900	$6,528,000	$9,365,900
Degrading	$16,080,700	$12,480,000	$13,508,600

The increase in property prices would be $144 per foot ($268 - $124). On the other hand, if water clarity declined to 1 m, the loss would be $124 [193 ln(1.9) - 193 ln (1.0)], the entire premium. The loss for less than a 1 m decline in water clarity is only slightly less than for an increase of greater than 3+ m increase due to the nonlinear, hedonic price equation (Figure 1).

Finally, many people, including legislators, community leaders, and others involved in protecting Maine's lakes, may want to know by how much a change in water clarity will affect aggregate property prices around a lake. This information is computed by multiplying the change in implicit price associated with a change in water clarity by the total foot frontage of a lake:

Total change in property prices for lake = Change in implicit price for lake * Foot frontage of lake

Examples of changes in aggregate property prices for selected lakes are presented in Table 5. These examples assume 100% developable land. Some of the land around a lake may not be developable because it is preserved for conservation, or is a wetland or a steep slope. If figures are available for the amount of developable land around a lake, these numbers can be used to get more accurate measures of the total change in property prices around a lake. For the examples below, we assume the land is all developable.

EXTENSIONS AND LIMITATIONS

It is important to realize there are limitations to the study results. The estimated implicit prices for water clarity are based on everything else being equal. For example, if the DEP's efforts to protect Maine's lakes are successful and water clarity in most lakes improves, the supply of properties on clear lakes would increase. A larger supply of properties on clear lakes will reduce the impact of water clarity on property prices. For current applications, with small changes in water clarity on a small number of lakes, the estimations are appropriate.

The estimates reported here are actually based on a very small percentage of Maine's lakes and ponds. The equations may be used to predict changes in property prices on lakes not selected for the study, but that are adjacent to the lakes within each lake group. For lakes not included in the study, the mean values for the variables in the equations need to be calculated for the properties on each lake to compute a new grand constant unique to each lake. The equations estimated in this study are not accurate predictors of changes in property prices occurring on lakes that are outside the real estate markets for the lakes included in the study.

Small ponds, of which Maine has many, were not included in any of the lake groups in this study. For example, 52% of the 5,787 lakes in Maine are less than ten acres in size and 29% are ten to 100 acres in size. This omission occurs because of limited water clarity measurements for these waters and the small numbers of property sales. Because the characteristics of these lakes, properties, and property purchasers may differ from larger lakes in Maine, the estimated equations can not accurately predict changes in property prices on small ponds inside or outside of the regions covered by the lake groups included in this study.

Finally, lakes with diminished clarity from cultural and noncultural eutrophication were included in the estimation. The estimated implicit prices are only appropriate for public policy where lake management activities can protect or enhance lake-water clarity.

CONCLUSIONS

The results of this study show that water clarity significantly affects property prices around Maine lakes. Controlling for both the current and historical water clarity of the lake in the implicit price equations, a 1 m improvement in lake water clarity results in changes in average property prices ranging from $11 per foot frontage for Echo Lake in the Augusta area (Group 2) to $200 per foot frontage for Sabbattus Lake in the Auburn area (Group 1). These implicit prices, when aggregated for an entire lake, equate to millions of dollars in improved property prices per lake.

The goal of lake management in Maine is to maintain stable trophic levels and to reduce algal blooms associated with cultural eutrophication. If cultural eutrophication advanced in Maine's lakes, further reducing water clarity, these implicit prices for changes in water clarity would be greater, producing an even larger impact on property prices. The Maine DEP has found that public education programs are their best defense against degrading water quality due to cultural eutrophication. The implicit prices for water clarity estimated in this study will be useful in public education programs to convince property owners that they gain when they take actions to protect lake water quality.

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APPENDIX 1—MEAN VALUES FOR VARIABLES BY LAKE GROUP AND FOR EACH LAKE WITHIN THE GROUPS.

Group 1—Auburn area.

	Group	Sabattus Lake	Taylor Pond	Thompson Lake	Tripp Pond
FTPRICE	870	749	1095	972	531
FRONT	131	81.6	102	149	170
STORY	0.244	0.450	0.417	0.136	0.143
LVAREA	886	849	998	886	846
FIRE	0.300	0.250	0.333	0.318	0.286
HEAT	0.367	0.400	0.500	0.364	0.214
ELHEAT	0.156	0.100	0.167	0.182	0.143
BSMNT	0.267	0.300	0.500	0.273	0.000
DECK	0.733	0.750	0.583	0.773	0.714
PLUMB	0.767	0.700	0.750	0.727	1.00
SEPTIC	0.798	0.800	0.727	0.750	1.00
GARAGE	0.167	0.150	0.250	0.159	0.143
LOTSZ	1.02	0.373	0.523	1.21	1.77
RDPUB	0.544	0.600	0.417	0.523	0.643
DNSTY	9.16	11.3	10.4	8.05	8.50
TAXRT	15.8	16.6	22.9	12.8	18.3
DIST	11.8	4.00	2.00	17.9	12.0
TREND	0.325	0.180	0.233	0.346	0.547
WATERQ	5.66	1.00	4.12	8.41	5.01
LKAREA (acres)	2802	1962	625	4426	768
TOTAL LAKE FRONTAGE (feet)	NA	NA	29,040	163,680	38,544
N	89	20	11	44	14

Group 2—Augusta area.

	Group	Anabessacook Lake	Androscoggin Lake	Cobbossee Lake	Echo Lake	Maranacook Lake	Togus Lake
FTPRICE	713	676	365	625	537	882	882
FRONT	135	115	136	162	191	117	106
STORY	0.286	0.429	0.000	0.364	0.000	0.385	0.231
LVAREA	770	691	391	693	677	914	970
FIRE	0.476	0.714	0.111	0.545	0.571	0.615	0.154
HEAT	0.321	0.571	0.111	0.318	0.286	0.192	0.615
ELHEAT	0.119	0.143	0.111	0.000	0.143	0.269	0.000
BSMNT	0.286	0.429	0.111	0.227	0.000	0.365	0.385
DECK	0.750	0.857	0.556	0.727	0.429	0.885	0.769
PLUMB	0.702	0.857	0.222	0.727	0.429	0.846	0.769
SEPTIC	0.738	0.857	0.333	0.773	0.571	0.846	0.769
GARAGE	0.265	0.333	0.111	0.136	0.429	0.192	0.615
LOTSZ	1.11	0.710	1.338	1.22	3.02	0.857	0.469
RDPUB	0.393	0.429	0.778	0.227	0.429	0.528	0.077
DNSTY	8.46	9.857	7.89	7.82	5.14	9.038	9.846
TAXRT	17.8	20.2	15.9	19.3	15.1	15.8	20.8
DIST	13.0	12.9	20.0	9.36	6.00	12.0	20.0
TREND	-0.140	-0.099	-0.051	-0.317	0.714	-0.519	-0.375
WATERQ	3.70	1.09	3.47	1.72	6.21	5.04	4.59
LKAREA (acres)	2713	1420	3980	5543	1155	1673	660
TOTAL LAKE FRONTAGE (feet)	N/A	N/A	N/A	192,000	63,888	92,664	40,656
N	84	7	9	22	7	26	13

Group 3—Waterville Area

	Group	China Lake	East Pond	Great Pond	Messa-lonskee Lake	North Pond	Three-mile Pond	Webber Pond
FTPRICE	691	904	639	690	755	532	583	303
FRONT	146	129	160	169	140	97.4	126	110
STORY	0.187	0.323	0.263	0.148	0.171	0.111	0.227	0.000
LVAREA	729	905	814	716	806	554	513	464
FIRE	0 212	0.226	0.263	0.185	0.341	0.000	0.182	0.000
HEAT	0.268	0.484	0.211	0.160	0.341	0.250	0.318	0.182
ELHEAT	0.089	0.065	0.211	0.099	0.073	0.125	0.045	0.000
BSMNT	0.234	0.484	0.474	0.099	0.244	0.111	0.227	0.182
DECK	0.638	0.710	0.684	0.642	0.659	0.500	0.500	0.636
PLUMB	0.626	0.645	0.737	0.617	0.707	0.333	0.500	0.636
SEPTIC	0.695	0.871	0.737	0.667	0.756	0.333	0.524	0.727
GARAGE	0.192	0.387	0.158	0.185	0.098	0.111	0.227	0.091
LOTSZ	1.48	0.902	2.57	2.01	1.19	0.350	0.820	0.625
RDPUB	0.262	0.226	0.684	0.136	0.268	0.667	0.273	0.182
DNSTY	8.97	9.48	8.74	8.82	8.49	9.44	9.18	10.0
TAXRT	11.0	14.7	13.2	8.51	9.96	9.84	14.7	13.2
DIST	10.9	7.00	12.7	10.5	12.5	19.0	9.36	13.0
TREND	-0.243	-0.929	-0.689	-0.267	0.126	-0.634	0.667	-0.236
WATERQ	4.17	1.93	3.03	5.84	5.02	2.71	2.79	0.982
LKAREA (acres)	4812	3845	1823	8239	3510	2873	1162	1201
TOTAL LAKE FRONTAGE (feet)	N/A	114,048	N/A	194,832	110,000	N/A	43,290	36,500
N	213	31	19	81	41	9	21	11

Group 6—Northern Maine

	Group	Cross Lake	Eagle Lake	Long Lake	Madawaska Lake	Square Lake
FTPRICE	317	248	449	228	518	66
FRONT	145	159	136	168	87	167
STORY	0.116	0.000	0.318	0.098	0.091	0.000
LVAREA	628	489	859	547	829	56
FIRE	0.077	0.083	0.045	0.061	0.152	0.000
HEAT	0.316	0.083	0.545	0.293	0.364	0.000
ELHEAT	0.026	0.083	0.045	0.012	0.030	0.000
BSMNT	0.143	0.000	0.273	0.159	0.094	0.000
DECK	0.626	0.417	0.773	0.549	0.879	0.167
PLUMB	0.471	0.250	0.636	0.378	0.758	0.000
SEPTIC	0.542	0.500	0.682	0.463	0.758	0.000
GARAGE	0.252	0.250	0.182	0.293	0.242	0.000
LOTSZ	0.807	1.18	0.781	0.851	0.606	0.670
RDPUB	0.639	0.083	0.545	0.878	0.242	1.00
DNSTY	8.66	7.42	6.73	8.23	11.9	10.0
TAXRT	14.4	8.79	18.0	16.8	9.14	8.42
DIST	21.3	18.8	20.0	17.8	27.5	48.0
TREND	-0.270	0.065	0.700	-0.589	-0.202	-0.503
WATERQ	2.83	1.89	4.60	2.77	2.06	3.17
LKAREA (acres)	4801	2515	5581	6000	1526	8150
TOTAL LAKE FRONTAGE (feet)	143,457	88,735	178,719	180,114	53,730	11,451
N	148	12	22	82	26	6

APPENDIX 2—ESTIMATED HEDONIC COEFFICIENTS

Variable	Group 1 (Auburn)	Group 2 (Augusta)	Group 3 (Waterville)	Group 6 (Northern Maine)
INTERCEPT	-1676.8*[a]	397.30	-210.13	1306.4***
	(1022.6)[b]	(303.88)	(209.28)	(427.81)
STORY	-46.491	157.31*	180.15**	90.634*
	(193.96)	(88.868)	(72.332)	(54.353)
LVAREA	0.01776	0.15574*	-0.0637	0.00447
	(0.19716)	(0.08902)	(0.06920)	(0.04922)
FIRE	17.211	-86.304	104.08*	29.248
	(128.59)	(71.696)	(62.140)	(56.118)
HEAT	388.37**	258.02***	317.90***	31.952
	(177.97)	(99.109)	(79.823)	(45.061)
ELHEAT	-357.41*	-129.48	-84.415	78.801
	(191.16)	(116.79)	(97.196)	(104.61)
BSMNT	173.82	-75.245	-16.040	28.011
	(165.65)	(96.675)	(81.580)	(54.268)
DECK	198.21	52.676	248.84***	37.425
	(165.00)	(111.97)	(69.758)	(44.363)
PLUMB	161.44	-23.022	64.027	113.01***
	(271.14)	(156.25)	(96.441)	(46.427)
SEPTIC	99.518	201.60	-9.3422	44.520
	(265.67)	(126.92)	(111.21)	(45.695)
GARAGE	-143.51	31.098	279.71***	62.865
	(186.31)	(90.650)	(68.829)	(42.271)
LOTSZ	-17.245	-13.838	-20.934*	-20.294
	(36.219)	(21.367)	(10.310)	(20.939)
RDPUB	2.5166	111.88	-5.3434	5.7184
	(133.96)	(78.259)	(57.990)	(37.164)
DNSTY	22.262	36.581***	26.974***	21.125***
	(19.524)	(10.200)	(7.0792)	(5.4391)
TAXRT	-13.078	15.006	10.407	0.68316
	(17.875)	(9.3324)	(8.6922)	(2.1798)
DIST	-49.945*	-13.931*	-4.5529	-3.2959
	(25.664)	(8.4241)	(7.9977)	(2.1144)
TREND	-26.772	-84.988	-87.704***	34.826
	(176.16)	(74.373)	(32.462)	(36.253)
ln(WATERQ)	288.55**	74.860**	192.97***	168.34***
	(124.39)	(33.564)	(53.253)	(56.028)
R^2	0.3660	0.6451	0.5511	0.6456
N	90	84	214	155

[a] *significant at the 90th percentile, **significant at the 95th percentile, ***significant at the 99th percentile.
[b] Standard errors are shown in parentheses.

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