Muskegon Lake Area of Concern Habitat Restoration Project:
Socio-Economic Assessment Revisited

Final Project Report

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INTRODUCTION

Pollution from historical and contemporary sources impairs the health of the industrial Midwest's inland lakes and rivers. The Environmental Protection Agency currently lists 27 water bodies in the Great Lakes as "Areas of Concern." These are defined under the US-Canada Great Lakes Water Quality Agreement as "geographic areas designated by the Parties where significant impairment of beneficial uses has occurred as a result of human activities at the local level" (US EPA 2013)

Muskegon Lake, a drowned river-mouth system that drains directly to Lake Michigan, is one such Area of Concern (AOC). The EPA designated Muskegon Lake as an AOC in 1985 because historical pollutant discharges degraded water quality and habitat. Large inputs of nutrients, solids, and toxics also caused algal blooms, created anoxic conditions in deep water, tainted sportfish, degraded fish and wildlife habitat, and contaminated groundwater (US EPA 2019). Historical pollution sources include sawmill residues from the 19th century lumbering era and 20th century industrial development such as foundries, metal finishing plants, a paper mill, and petrochemical storage facilities (Steinman et al. 2008). The paper mill and many foundries closed as the city deindustrialized in the late 20th century. The BC Cobb coal-fired power plant closed in 2016 ending an era of lakeshore industrial development (McGuire 2017).

Despite Muskegon Lake's history of environmental problems, it is still an important recreational resource for West Michigan (Alexander 2006). Muskegon Lake is an approximately 1,700 ha lake with the Muskegon River flowing into it from the east and a navigation channel flowing from the lake into Lake Michigan to the west (Steinman et al. 2008) (Figure 1). Recreation on the lake consists of activities such as power boating, kayaking, angling, sailing, and wildlife-watching. A trail along its south shore creates access along the lake for walking, rollerblading, skateboarding, and cycling.

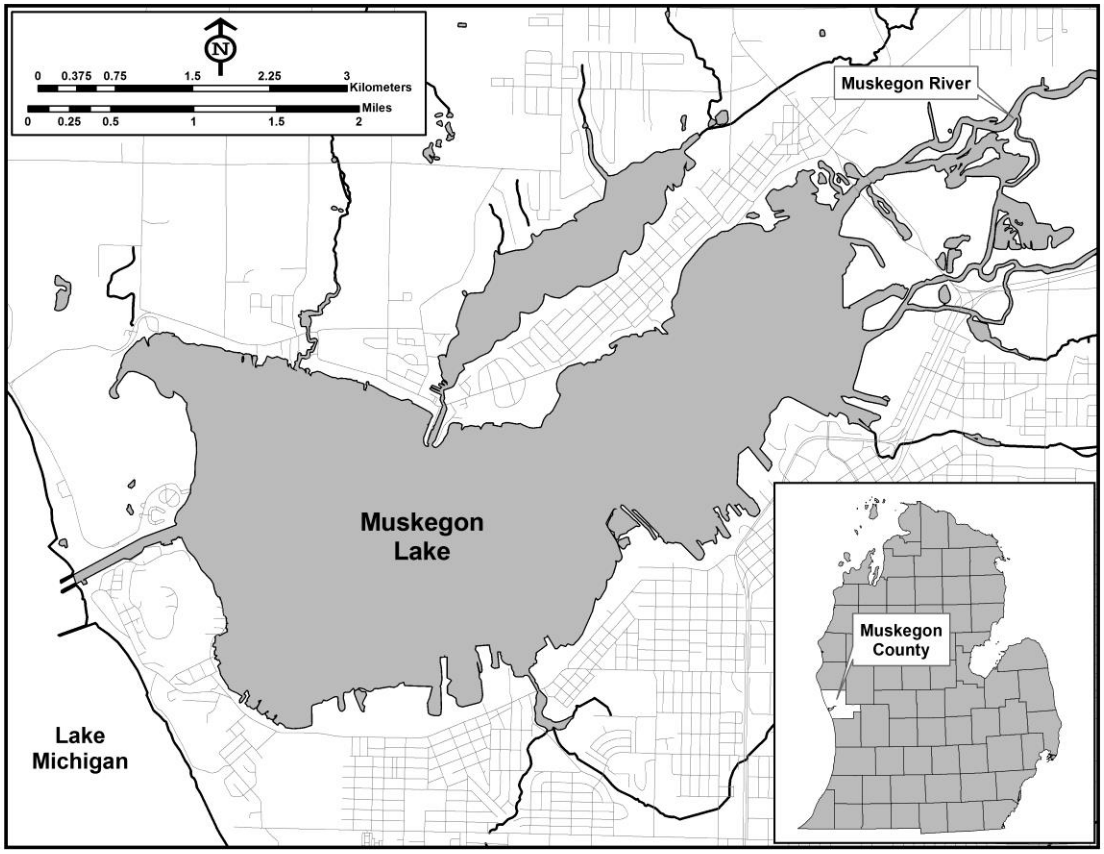


Figure 1: Muskegon Lake's geographic location in Muskegon County in the western portion of Michigan's lower peninsula.

Several lakes, including Michigan's White Lake, have been "delisted" as Areas of Concern. Muskegon Lake's condition is improving as efforts to restore critical habitat and remediate contaminated sites progress. Since 2013, three beneficial use impairments have been lifted: restrictions on drinking water consumption, restrictions on fish and wildlife consumption, and beach closing (US EPA 2019). Water quality has improved as the city's wastewater is diverted and treated at the Muskegon County Wastewater Management System. Invasive zebra mussels (*Dreissena polymorpha*) have also contributed to water quality improvements by filtering out phytoplankton (Steinman et al. 2008). The Annis Water Resources Institute maintains a dashboard of water quality measures for Muskegon Lake. This dashboard shows dramatic historical improvements since 1972, but also shows that many of these indicators have appeared to show improvements and met goals over the last ten years (Annis Water Resources Institute 2020).

Muskegon Lake's condition, however, must improve before it can be delisted as an AOC. The Michigan Department of Environmental Quality (now the Department of Environmental, Great Lakes, and Energy) approved delisting targets for the remaining beneficial use impairments (BUIs). These include the degradation of benthos; eutrophication and undesirable algae; degradation of aesthetics; loss of fish and wildlife habitat; and degradation of fish and wildlife populations (West Michigan Shoreline Regional Development Commission 2020). The last three BUIs are associated with Muskegon Lake's hardened shorelines. In 2008, almost three-quarters of the AOC was hardened shoreline. The lake's downtown shoreline was more than 85 percent hardened.

In the past, engineers often hardened shorelines by constructing concrete breakwalls or steel sheeting (Caulk et al. 2000). These structures can enhance commercial navigation or industrial development but also impose costs on society. Efforts to improve shoreline conditions focus on using "soft engineering." Softening the shoreline by using ecological principles and practices reduces erosion and stabilizes shorelines "while enhancing habitat, improving aesthetics, and saving money" (Caulk et al. 2000, 2). The BUI target calls for reducing the AOC's hardened shoreline to 52 percent by softening more than 7,300 linear meters of shoreline. It also calls for restoring 37 ha of additional wetland habitat and removing 50 ha of unnatural lake fill (West Michigan Shoreline Regional Development Commission 2020).

The National Oceanic and Atmospheric Administration in 2009 allocated $10 million to remediate contaminated sediments and restore habitat on Muskegon Lake. Goals included softening about 3,000 meters of shoreline, restoring 11 ha of wetland habitat, and removing or improving about 10 ha of unnatural lake fill (Isely et al. 2018).

Isely et al. (2018) assessed the anticipated economic benefits from the shoreline and lake condition improvements using both a hedonic model of housing sales and a travel cost survey for lake-based recreation. The study estimated that natural shorelines (including "softened" shorelines), while accounting for other housing attributes, were associated with higher sale prices. Conversely, hardened shorelines were associated with lower sale prices. The total value of anticipated shoreline improvements based on home sale prices was estimated at $11.9 million. An improved environment also leads to improved recreational opportunities. This leads to more visits to the lake and the value of the additional visits was estimated at $3.3 million annually. However Isely et al.'s study was conducted in 2009 before the remediation was completed, so it was based on the anticipated improvements.

This current research builds on the work of Isely et al. (2018)to estimate the effect of Muskegon Lake shoreline changes on both home sale prices and recreation values both before and after remediation and habitat restoration. Although the aesthetic effects were apparent almost immediately, many of the hoped-for ecological changes were expected to take longer to be evident. Items like water quality and native fish species take time to recover. The early signs of this improvement, however, can be seen at the Muskegon Lake dashboard (Annis Water Resources Institute 2020). Isely et al. (2018) used the travel cost method and a hedonic analysis with data gathered during the active remediation period 2009-2011. These methods were revisited using new data gathered during 2017-2018 in order to validate the expected changes. The methods used in revisiting the valuation after the fact are described in the methods section that follows. It is important to note that the methods used are consistent with the study described in Isely et al. (2018)but are not identical because of differences in both the lake and estimation techniques since the original study began in 2009.

METHODS

The travel cost method used is a revealed preference approach to environmental valuation. It uses behavioral data such as travel distance to recreational sites, frequency of visits, and actual trip expenses, to estimate users' willingness-to-pay for recreational activities and opportunities (Seller, Stoll, and Chavas 1985; Sutherland 1982; Whitehead et al. 2009).

In addition to recreation, the softening of the shoreline would be a highly visible part of the remediation and habitat restoration project, and therefore would likely affect housing prices. Since 2010 housing prices have been rising across the United States and West Michigan. The question becomes, are houses affected most by the remediation and habitat restoration rising faster than the prices of other houses? Hedonic analysis is a common and well-known method used when examining housing markets, and reveals through actual market transactions the marginal implicit price of individual housing attributes (Rosen 1974). Hedonic analysis is used to reveal how much homebuyers are willing to pay for different attributes. This identifies a marginal price for housing attributes, and we are able to determine the prices of not only structural features, but also locational and environmental amenities.

Travel Cost Survey

The "Travel Cost Survey of Recreational Users of Muskegon Lake, MI" elicits individual information regarding recreational trip length, primary recreation activity, frequency of visits to different sites on Muskegon Lake, trip expenses, and demographic information (See, Appendix A). We orally administered the survey to recreational users accessing the lake along the south shoreline. The data informed a single-site travel cost model for Muskegon Lake.

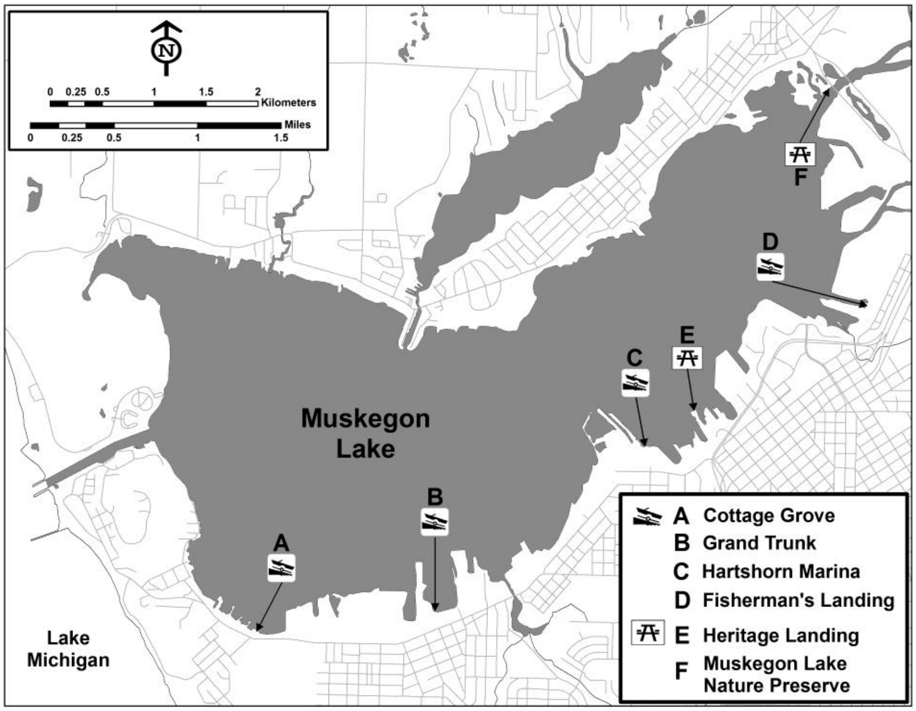


Figure 2: Travel Cost survey site locations along the south shoreline of Muskegon Lake.

Survey sites were selected to be identical to those used for data gathering for Isely et al. (2018) from the targeted restoration areas along the south shore of Muskegon Lake that also had public access to the lakeshore (Figure 2). Surveys were generally administered in four hour shifts at each site on randomly selected weekend days and randomly selected weekdays. To randomize the sample of recreational users, we interviewed every third adult-user at each location (Parsons 2017). Originally surveying was to occur during just the summer of 2017, but after review one survey administrator's data was declared invalid due to deviations from protocols. To generate the approximately 250 observations for the study after eliminating this data, additional surveys were administered during 2018. This sample size created the power necessary for the Poisson regression as well as for allowing the use of the central limit theorem when looking at means of sub-samples.

Data gathered from the travel cost survey needed to be adjusted for outliers and other data problems. First, only day trips were included in the model, so multi-day trips were eliminated. Second, observations where the respondent reported more than 365 visits a year were eliminated as outliers. Finally, observations where the individual reported costs that were excessive or too small (the top 5% and bottom 5% of reported costs) for the activity were eliminated as outliers.

The remaining data were used to calculate travel costs in two different ways. Travel Cost 1 is calculated by taking the respondent's answer regarding how much money was spent and dividing it by the number of people travelled with. This value is then added to trip time value. Trip time value was calculated as 1/3 of the survey respondent's income divided by 2080 (the number of hours worked in a year given 40 hour weeks) which was then multiplied by the length of their trip, measured in hours. Travel Cost 2 is calculated by adding the cost of a launch fee ($10) to the distance costs, which is the distance to Muskegon Lake roundtrip multiplied by $0.31/km ($0.50/mile), and finally dividing by the number of travelers. This value is then added to their trip time value. Summary statistics for these variables can be seen in Table 1.

Table 1 Travel Cost Variables

Variable	Definition	Mean (S.D.)	Expected sign
Dependent variable			
Trips	Number of annual trips reported minus 1	32.48 (66.98)	
Independent variables			
Trip Cost	Average of Trip Cost 1 and Trip Cost 2	49.67 (41.31)	-
Travel Cost SL	Travel Cost plus the additional cost of travel cost need to go to the substitute location of Spring Lake.	50.39 (40.85)	+
Fishing	Is an indicator variable that is 1 if the primary purpose at Muskegon Lake is fishing, 0 otherwise	0.39 (0.49)	+

Male	Is an indicator variable that is 1 if individual is male, 0 otherwise	0.68 (0.47)	+
Access	Is an indicator variable that is 1 if the person is accessing Muskegon Lake from Heritage Landing, 0 otherwise	.061 (0.24)	+
n=247			

Number of trips per year can then be modeled using a basic travel cost model (Parsons 2017). The expected number of trips by an individual, k, can be hypothesized as an exponential function:

(1) $E[TRIPS_k|X_k] = \lambda_k = exp(X_k\beta)$

This estimation can be handled by a Poisson regression since *TRIPS* is a non-negative integer.

Four specific data issues were addressed: heteroscedasticity, over-dispersion, endogenous stratification, and zero truncation. Tests for heteroscedasticity could not be rejected at the 10% level. In addition there was some evidence of over-dispersion; both problems were addressed by using robust standard errors (White-corrected standard errors). Using robust standard errors with the Poisson regression provided consistent estimators. The recreation user's surveys given only to actual users of Muskegon Lake also resulted in a zero truncation. To correct for zero truncation and the possibility of endogenous stratification, the 1 was subtracted from trips for each user, following Loomis et al. (2003).

A second survey taken away from the lake, primarily at the Muskegon farmers market, was used to help estimate the number of users of Muskegon Lake. These surveys asked the respondents their ZIP code and how often they used the lake for recreation. This allowed us to take into account Muskegon residents (ZIP codes 49440 – 49445) that did not use the lake. While the survey locations and times were not determined randomly because of time constraints and efforts to reach the desired demographics, random sampling was done at each location by asking every n^{th} person depending on the flow of people.

Respondents were read the background information regarding the impairments of the Muskegon Lake ecosystem, the proposed improvements, and the benefits such a project would generate. The interviewer asked questions on lake usage and gender. A comparison of the survey data against that of Muskegon County using chi-square goodness of fit and one-sample binomial tests revealed no statistically significant differences among ZIP code reported and gender variables. The number of visits for those that visited the lake was statistically similar to travel cost results. The survey results showed that 1.88 percent of the sample from Muskegon residents did not visit the lake based on a sample of 160 Muskegon residents.

Hedonic housing valuation

The hedonic model included several sources of data. The main parcel dataset included sales prices, locations, and housing attributes. However, it only included sales from 1995 to 2009. An additional dataset included sales prices from 2010 to 2016 and parcel numbers, but did not include housing attributes. Therefore, the 2010-2016 housing sales were joined to the attributes tables from 2009. This assumes that the key housing attributes did not change during this time and provides a consistent set of attributes over time. The model uses a limited number of housing attributes (see Table 2) and these are unlikely to change in the short term unless a major renovation is undertaken. Joining the post-remediation and habitat restoration prices to the pre-remediation and habitat restoration attributes as defined in Table 2 is a second-best method, but is a reasonable assumption.

The property sales were filtered based on the following conditions: arms-length transactions (essentially a sale between two entities that are not related/conflicted with each other), at least one bedroom, valid XY location, nominal sales price greater than $40,000, less than 150 years old, floor area greater than 500 square feet, floor area less than 4,000 square feet, and between 100 and 800 m from Muskegon Lake. The last variable ensured that the homes were primary residences because many waterfront houses (less than 100 m from Muskegon Lake) are seasonal rentals and vacation homes. Furthermore, houses on the west end of the lake and along the channel to Lake Michigan are better described as being on Lake Michigan ("the big lake") rather than on Muskegon Lake. Lake Michigan homes are a distinct market. Some homes sold multiple times during the study period. Having multiple observations at the same location causes problems with the spatial regression analysis. In such cases, only the most recent sale was included in the analysis.

The use of two datasets introduced a possibility of a structural break in the data. A Chow test was conducted on the combined dataset (1995-2016 sales). The Chow test rejected the null hypothesis that there was no structural break. Sales from the early years were trimmed until the Chow test failed to reject the null hypothesis. The final dataset included sales from 2001 to 2016. This included 571 sales, 242 of which occurred in or after remediation and habitat restoration in 2010.

A number of spatial variables (*Bear Lake*, *Muskegon Lake Distance*, *Natural Shoreline Ratio*, *Hardened Shoreline Ratio*), were calculated using ArcGIS with data in the Michigan GeoRef (meters) projected coordinate system.

Sale prices were adjusted for inflation to 2016 dollars using the annual average Consumer Price Index (Series ID CUUR0000SA0). The housing dataset included a large number of structural, neighborhood, and environmental variables that presumably could influence home sale prices. There is no theoretical guidance as to the selection of independent variables. A stepwise regression performed in SPSS identified a limited number of explanatory variables. Additional variables of interest (*Beachwood-Bluffton*, *Muskegon Lake Distance*, *Hardened Shoreline Ratio*) were included in the final model (Table 2).
Some of these variables were different compared to Isely et. al. (2018). We preferred to limit the number of variables that were extended into the 2010-2016 time period. The variables that are not included either were not statistically significant, or were not quantitatively significant in the 2018 study. In addition,

extensive testing was done in a previous study (Isely et al. 2018) to show that the results on softened shoreline were stable even with substantially different control variables.

Table 2: Hedonic model variables.

Variable	Definition	Mean (S.D.)	Expected sign
Dependent variable			
Adjusted Sale Price	Home sale price adjusted to 2016 dollars	\$120,598.70 (61,608.45)	
Ln Adjusted Sale Price	Natural-log transformed Adjusted Sale Price	11.59 (0.44)	
Independent variables			
Structural			
Floor Area	Above-ground floor area in square meters	132.13 (45.72)	+
Basement Area	Basement area in square meters	82.48 (39.92)	+
Garage Type	Number of garage stalls	1.25 (0.70)	+
Age at Sale	Age of home at time of sale in years	61.98 (31.00)	-
Post-Remediation	Binary variable, 1 if sold in or after 2010 when remediation and habitat restoration took place, 0 otherwise	0.42 (0.49)	unclear
Neighborhood			
Beachwood-Bluffton	Binary variable, 1 if location in the Beachwood-Bluffton neighborhood, 0 otherwise	0.15 (0.36)	+
Jackson Hill	Binary variable, 1 if location in the Jackson Hill neighborhood, 0 otherwise	0.02 (0.15)	-
Lakeside	Binary variable, 1 if location in the Lakeside neighborhood, 0 otherwise	0.32 (0.47)	-

Nelson	Binary variable, 1 if location within the Nelson neighborhood, 0 otherwise	0.02 (0.15)	-
Nims	Binary variable, 1 if location within the Nims neighborhood, 0 otherwise	0.19 (0.39)	-
Environmental			
Bear Lake	Binary variable, 1 if within 100 m of Bear Lake, 0 otherwise	0.02 (0.13)	+
Muskegon Lake Distance	Shortest distance to Muskegon Lake shoreline in meters	450.34 (189.80)	-
Ln Natural Shoreline Ratio	Natural log of the ratio of natural shoreline length divided by distance to natural shoreline	-0.49 (1.12)	+
Ln Hardened Shoreline Ratio	Natural log of the ratio of hardened shoreline length divided by distance to hardened shoreline	0.60 (1.16)	-
n=571 sales			

Regression coefficients for *Floor Area*, *Basement Area*, and *Garage Type* were all expected to have a positive sign. The sale price should be positively associated with larger values of these variables. *Age at Sale* was expected to have a negative sign because newer homes (lower age) typically sell for higher prices. The expected sign for *Post Remediation* is unclear. One the one hand, the remediation and habitat restoration should increase home values. On the other hand, the remediation and habitat restoration occurred in 2010, at the low point of the housing crisis. Home sale prices have only recently recovered to pre-recession levels.

The model includes several neighborhoods within the city of Muskegon as well as sales outside the city particularly along the lake's north shore. City properties generally sell for less than homes outside the city. Most neighborhoods, therefore, are expected to have a negative sign. The exception may be *Beachwood-Bluffton*. Located in between Lake Michigan and Muskegon Lake, home values in this neighborhood are generally higher than those in other parts of the city and comparable to areas outside the city. It is expected to have a positive sign. Proximity to *Bear Lake* should have a positive sign. *Muskegon Lake Distance*, on the other hand, should have a negative sign. That is, price increases as distance to the lake decreases.

The shoreline variables require some description. The *Natural Shoreline Ratio* and *Hardened Shoreline Ratio* were calculated in three steps. First, the distance to nearest respective shoreline (natural or hardened) was measured using the Near tool in ArcGIS. This also provided the feature identification number of the Near feature. Next, the shoreline feature class (natural or hardened) was joined to the property centroid feature class based on the Near feature ID. The join allowed the feature's length to be appended to the property centroid's attribute table. Finally, the ratio was calculated by dividing the feature length by the distance and applying a natural log transformation. Properties that are close to long stretches of natural or hardened shorelines have large, positive values. Properties that are far away from small shoreline segments have large, negative values. The *Natural Shoreline Ratio* is expected to have a positive coefficient. That is, being closer to a large stretch of natural shoreline should be associated with a higher sale price. In contrast, *Hardened Shoreline Ratio* is expected to have a negative coefficient. Being close to a large stretch of hardened shoreline should be negatively associated with sale price.

More than 3,200 meters of hardened shoreline was remediated in 2010. Twelve segments of hardened shoreline were softened to a more natural condition. When calculating the *Natural Shoreline Ratio* and *Hardened Shoreline Ratio* variables, the pre-remediation and habitat restoration shoreline conditions apply to sales in 2001-2009 and the post-remediation and habitat restoration condition apply to sales in 2010-2016.

ArcGIS was used to test for spatial autocorrelation. The dependent variable (*Ln Adjusted Price*) in both models showed statistically significant spatial autocorrelation (Moran's $I = 0.38$, $p<0.05$, inverse distance method). Therefore a spatial error regression model was calculated in the GeoDa spatial econometrics software package.

Both shoreline variables are log-transformed, as is the dependent variable. Therefore, the coefficients can be interpreted as elasticities. A one-percent change in the *Natural* / *Hardened Shoreline Ratio* (before log transformation) is associated with a (0.01^{β}) percent change in home sale price.

Calculating the one percent change in *Natural* or *Hardened Shoreline Ratio* involved several steps. First the ratios' geometric means were calculated and the one-percent change was applied. This was associated with the geometric mean sale price to estimate the implicit prices of the shoreline changes. A change in the ratio can mean either a change in shoreline length or in shoreline distance (or both). In this case, shoreline distance was held constant at the geometric mean. Then the corresponding change in shoreline length was calculated. The change in natural or hardened shoreline length could then be associated with the change in sale price.

Once implicit prices for *Natural* and *Hardened Shoreline Ratios* were calculated, the implicit prices were applied to a GIS feature class of all property centroids in the study area (between 100 m and 800 m of Muskegon Lake excluding those near Lake Michigan). The shoreline distances, lengths, and ratios were calculated for each property centroid using the natural and hardened shorelines before and after remediation. The implicit prices were then applied to the respective differences in the ratios. The total change in property value from the remediation was the sum of the changes in value from the natural shoreline and hardened shoreline (Equation 2).

$$Hedonic\ Value\ of\ Shoreline\ Remediation = \sum_{i=1}^{n}\left(\left(\frac{PostNSR_i - PreNSR_i}{1\%\ Geometric\ mean_{NSR}}\right) \times Implicit\ price_{NSR}\right) + \left(\left(\frac{PostHSR_i - PreHSR_i}{1\%\ Geometric\ mean_{HSR}}\right) \times Implicit\ price_{HSR}\right)$$

Where $PostNSR_i$ is the post-remediation and habitat restoration natural shoreline ratio (length/distance) for parcel i; $PreNSR_i$ is the pre-remediation and habitat restoration natural shoreline ratio for parcel i; $PostHSR_i$ is the post-remediation and habitat restoration hardened shoreline ratio for parcel i; $PreHSR_i$ is the pre-remediation and habitat restoration hardened shoreline ratio for parcel i; $1\%\ Geometric\ mean_{NSR}$ is one-percent of the natural shoreline ratio's geometric mean; $1\%\ Geometric\ mean_{HSR}$ is one-percent of the hardened shoreline ratio's geometric mean; $Implicit\ price_{NSR}$ is the implicit price of a one-percent change in natural shoreline ratio calculated at geometric mean; and $Implicit\ price_{HSR}$ is the implicit price of a one-percent change in hardened shoreline ratio calculated at geometric mean.

RESULTS

Travel Cost

Equation 1 can be estimated by a Poisson regression since *TRIPS* is a non-negative integer. The primary result of the Poisson regression was a coefficient on *TRAVEL COST* of -0.0177 (Table 3). Following the single trip cost model (Parsons 2017), the travel value of a single trip is found using 1/(-β*TRAVEL COST*). The negative inverse of the *TRAVEL COST* coefficient resulted in a travel value of $56.46, which is larger than the mean travel cost, which is $49.67 (Table 1). This value provides a basis for determining the effect of improved environmental benefits over the next few years.

Table 3 Results of Poisson Regression

Variable	**Coefficient (*β*)**	**S.E.**	**Sig.**
Trip Cost	-0.0177	0.0070	*
Travel Cost SL	0.0113	0.0071	
Fishing	-1.0660	0.2209	*
Male	0.5937	0.3134	
Access	-0.2701	0.4365	
Constant	3.6195	0.3121	*
n = 247 *Pseudo* R^2 = 0.1384		*statistically significant α = 0.05	

The second step to determine the increase in value for the environmental improvement is to calculate the increased number of trips attributed to the environmental changes. This is accomplished by first determining the population of Muskegon that visits the lake. The adult population of the Muskegon ZIPcodes (49440 – 49445) is 98,886 in 2017 estimated using American Community Survey 2013-2017 (U.S. Census 2018). Since our survey showed 1.88% of people from these ZIP codes do not visit the lake, we estimated that 97,027 Muskegon adults visit the lake. The survey also collected information on visitor habits. It noted the number of lake visits per Muskegon adult. It also noted the increase in visits for those who visited prior to 2010. The results are seen in Table 4.

Table 4 Muskegon Lake Use

	Mean	Standard Error	[95% Conf. Interval]	
Annual Trips	38.43	5.49	27.61	49.26
Increase in Trips since 2009	4.29	0.74	2.83	5.74
N = 187 Muskegon Residents				

The mean value self-reported increase in annual lake trips (4.29) is larger than the increase in raw annual lake trips from 2010 to 2018 (2). However, the 95% confidence interval of both estimates overlap. Taking the mean trips for Muskegon Residents and applying it against the population that visits the lake generated the number of visits to the lake by Muskegon Residents. Then taking the ratio of visitors to residents (18.6 in the survey) generated the number of external visitors. Using the change in trips can be used the same way. The summary of these results is seen in Table 5

Table 5 Lake use

	Total Trips Muskegon Residents	Change Since 2009	Visitors from Outside Muskegon	Change Since 2009
95% Confidence Low	2,677,944	271,675	498,098	50,532
Mean	3,725,835	417,216	693,005	77,602
95% Confidence High	4,783,428	553,054	889,718	102,868

The mean change is 417,216 visits from local residents and 77,602 visits from non-local visitors. Since the value of a visit to the individual is calculated at $56.46, the value of the additional recreation is $27.9 million annually. The value at the lower bound of the 95% confidence interval is still $18.2 million annually. Of the change, $4.4 million is additional value to people that live outside of the Muskegon ZIP codes (49440 – 49445).

Hedonic Valuation

The spatial error regression model explains about 65% of the observed variation in home sale prices (R^2 = 0.685) (Table 6). All but one of the 14 explanatory variables was statistically significant and most had the expected sign. The Likelihood Ratio Test for spatial error dependence failed to reject the null hypothesis. This indicates that the spatial error model resolved the spatial autocorrelation issues in the data.

Table 6: Results of the spatial error regression model.

Variable	**Coefficient (β)**	**S.E.**	**Sig.**
Constant	11.3325	0.0667	*
Floor Area	0.0043	0.0003	*
Basement Area	0.0007	0.0003	*
Garage Type	0.0868	0.0179	*
Age at Sale	-0.0023	0.0004	*
Post-Remediation	-0.2814	0.0222	*
Beachwood-Bluffton	0.0933	0.0543	
Jackson Hill	-0.4194	0.0759	*

Lakeside	-0.1140	0.0473	*
Nelson	-0.3746	0.0812	*
Nims	-0.2690	0.0358	*
Bear Lake	0.3765	0.0817	*
Muskegon Lake Distance	-0.0002	0.0001	*
Ln Natural Shoreline Ratio	0.0391	0.0119	*
Ln Hardened Shoreline Ratio	-0.0479	0.0180	*
n = 571 sales R^2 = 0.685 Log likelihood = -16.554		*statistically significant α = 0.05	

The shoreline ratio variables were both statistically significant and have the expected signs. Sale prices tend to be higher the closer the property is to a large segment of natural shoreline. Prices are lower the closer a property is to a large stretch of hardened shoreline.

The geometric mean of the *Natural Shoreline Ratio* is 0.6109. A one-percent increase in the *Natural Shoreline Ratio* (0.0061) results in a 0.039 percent increase in a home's sale price at the geometric mean. The geometric mean of *Adjusted Sale Price* is $108,596 so a 0.039% increase would be $42.26. Keeping the distance to the natural shoreline constant at the geometric mean, the one-percent change in the *Natural Shoreline Ratio* is associated with a 2.69 m increase in the natural shoreline length. This has a price of $15.71/m/house.

Likewise, a one-percent increase in the Hardened Shoreline Ratio (0.0183) results in a 0.048 percent decrease in the geometric mean sale price, or $-52.27. The change in ratio corresponds to a 7.89 m change in hardened shoreline length, keeping the distance constant at the geometric mean. It has a price of $-6.62/m/house.

The implicit prices for the *Natural Shoreline Ratio* ($42.26) and *Hardened Shoreline Ratio* ($-52.27) were applied to the changes in shoreline ratios for all 3,226 residential parcels in the study area. The table (Table 3) below illustrates how the hedonic value of a representative parcel was calculated (see Equation 2).

Table 3: Representative calculation of the value of natural shoreline remediation and habitat restoration for one generic house.

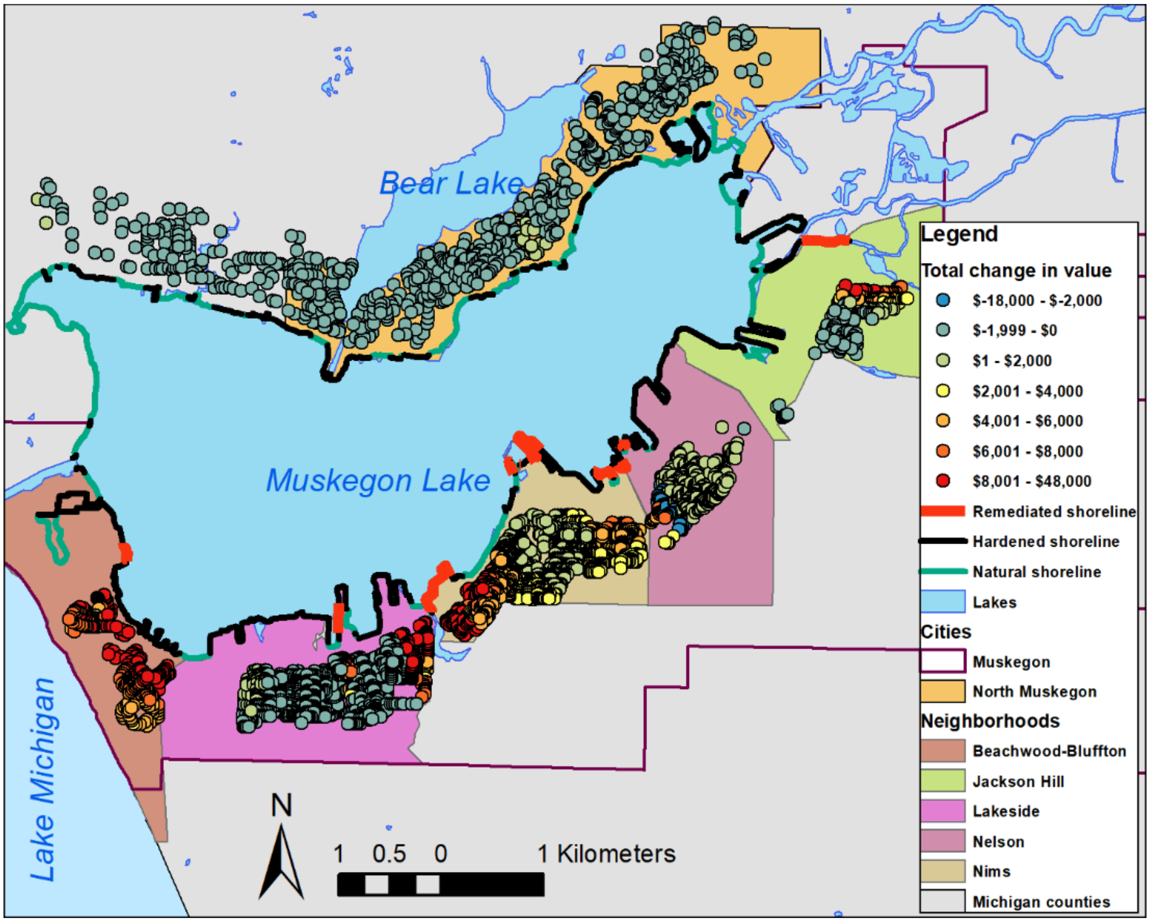
	Pre-remediation and habitat restoration	Post-remediation and habitat restoration
Natural shoreline length	576.79 m	476.63 m
Natural shoreline distance	1,062.61 m	705.22 m
Natural shoreline ratio	0.543	0.676
Change in natural shoreline ratio		0.133
1% of the natural shoreline ratio's geometric mean		0.0061
Implicit price of a 1% change in natural shoreline ratio		$42.26
Hedonic value of remediated shoreline		$921.42

Increasing the natural shoreline through remediation and habitat restoration is associated with an average increase in parcel sale price of $919 and a total value of $2.96 million. Decreasing the hardened shoreline is associated with an average increase in parcel sale price of $1,377 and a total value of $4.44 million. The total value of the remediation and habitat restoration as reflected in sale prices of all 3,226 parcels is $7.41 million (Table 4).

Table 1: Descriptive statistics for shoreline remediation based on 3,226 parcels.

	Value of change in natural shoreline	Value of change in hardened shoreline	Value of shoreline remediation
Minimum	$-13,088.86	$-17,138.14	$-17,138.14
Maximum	$47,552.44	$30,406.61	$47,957.62
Mean (standard deviation)	$918.85 (3,756.44)	$1,377.48 (3,770.78)	$2,296.33 (4,863.78)
Sum	$2,964,217.11	$4,443,753.07	$7,407,970.17

Figure 3 Housing Prices Changes



DISCUSSION and CONCLUSION

Muskegon Lake, a drowned river-mouth system that drains directly to Lake Michigan, is impaired by degraded water quality and habitat. The lake's high proportion of hardened shorelines continues to be associated with several beneficial use impairments, such as degradation of aesthetics; loss of fish and wildlife habitat; and degradation of fish and wildlife populations (West Michigan Shoreline Regional Development Commission 2020). However, Muskegon Lake's condition is improving as remediation and habitat restoration progresses, including the softening of 3,200 meters of hardened shoreline. Shoreline softening cost $10 million in 2009 dollars. An initial 2009 study forecast the economic value of remediation, including effects on home sale prices and recreation opportunities. We revisited this estimated in 2018 to see if the forward-looking components of the initial study held true for the first decade. The updated housing price hedonic model estimated an increase of $7.41 million compared to the initial forecast of $11.9 million ($12.7 million in 2019 dollars). The value is likely smaller for several reasons:

1. The regression coefficient for the natural shoreline variable was consistent across the two studies. The hardened shoreline coefficient in the updated study, however, was about considerably smaller than that of the original study (-0.0479 vs. -0.1190). This results in a lower implicit price for shoreline remediation and habitat restoration in the updated study.
2. The two studies differed slightly in the calculation methods for the implicit price of shoreline remediation and habitat restoration. For example, the original study based the implicit price off the arithmetic mean of the home sale price. The updated study used the geometric mean of the home sale price. Although both studies had similar arithmetic means, the updated study's geometric mean was about 10 percent less than its arithmetic mean. That would also contribute to a lower overall value for the restoration and habitat remediation.
3. There have been other remediation activities, most notably the removal of the Sappi paper mill, as more shoreline is softened, the marginal value of additional softening decreases.
4. Because of the ongoing improvements on the south shore of Lake Muskegon, the units owned by financially secure individuals (which tend to be worth more) have been held off the market to wait for the expected increases following the removal of the Sappi paper mill.
5. The city has improved the downtown dramatically over the last 10 years. This improves the values of all houses in the area, decreasing the marginal effect seen from the remediation.

Even with all of these changes, the perceived improvements in the study sites still resulted in $7.41 million in improved property values. At least part of the reason that the value is smaller than originally predicted was other environmental improvements. This shows that property owners value owning property near softened shoreline compared to hardened or industrial shoreline.

The updated travel cost model estimated that the lake's recreation value increased by $27.9 million annually compared to the initial forecast of $3.3 million ($3.5 million in 2019 dollars) The difference is due primarily to two things:

1. An increase in the value of each trip compared to the original estimate ($49.67 vs. $38.41).
2. A four-fold increase in the number of lake visits compared to the initial estimate (494,818 vs. 82,624).

In the initial study, residents were asked whether they would come more often after the remediation, but not how much more often. Therefore, we assumed each person would make only one additional visit. In the updated study, respondents were asked how many additional trips they would take. They reported an average of 4.3 additional trips. The raw data show the respondents reported two additional trips in the updated study compared to the original study. However, these samples were drawn from different populations and are not directly comparable. The original study's estimate of additional visits is within the updated study's 95 percent confidence interval when population changes and the assumption of one additional visit are accounted for. The improved perception of the Muskegon Lakes quality has led individuals to visit 2 – 4 times more a year. However, this improved impression is the result of more than the initial study's improvements.

In Isely et al. (2018) the value for a day visit to Muskegon Lake was found to be $39.76 ($42.54 in 2019 dollars) in the current study it was found to be $56.46. It is not possible to attribute the change to one thing. During the original study, individuals were faced with a deep recession, so they might not have spent as much during a visit. In addition, there have been many environmental improvements in the lake as just GLRI spending has exceed four times the remediation being viewed in the original study (Great Lakes Restoration Initiative 2019).

Because it is hard to reconcile one part of the restoration in Muskegon Lake with another, it is not possible to generate an ROI. However, there is an increase in housing value because of improved and softened shorelines as well as an increase in recreation visits because of a perceived increase in the quality of the lake's environment. The combination of the two results in $7.4 million in additional housing value, $27.9 million annually in additional recreation value, and approximately 495,000 additional visits to the lake because of the perceived environmental improvement.

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Appendix A: Muskegon Lake Wetland Habitat Restoration Project Survey Instruments

1.Travel Cost Study of Recreational Users of Muskegon Lake, MI

Travel Cost Study of Recreational Users of Muskegon Lake, MI

For the purposes of this study, a trip is the total time you spent between leaving and returning to your home address. It includes all activities that you may have done in that time period. A day-trip includes no overnight stay; a multiple day trip includes one or more overnight stays.

1. When did you leave home? (Date/time) ____

2. When do you expect to return home? (Date/time) ________________________________

3. What is the zip code at your home address? ____________________________________

4. What is your primary activity at Muskegon Lake today? (choose 1)

   a) Fishing _______
   b) Boating or Jet-Skiing ______
   c) Kayaking/SUP______
   d) Hiking _______
   e) Biking ______
   f) Bird-/Wildlife-Watching _____
   g) Festival/Special Event ______
   h) Other (specify) ____

5. Please identify other activities you have done/planned on this trip: (check all that apply)

   a) Fishing _______
   b) Boating or Jet-Skiing ______
   c) Kayaking/SUP________
   d) Hiking _______
   e) Biking ______
   f) Bird-/Wildlife-Watching _____
   g) Festival/Special Event ______
   h) Other (specify) ____

6. Including yourself, what is your total party size on this trip (adults and kids)? __________

7. Approximately how much money did you spend in total on this trip? Include gas, food, lodging, souvenirs, bait, etc.

   $___________________

8. How many times do you plan to come to this location (launch/nature preserve) this year?

   1 to 2   3 to 4   5 to 6   7 to 8   9 to 10   11 to 12   13 to 14

15 or more (How many?)___________

9. How many times to you plan to go to any location for recreation on Muskegon Lake this year?

0 times   1 to 2   3 to 4   5 to 6   7 to 8   9 to 10   11 to 12   13 to 14

15 or more (How many?)___

10. Did you come to Muskegon Lake before 2010?   YES   NO

11. Muskegon Lake has had a series of environmental restorations since 2010. B**ecause of these restorations**, have you visited Muskegon Lake:

LESS   MORE   NO DIFFERENCE IN NUMBER OF VISITS

12. If you answered "LESS" or "MORE" to Question 11; How much more or less do you visit Muskegon Lake now?

Fewer visits	-14 to -13	-12 to -11	-10 to -9	-8 to -7	-6 to -5	-4 to -3	-2 to -1
More visits	1 to 2	3 to 4	5 to 6	7 to 8	9 to 10	11 to 12	13 to 14

OTHER please specify _______________

A Few Demographic Questions to Ensure Study Validity

13. What is your gender?   _____MALE   _____FEMALE

14. What is your age?   _____18 - 25   _____26 - 35   _____36 – 45

_____ 46 - 55   _____56 - 65   _____66 - 75   _____Over 75

15. What is your annual income?
    a. Less than $20,000 _____________
    b. $20,000 - $39,999 _____________
    c. $40,000 - $59,999 _____________
    d. $60,000 - $79,999 _____________
    e. $80,000 - $99,999 _____________
    f. $100,000 - $119,999 _____________
    g. More than $120,000 _____________

16. How much of your annual household budget do you spend on recreation in a year?

a. Less than 5% ________
b. 6% - 10% ___________
c. 11% - 25% ___________
d. More than 25% _____________

17. Have you answered this survey more than once? NO YES (How many times? __)

Thank you for participating in this research survey.

2. Muskegon Lake Area of Concern Habitat Restoration Survey

GVSU Research Questionnaire

Thank you for completing this voluntary survey

Home Zip Code: ____________________

Gender: ___________M ____________F ____________Prefer not to answer

How many times have you recreated on Muskegon Lake in the past 12 months? _________________

From which access points (check all that apply)

?	Location	?	Location
	Cottage Grove/Jaycees		Muskegon State Park
	Fisherman's Landing		Yacht Club / Private Marina
	Grand Trunk		Cottage or home
	Hartshorn Marina		Pere Marquette Park
	Heritage Landing		From Lake Michigan
	Nature Preserve / Wilder		Other: