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# Comparing Pollution Where You Live and Play: A Hedonic Analysis of Enterococcus in the Long Island Sound

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**Abstract:** Hedonic property value methods typically examine the effect of water quality on home prices by focusing on waters nearest a home. While this captures any aesthetic values households may hold for water quality improvements, it may not fully reflect recreational values, particularly for nearby residents that do not live on the waterfront. This study is the first to compare the conventional approach of examining how property prices vary with the quality of waters closest to a home, versus water quality levels at the closest point of access for recreation (i.e., the beach). Using spatial econometric models, we conduct a hedonic analysis of residences within five kilometers of the Long Island Sound. Due to an aging infrastructure, high levels of precipitation often lead to sewage overflows, resulting in high counts of enterococcus – a bacterial indicator of fecal pollution. We also estimate the effect of subsequent beach closures, which we posit as an alternative and more salient signal of local water quality to residents. In line with previous literature, we find that enterococcus levels at waters nearest a home negatively affect home prices within 1 kilometer. However, this effect becomes insignificant when controlling for levels at the nearest beach. In contrast, enterococcus at the closest beach yields a negative 0.03% to 0.02% elasticity that extends 2.5 km. Controlling for beach closures suggests negative effects as far as 3.5 km from beaches. Our findings demonstrate that the impact of water quality on home prices may extend further than previously suggested by the literature, at least at large iconic waterbodies like the Sound.

**JEL Classification:** Q24; Q51; Q53

**Keywords:** beach; enterococcus; hedonic; Long Island Sound; property value; water quality

# Comparing Pollution Where You Live and Play:
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## I. Introduction[2]

Hedonic property value methods are a common approach to estimate the implicit price households have for local improvements in water quality. Studies typically examine the effect of water quality on home prices by focusing on the waters nearest a home. This captures any aesthetic values households may hold for water quality improvements, but may not fully reflect recreational values, particularly for nearby residents that do not live on the waterfront. Although non-waterfront homes may be in view of the nearest waters, residents may not have direct access. At the same time, non-waterfront houses have recently received increased attention in the hedonic literature (Walsh et al. 2011, 2017, Netusil et al. 2014).

The objective of this study is to compare the conventional approach of examining how property prices vary with the quality of waters closest to a home versus water quality levels at the closest point of access for recreation – more specifically, the nearest beach. We conduct a hedonic analysis of residential properties in Westchester County, NY that are within five kilometers of the

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Long Island Sound. The water quality measure of interest is enterococcus – a type of bacteria and indicator of fecal pollution.

Westchester has long struggled with fecal pollution in the Sound, primarily due to stormwater runoff and sewage overflows. Beginning in 1909 with the construction of the county's first main sewer line (Smith 1912, Harding 1950), the county's sanitary sewage system was built to keep sewage and stormwater separate. Nonetheless, cracks in the pipes of this aging infrastructure have led to the intrusion of stormwater into the sewage system during excessive rain events. As a result, the overwhelmed sewage treatment plants must sometimes discharge untreated or partially treated sewage directly into the Sound, leading to reduced water clarity, foul odors, and an increased risk of gastrointestinal illness among swimmers.

Beaches are closed when enterococcus levels exceed 104 colony forming units (CFU) per 100mL, and are often preemptively closed before heavy rains (LISS 2017). During our study period (2003-2014), the average beach in Westchester was closed for 7% of the summer season. Besides the visual cues and foul odors, there are many formal mechanisms keeping residents well-informed of pollution levels and beach closures.

Briefly, the hedonic results suggest that under the conventional approach of examining enterococcus levels at the waters nearest a home, prices respond negatively, suggesting a -0.014 elasticity. In other words, a 10% increase in enterococcus suggests a 0.14% decrease in home values, which translates to an average depreciation of $1,543. This effect gradually declines with distance, and in line with previous studies (Poor et al. 2007, Walsh and Milon 2015), only extends to non-waterfront homes up to one kilometer from the water.

In contrast, when focusing on water quality at the nearest beach, we find that the negative price effects associated with enterococcus levels are larger and extend much further. Homes nearest the beach face a negative elasticity of -0.034, an effect that significantly impacts homes up to 2.5 kilometers away. At the same time, when controlling for water quality at the nearest beach, we see that the elasticities with respect to enterococcus levels at the waters closest to the home become statistically insignificant across all distance bins. This result is robust when accounting for beach closures, which provides a more perceivable signal of local water quality levels to nearby residents. We find the elasticity with respect to beach closures during the summer season has a much more precisely estimated negative effect on house prices, impacting homes up to 3.5 km away.

This is the first study to simultaneously control for water quality near the home and at the nearest beach. Our findings suggest that water quality at beaches are capitalized in home prices, and that accounting for this demonstrates a farther reaching impact than previously suggested in the hedonic literature – a result that has significant implications for defining the extent of the market in benefit-cost analyses. Local recreational opportunities are an important component of a neighborhood, and it should be no surprise that their quality can affect nearby home prices.

The paper is outlined as follows. We next provide further background about the study location and water quality issues in section II, followed by a description of the data in section III. The empirical methods and results are then presented in sections IV and V, respectively. Section VI discusses the implications of the findings and provides some concluding remarks.

## II. Background

Westchester County is located just north of New York City and next to the Long Island Sound. The Sound offers many aesthetic and recreational amenities, such as swimming, fishing, and boating. As of 2015, the county was home to about 967,000 people. It is a relatively affluent area, with 2015 Census data showing a median household income of $83,958, which is notably higher than the national median of $53,373.[3]

Westchester has long struggled with fecal pollution in the Sound, primarily due to stormwater runoff and sewage overflows. The county's sanitary sewage system, which was started in 1909 with the construction of the Bronx Valley main sewer line, was built to keep sewage and stormwater in separate pipes (i.e., it is *not* a combined sewage system) (Smith 1912, Harding 1950). However, cracks in the pipes of this aging infrastructure have caused stormwater to leak into sewage pipes during excessive rain events, resulting in raw sewage flowing into the Sound from several pathways. Sewage can overflow from manholes and ultimately run into the Sound, or it can leak out of pipes and into groundwater and the Sound. Moreover, excess water flows to the county's sewage treatment plants sometimes causes the need to discharge untreated or partially treated sewage into the Sound. The county found in 2013 that the flow of stormwater into sewage pipes contributes up to half of the water volume flowing to sewage plants (Westchester County Department of Public Works and Transportation, et. al 2013) .

As part of the response to this problem, the county constructed two overflow retention facilities in 2004 to take in extra wastewater and minimize untreated discharges. But as recently as 2015, a nonprofit group called "Save the Sound" sued Westchester County for failing to stop the overflows (Garcia 2015).

[3] U.S. Census American FactFinder. Accessed September 5, 2017. https://factfinder.census.gov/faces/nav/jsf/pages/community_facts.xhtml.

Exposure to fecal bacteria in water can lead to a variety of health problems, including gastrointestinal, skin, eye, ear, and respiratory illnesses (EPA 2015). Because enterococci bacteria are often found in fecal waste, jurisdictions commonly use measurements of enterococci to determine whether waters are suitable for recreation. Westchester's policy is to close beaches when enterococci counts exceed 104 colony forming units per 100mL. The county also closes both public and private beaches preemptively in anticipation of excessive rain events. Due to these pollution concerns, the county closes certain beaches for one day if there is at least half an inch of rain and two days if there is at least one inch of rain. If it rains more than two inches, the county decides the appropriate length of time to close the beaches (Westchester County Department of Public Health 2017).

There are a number of ways the public is informed of water quality in the Sound. Beach closures are announced on the county website. The non-profit group "Save the Sound" e-mails beach closure alerts and provides an interactive map of water quality on its website.[4] The local media report[5] on beach closures and sewage overflows, and signs are posted at beaches (New York State Department of Health 2012).

## Literature Review

Dating back to David's (1968) report, the literature examining the impacts of surface water quality on residential property values is fairly established. The focus, however, has been primarily

[4] Sound Health Explorer. Accessed November 6, 2017. http://soundhealthexplorer.org/.

[5] "Sewage leak causes beaches to close," News 12 Westchester, July 13, 2003, http://westchester.news12.com/story/34908122/sewage-leak-causes-beaches-to-close; "Sun Is Out But Beaches Are Closed Along the Sound in Westchester County," Harrison Daily Voice, June 8, 2013, http://harrison.dailyvoice.com/news/sun-is-out-but-beaches-are-closed-along-the-sound-in-westchester-county/581604/; "Sewage Leak in Long Island Sound Forces Beach Closures Amid Heat Wave," NBC 4 New York, July 16, 2013, https://www.nbcnewyork.com/news/local/Sewage-Leak-Long-Island-Sound-Westchester-Beach-Closure-Heat-Wave-215660261.html. Accessed November 13, 2017.

on price impacts among waterfront homes, particularly in earlier studies (Michael et al. 1996, Boyle et al. 1999, Leggett and Bockstael 2000, Young 1984). More recently studies have expanded the analyses to both waterfront and non-waterfront homes, and found that water quality can affect homes as far away as one mile from waterbodies (Netusil et al. 2014, Walsh et al. 2011, Klemick et al. 2016) .

The current study expands on the growing hedonic literature examining the impacts of surface water quality on home prices in four main ways. First, to our knowledge this is the first study to examine how water quality at the nearest point of access for recreation (i.e., the nearest beach) impacts residential property values and how far this impact may extend. The literature has almost exclusively considered water quality nearest the home, linking residential transactions to water quality levels measured at the nearest monitor (or a few monitors) (Boyle et al. 1999, Michael et al. 2000, Poor et al. 2007).[6] However, this may not always be the most appropriate measure, particularly among non-waterfront homes. A dissertation chapter by Ara (2007) linked homes to water quality measured at the closest beach, but found mixed results. She did not include interactions between beach distance and water quality, however, so it is unclear how far the price impact of water quality extended. We investigate whether water quality at the nearest beach access point has a stronger (and perhaps independent) effect on house prices.

Second, by focusing on the Long Island Sound, a large and iconic estuary in the northeast US, our study adds to the relatively small subset of hedonic studies of water quality in estuaries. Leggett and Bockstael (2000) examined the impact of fecal coliform on waterfront homes along the Chesapeake Bay and found significant negative effects. Walsh et al. (2017) and Klemick et al.

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[6] One exception is a study by Brashares (1985), who did consider water quality interacted with distance to public and private access points and found insignificant results for these interactions.

(2016) examined homes in 14 counties adjacent to the Chesapeake Bay and found that home values appreciate significantly with higher levels of water clarity, an effect that extended as far as one kilometer in some counties. Liu et al. (2017) focused on non-waterfront homes by Narragansett Bay and found that chlorophyll concentrations had significant negative effects on homes up to 1,500 meters from the shore.

Third, to our knowledge this is the only hedonic study utilizing measurements of enterococci bacteria counts, despite its common use as an indicator for recreational water safety. Previous studies have examined the impacts of fecal coliform counts (Brashares 1985, Leggett and Bockstael 2000, Ara 2007) and E. coli (Netusil et al. 2014), but since 1986 enteroccoci has been deemed the appropriate measure for setting federal standards in the US (EPA 2004).

Fourth, to our knowledge this is the first hedonic study to explicitly examine the effect of beach closures on residential property values. Beach closures provide a more discrete and perceivable signal of water quality to local residents, and local beaches can be an integral component of neighborhood recreation. Further, we investigate whether closures have an effect even after controlling for water quality.

## III. Data

### Property Data

Property sales data in Westchester County from 2003 to 2015 were obtained from the New York State Department of Taxation and Finance. We limited our study to arms-length sales of single family homes and townhomes within five kilometers of the Long Island Sound, resulting in a final dataset of 16,926 transactions.[7] Home prices were normalized to 2015 dollars using the Consumer Price Index for All Urban Consumers.[8] The property sales data includes variables for structural and parcel characteristics, such as square footage, number of bedrooms and bathrooms, age, the presence of a basement, and parcel acreage.

We controlled for a number of locational factors by using Geographic Information Systems (GIS) to generate variables for distances of homes to primary roads[9] , New York City[10], and the Long Island Sound.[11] We also included distance to the nearest sewage treatment plant[12] to control for other polluter effects besides pollution, such as noise and unsightly aesthetics, which Leggett and Bockstael (2000) found to be significant in their study of a similar iconic waterbody (the Chesapeake Bay). Socioeconomic variables of the neighborhood were obtained from the 2010 decennial Census and were included as covariates in the hedonic regressions, including: median household income,[13] race, population density, and percent owner-occupied housing. Data of local school ratings were obtained from GreatSchools.org,[14] which the real estate website Zillow displays alongside their home listings. The full list of control variables in our model, and the corresponding descriptive statistics of the data, can be found in Table 1.

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[7] Homes with prices in the lowest percentile (less than $152,613) and highest percentile (greater than $3,638,694) were dropped from our dataset to eliminate outliers, leaving 20,079 home transactions. An additional 3,153 sales were dropped due to missing water quality data from the three nearest monitoring stations during the summer season corresponding to the date of transaction, leaving a final sample size of n=16,926 transactions.

[8] Bureau of Labor Statistics. 2016. Accessed March 28, 2016. http://www.bls.gov/cpi/cpid1602.pdf.

[9] U.S. Census Bureau. 2010. "Topographically Integrated Geographic Encoding and Referencing (TIGER)/Line Primary and Secondary Road Shapefiles." Accessed September 16, 2013. http://www.census.gov/geo/maps-data/data/tiger-line.html.

[10] U.S. Census Bureau. 2010. "Gazeteer Shapefiles of Major U.S. Cities." Accessed September 16, 2013. http://www.census.gov/geo/maps-data/data/gazetteer2010.html.

[11] U.S. Geological Survey. 2015. "NHD High Resolution Dataset." Accessed August 2015.

[12] Westchester County Geographic Information Systems Data Warehouse. Accessed October 25, 2016. http://giswww.westchestergov.com/wcgis/datawarehouse.htm.

[13] Data on household income was not collected as part of the 2010 decennial Census in Westchester. Median household income from the 2013 American Community Survey was used instead. Income greater than $250,000 was coded as $250,000+ in the raw data, hence a dummy variable for income greater than $250,000 was created.

[14] GreatSchools. Accessed March 21, 2017. https://www.greatschools.org.

**Water Quality Data**

Data on enterococcus levels in the Sound were obtained from the Water Quality Portal.[15] The vast majority of enterococcus sampling occurs during the beach season, from May to September. During these months in our study period there were 5,210 samples from 35 different monitoring sites located throughout the Sound (see Figure 1). Enterococcus levels were measured and expressed in terms of CFU (colony-forming units) per 100mL. We find that enterococcus levels vary both temporally and spatially, but the majority of the observed variation tends to be spatial in nature (see Appendix B for details).

We averaged enterococcus levels for each monitoring site and month, and then averaged the monthly means for each monitoring site and for each beach season. Homes sold during and after May were matched to the average enterococcus levels for the beach season that year. Homes sold before May were matched to the average enterococcus levels for the beach season of the previous year.

Homes were spatially matched to water quality monitoring sites in two ways. First, we identified the closest three monitoring sites for each home. Of the three monitoring sites, homes were then matched to the nearest one where enterococcus was sampled and measured for the corresponding summer season. Second, we matched homes to the average water quality measure at the nearest beach. Most beaches had only one monitoring site, but some had multiple sites. For beaches with multiple sites, we averaged water quality values across all monitor sites within 150 meters of the beach. Descriptive statistics of water quality variables can be found in Table 2.

[15] Sponsored by the United States Geological Survey, Environmental Protection Agency, and National Water Quality Monitoring Council. Accessed April 3, 2015. https://www.waterqualitydata.us/.

**Beach Data**

Along the Long Island Sound, there are 22 beaches, of which 17 are private and 5 are public. Beach closure data came from EPA's BEACON database.[16] The data indicate that the length of the beach season was 107 days for most beaches, but for some private beaches the seasons were slightly longer. For consistency, we only accounted for beach closures within the 107-day season, which begins about a week before Memorial Day in May and ends about a week after Labor Day in September. Closures are measured as the number of days the beach is closed. As shown in Table 2, a beach is closed for about 7 days each beach season on average.

It is possible that beaches with better water quality (and hence less beach closures, and lower levels of enterococcus) tend to have other desirable characteristics. If that is the case, then not controlling for heterogeneity in the various features offered by different beaches could present an omitted variable bias. To control for such heterogeneity, and better minimize the potential for such confounding effects, we obtained GIS data on beaches and boat launches from the Westchester County Geographic Information Systems Data Warehouse,[17] which were used to derive two variables – the length of the beach and whether a boat launch is present.[18] Multiple studies on beach erosion have shown that beach width is capitalized in nearby home prices (Edwards and Gable 1991, Landry and Hindsley 2011, Landry and Allen 2016). Although we only have the data to measure beach length, we know that people place greater value on beaches with greater area. In addition, we also control for whether a beach is publicly or privately owned, and later examine heterogeneity in the price impacts of water quality in this regard. Nearly all of the

[16] Beacon 2.0. Accessed October 12, 2016. https://watersgeo.epa.gov/beacon2/.

[17] Westchester County Geographic Information Systems Data Warehouse. Accessed July 10, 2017. http://giswww.westchestergov.com/wcgis/datawarehouse.htm.

[18] Using these data in conjunction with satellite imagery, we measured the length of each beach in ArcGIS. A boat launch was considered to be at the beach if it was located in a parcel that included the beach, or in a nearby parcel that was listed as having the same owner as the beach.

17 private beaches along the Sound are owned by country clubs. The five public beaches provide similar features to visitors, including restroom facilities, lifeguards, and parking lots.

## IV. Empirical Methods

We estimate a series of hedonic property value regressions, where the dependent variable $\ln p_{ijt}$ is the natural log of the transaction price for home *i*, in neighborhood *j*, when it was sold in year *t*. This is estimated as a function of characteristics of the parcel, the home itself, and the surrounding neighborhood, all denoted as $\mathbf{x}_{ijt}$. A vector of year and quarterly dummy variables $\mathbf{M}_t$ is included to control for broader housing market trends and seasonal effects.

To account for spatial dependence and absorb any otherwise confounding spatially correlated unobservables (Anselin and Le Gallo 2006) we estimate a general spatial model (referred to as the SAC model by LeSage and Pace (2009)), as shown below. Let $wp_{[ijt]}$ denote the corresponding element from the n × 1 vector obtained after multiplying the spatial weight matrix (SWM) **W**, by the price vector **P**. In other words, $wp_{[ijt]}$ is the spatially and temporally weighted average of neighboring prices allowed to influence the price of home *i* sold in period *t*.[19] Similarly, $w\varepsilon_{[ijt]}$ is the corresponding element from the n × 1 vector obtained after multiplying **W** by the vector of error terms **ε**. The random component of the error term is denoted as $u_{ijt} \sim N(0,\sigma^2)$.

Our base hedonic specification, Model 1, is:

$$\ln p_{ijt} = \rho w p_{[ijt]} + \mathbf{x}_{ijt}\boldsymbol{\beta} + \mathbf{M}_t\boldsymbol{\alpha} + \boldsymbol{Beach_{ib}\theta_2} + \boldsymbol{D_i\theta_1} + \{\boldsymbol{D_i} \times ln(WQ_{it})\}\boldsymbol{\gamma_1} + \varepsilon_{ijt}$$
$$\text{where } \varepsilon_{ijt} = \lambda w \varepsilon_{[ijt]} + u_{ijt} \quad (1)$$

[19] To reflect local spatial dependence in neighborhoods, particularly as a result of the use of "comparable sales" for real estate appraisal by real estate agents and mortgage lenders, we use an inverse-distance based SWM on the spatial lag that includes homes sold 6 months before and three months after each home. A distance radius of a half mile is also applied. To control for remaining spatial autocorrelation, the spatial error term uses a 20 nearest neighbor SWM (Lesage and Pace, 2009, Walsh et al., 2017).

and **β**, **α**, $\boldsymbol{\theta_1}$, $\boldsymbol{\theta_2}$, $\boldsymbol{\gamma_1}$, ρ, and λ are all coefficients to be estimated. In particular, ρ is the spatial lag parameter and λ is the spatial error parameter.

The variables of primary interest are $\boldsymbol{D_i}$ and $WQ_{it}$. $\boldsymbol{D_i}$ is a vector of dummy variables denoting distance of house *i* to the nearest portion of the Long Island Sound, measured using 500-meter bins, starting with 0 to 500 meters and extending out to five kilometers.[20, 21] The parameter vector to be estimated, $\boldsymbol{\theta_1}$, captures the price gradient associated with being in close proximity to the Long Island Sound. $\boldsymbol{D_i}$ is also interacted with the natural log of water quality at the waters closest to home *i*, in period *t* ($WQ_{it}$). We control for distance to the nearest beach (*b*), again using a vector of dummy variables denoting 500-meter bins extending out to five kilometers, $\boldsymbol{Beach_{ib}}$. The vector $\boldsymbol{\theta_2}$ captures the price gradient associated with proximity to a beach.

In this study we measure water quality using enterococci counts (CFU per 100mL). Therefore, $\boldsymbol{\gamma}$ is a vector of parameters to be estimated where each element reflects the elasticity of house prices with respect to enterococci counts at the waters closest to a home and among homes in the corresponding distance bin. In other words, $\boldsymbol{\gamma}$ captures how the elasticity of house prices with respect to water quality at the waters nearest the home vary with proximity to those waters.

Subsequent models build on Model 1 by explicitly accounting for beach water quality, controlling for beach closures in response to poor water quality, and accounting for other features of the nearest beaches, including whether they are publicly accessible or considered private.

Model 2 separately controls for water quality at the waters nearest the home ($WQ_{it}$), and at the nearest beach ($WQ_{ibt}$). The variable of particular interest, $\boldsymbol{\gamma_2}$ is a vector of house price

[20] The last 500-meter bin (4,500 to 5,000 meters) is the omitted category.
[21] The results subsequently presented are robust to smaller 250-meter wide bins.

elasticities with respect to enterococci counts at the nearest beach, where each element corresponds to a 500-meter bin. More formally:

$$\ln p_{ijt} = \rho w p_{[ijt]} + \mathbf{x}_{ijt}\boldsymbol{\beta} + \mathbf{M}_t\boldsymbol{\alpha} + \boldsymbol{D_i\theta_1} + \{\boldsymbol{D_i} \times ln(WQ_{it})\}\boldsymbol{\gamma_1} + \\ + \boldsymbol{Beach_{ib}\theta_2} + \{\boldsymbol{Beach_{ib}} \times ln(WQ_{ibt})\}\boldsymbol{\gamma_2} + \varepsilon_{ijt} \qquad (2)$$

Model 3 builds on the previous model by explicitly accounting for beach closures in response to actual or anticipated high enterococcus counts. Beach closures $(Closures_{ibt})$ are expressed as the number of summer season days closed. More formally:

$$\ln p_{ijt} = \rho w p_{[ijt]} + \mathbf{x}_{ijt}\boldsymbol{\beta} + \mathbf{M}_t\boldsymbol{\alpha} + \boldsymbol{D_i\theta_1} + \{\boldsymbol{D_i} \times ln(WQ_{it})\}\boldsymbol{\gamma_1} + \\ + \boldsymbol{Beach_{ib}\theta_2} + \{\boldsymbol{Beach_{ib}} \times ln(WQ_{ibt})\}\boldsymbol{\gamma_2} + \\ + \{\boldsymbol{Beach_{ib}} \times ln(Closures_{ibt})\}\boldsymbol{\gamma_3} + \varepsilon_{ijt} \qquad (3)$$

Here the newly added vector $\boldsymbol{\gamma_3}$ reflects the elasticity of home prices with respect to beach closures at the nearest beach.

Model 4 builds on Model 3 by including additional characteristics of the nearest beach $b$. This was done to control for the possibility that other desirable or undesirable features of a beach may be correlated with water quality, which if not otherwise controlled for would present the possibility of an omitted variable bias.

In subsequent models, we examine for potential heterogeneity in the impacts of beach water quality on home values, depending on whether a beach is privately owned or accessible by the public. Interaction terms between $\boldsymbol{Beach_{ib}}$ and dummy variables denoting whether a beach is public or private are added, allowing the price gradient with respect to beach proximity $(\boldsymbol{\theta_2})$ to vary across public versus private beaches. The public and private beach dummy variables are then interacted with $Closures_{ibt}$, thus allowing us to test for heterogeneity in the price impacts of beach closures.

## V. Results

We next summarize the results of the models discussed in section IV. Only the estimates of interest are presented here, but the full hedonic regression results are provided in Appendix A. The majority of the coefficient signs that are not of primary interest are as expected and significant. For example, home prices increase with higher square footage, better school ratings, and lower population density.[22]

The coefficient estimates of interest for Models 1 through 4 are presented in two different tables to distinguish between water quality nearest the home versus at the nearest beach, but these estimates are from the same hedonic regressions. The results show that home prices generally respond negatively to increased enterococcus levels, and the effect is strongest among homes within close proximity to the water and then diminishes with distance. First consider Model 1, which follows the conventional approach in the literature and links homes to the water quality measures at the closest monitoring station (Gibbs et al. 2002, Michael et al. 2000). As shown in Table 3, the results suggest a negative elasticity that is greatest in magnitude among homes located in the nearest distance bins (0-500 m and 500-1000 m).

[22] There is one counterintuitive result warranting some brief discussion – negative signs on the dummy variables for closer proximity to the Long Island Sound. We believe this may reflect that the omitted distance bin, which comprises homes 4500-5000 meters from the Sound, covers relatively wealthy neighborhoods in Bronxville and Scarsdale, which both ranked among America's top 10 richest places by Bloomberg, who based their ranking on 2015 Census data www.bloomberg.com/graphics/2017-hundred-richest-places/ (accessed September 5, 2017). The inclusion of the distance bin vector helps absorb such factors that could otherwise confound the water quality parameter of primary interest. It is also reassuring that the coefficients corresponding to the distance bins denoting proximity to the nearest beach suggest a distance gradient of the expected sign – i.e., homes closer to the beach sell at a higher price.

We can see that homes within 500 meters of the Sound are affected the most; which on average experiencing a decrease in sales price of 0.14% for every 10% increase in enterococci. For these homes, this translates to an average decrease in home value of $1,543. This negative effect diminishes at farther distances but remains significant out to 1000 meters, as shown in Figure 2. The spatial extent of this impact is in line with the literature (Netusil et al. 2014, Walsh et al. 2011, Giudice and Liu 2017).

In Models 2 through 4 we deviate from the conventional approach, and explicitly account for water quality at the nearest beach. In doing so, we see in

Table 3 that the water quality price gradient associated with enterococcus levels at the waters nearest the home become much smaller in magnitude and statistically indistinguishable from zero.

In contrast, when we consider water quality at the closest beach, conditional on water quality nearest the home, we see a strong negative effect that is larger in magnitude and spatial extent. The elasticity estimates corresponding to enterococcus measured at the nearest beach are shown in Table 4. First looking at Model 2, we see that among homes in the nearest 0-500 meter bin from the beach that a 10% increase in enterococci decreases house prices by 0.34%. As shown in Figure 3 and Table 4, the negative elasticity associated with beach water quality remains statistically significant in most 500-meter bins out to 2,500 meters. These results translate to implicit prices of $4,730 for homes within 500 meters of beaches and $1,845 for homes in the farthest significant distance bin, 2000-2500 meters.

In Model 3 we account for the number of beach closure days in the corresponding summer season. The results suggest that home buyers and sellers do, on average, seem to respond more to beach closures than enterococcus levels. This is reasonable given that beach closures and notifications are a more direct and salient signal to local residents regarding water quality. When comparing estimates across Models 2 and 3 in Table 4, we see that accounting explicitly for beach closures decreases the magnitude of the estimated elasticities corresponding to beach enterococci, and results in the estimates becoming statistically insignificant, at least among homes in the nearest distance bins. The estimated elasticities with respect to enterococcus do remain fairly robust in the further bins (1,000 to 2,500 meters). The estimated elasticities with respect to beach closures are of the expected negative sign, with statistically significant effects extending out to the 3,000-3,500 meter bin.

Similar results are found in Model 4, where we control for size of the beach and presence of amenities, like a boat ramp.[23] Figure 4 graphically compares the estimates for beach water quality and beach closures from Model 4. We highlight two features of this graph. First, the elasticity estimates corresponding to the more direct and salient beach closure measure are much more precise, as can be seen by the relatively tight 95% confidence intervals around the estimates and the consistently negative price gradient. Second, the statistically significant negative effects of the beach closures measure extend to homes as far as 3000 meters. The estimates translate to an average decrease in home values of $162 for homes in the 0-500 meter bin and $77 for homes in the 2500-3000 meter bin for one additional beach day closed each year. Although these numbers do not seem economically significant, they suggest that if the nearest beach is closed an additional week every year, there would be an average price decrease of $1,134 for homes in the 0-500 meter bin and $539 for homes in the 2500-3000 meter bin. This is a plausible scenario; the average

[23] More specifically, we include an intercept term denoting whether the closest beach has a boat ramp, and interact beach length with each of the 500-meter distance bins. The signs on the beach length variables are positive and significant as expected, suggesting that larger beaches covering more shoreline are more desirable. The coefficient on the boat ramp variable is insignificant, but was found to be negative and significant in earlier OLS models – a result that has been found previously in the literature (Brashares, 1985).

number of beach days closed per season is seven, and there have been instances where beaches were closed for most of, or even the entire, season.[24]

In the remaining models, focus is drawn to only the more salient measure of beach water quality – beach closures. We disregard beach enterococcus levels and focus on just beach closures in order to circumvent potential multicollinearity issues, particularly when examining impact heterogeneity across private versus public beaches. Model 5 (Table 5) is the same as Model 4, but excludes enterococcus levels at the nearest beach. Comparison of the results to Model 4 (Table 4, Table 5) demonstrates that the other results of interest are robust to the exclusion of beach enterococcus levels. Figure 5 visually shows the declining magnitude of negative price effects. Statistically negative price effects extend as far as 3500 meters.

Model 6 includes interaction terms between dummy variables denoting private versus public beaches, and the corresponding distance bins, as well as with the beach closures variable. This allows us to examine whether the magnitude and spatial extent of the impact of beach closures on home prices varies based on ownership and ease of access for local residents. As shown in Table 5, the results suggest noticeable heterogeneity. The elasticities for beach closures in the nearest distance bins are very similar, but as we move further away, the estimates start to diverge. At around 1,500 meters, closures at public beaches seem to have a greater impact on home prices than those at private beaches, with significant negative price impacts extending as far as 4,000

[24] Estimating variants of Models 1 through 4 that include tract-level fixed effects yield results qualitatively similar to those discussed, but the estimates are often statistically insignificant. Including coarser municipal-level fixed effects, however, leads to similar results as our SAC models in terms of sign, magnitude, and statistical significance. In fact, the estimated elasticities with respect to beach closures were even stronger in magnitude, suggesting statistically significant impacts as far as 4,500 meters. The results of these models are provided in Appendix B. In any case, we believe the use of spatial fixed effects may be inappropriate in the current context. Variation in annual enterococcus levels are primarily based on variation over space, as opposed to time (see Appendix B for details). Spatial fixed effects absorb much of the price variation of primary interest. Instead, we include a spatio-temporal lag of the dependent variable in our spatial autoregressive combined (SAC) models to help control for any spatially correlated omitted variables.

meters.[25] In contrast, closures at a nearby private beach only seem to significantly impact home prices out to about 2,000 meters. The empirical estimates are in line with the intuition – more people visit and have access to public beaches, and so it makes sense that closure of a more widely used resource would have a broader impact on property values and local residents.[26] This has implications for policymakers when choosing how to allocate resources for pollution abatement, in that efforts at public beaches may provide greater benefits to local constituents than similar efforts at private beaches.

## VI. Conclusion

As the number of water quality hedonics studies has grown, the focus has expanded to include impacts to both waterfront and non-waterfront residents living near these waters. This study utilizes data on residential transactions near the Long Island Sound in Westchester County, NY, where sewage overflows caused by an aging infrastructure have been a longstanding problem. Our results are the first to show that when we consider water quality at the nearest recreational access point (a beach in our case), the negative price impact can extend to homes beyond what has been previously suggested in the literature. This has important implications for benefit-transfer and in defining the "extent of the market" for benefit-cost analyses of policies and projects aimed at improving surface water quality.

[25] Among the nearest distance bins (0-500, 500-1000, and 1000-1500 meters), a series of t-tests (Kennedy 2001) fail to reject the null hypothesis that the negative price impacts are statistically equal, suggesting that closures at private versus public beaches have a similar impact on homes in relatively close proximity. Moving into the farther distance bins, however, we do generally find statistically significant differences between the price impacts of closures at private versus public beaches.

[26] Although we do not believe such models are appropriate in the current context, we must note that this finding is sensitive to the inclusion of municipal-level fixed effects (see Appendix B).

In our conventional hedonic specification where homes are linked to enterococcus counts at the nearest waters, irrespective of a resident's ability to access those waters, we find negative price effects that extend up to one kilometer from the Long Island Sound, which is largely in line with the magnitude and spatial extent of estimates previously suggested in the literature (Walsh et al. 2011, Netusil et al. 2014). However, when we examine enterococcus counts at the closest beach, the negative effects extend to 2.5 km. And when focusing on the more perceivable water quality signal of beach closures, we find a more precisely estimated and slightly farther extending effect, impacting homes out to three kilometers, and even as far as four kilometers when focusing on more the accessible public beaches.

We argue that accounting for water quality and closures at the nearest beach may better capture recreational and aesthetic values held by nearby residents than water quality nearest the home. Our results suggest that in order to more fully account for water quality benefits, future analyses, at least those of large iconic waterbodies like the Long Island Sound, should consider homes and residents at farther distances and, in addition to water quality nearest a home, account for water quality levels at key access points.

# Tables and Figures

*Table 1. Home transaction descriptive statistics*

| | Count | Mean | St Dev | Min | Max |
|---|---|---|---|---|---|
| Home price (2015$ USD) | 16,926 | 934,298.10 | 611,056.20 | 142,168.50 | 4,320,623.00 |
| | | | | | |
| *Structural variables* | | | | | |
| Age of home (years) | 9,452 | 67.43 | 28.57 | 0.00 | 312.00 |
| Dummy: age missing | 16,926 | 0.44 | 0.50 | 0.00 | 1.00 |
| Home square footage | 9,425 | 2,384.92 | 1,006.46 | 10.00 | 10,110.00 |
| Dummy: home square footage missing | 16,926 | 0.44 | 0.50 | 0.00 | 1.00 |
| Parcel acreage | 16,926 | 0.22 | 0.44 | 0.01 | 40.06 |
| Dummy: townhome | 16,926 | 0.16 | 0.37 | 0.00 | 1.00 |
| Bedrooms | 9,642 | 3.39 | 1.69 | 0.00 | 10.00 |
| Dummy: bedroom missing | 16,926 | 0.43 | 0.50 | 0.00 | 1.00 |
| Bathrooms | 9,132 | 2.85 | 1.18 | 1.00 | 9.00 |
| Dummy: bathrooms missing | 16,926 | 0.46 | 0.50 | 0.00 | 1.00 |
| Dummy: pool | 7,015 | 0.04 | 0.18 | 0.00 | 1.00 |
| Dummy: pool missing | 16,926 | 0.59 | 0.49 | 0.00 | 1.00 |
| Dummy: porch | 7,015 | 0.83 | 0.37 | 0.00 | 1.00 |
| Dummy: porch missing | 16,926 | 0.59 | 0.49 | 0.00 | 1.00 |
| Dummy: A/C | 3,177 | 1.00 | 0.00 | 1.00 | 1.00 |
| Dummy: A/C missing | 16,926 | 0.81 | 0.39 | 0.00 | 1.00 |
| Dummy: basement | 9,642 | 0.68 | 0.47 | 0.00 | 1.00 |
| Dummy: basement missing | 16,926 | 0.43 | 0.50 | 0.00 | 1.00 |
| | | | | | |
| *Location variables* | | | | | |
| Distance to primary road (m) | 16,926 | 818.06 | 577.94 | 21.61 | 3,162.98 |
| % Developed by block group | 16,926 | 65.63% | 24.51% | 13.97% | 100% |
| Distance to NYC (km) | 16,926 | 28.85 | 4.80 | 22.25 | 42.48 |
| Distance to sewage plant (m) | 16,926 | 3,672.02 | 2,157.56 | 91.52 | 9,403.98 |
| School rating | 13,190 | 6.66 | 2.73 | 1.00 | 10.00 |
| Dummy: school rating missing | 16,926 | 0.22 | 0.41 | 0.00 | 1.00 |
| Dummy: in 100-yr flood plain | 16,926 | 0.03 | 0.18 | 0.00 | 1.00 |
| Distance to Sound (m) | 16,926 | 2,038.85 | 1,456.05 | 0.00 | 4,999.99 |
| Distance to beach (m) | 16,926 | 3,767.86 | 2,170.00 | 44.24 | 8,730.98 |
| Distance to public beach (m) | 9,507 | 3,844.83 | 2,118.24 | 171.60 | 8,730.98 |
| Distance to private beach (m) | 7,419 | 3,669.23 | 2,230.83 | 44.24 | 8,681.24 |
| Length of closest beach (m) | 16,926 | 219.60 | 104.03 | 29.00 | 430.00 |
| Dummy: boat launch at closest beach | 16,926 | 0.55 | 0.50 | 0.00 | 1.00 |
| | | | | | |
| *Neighborhood variables by block group* | | | | | |
| Median household income | 16,926 | 94,428.41 | 61,078.17 | 0.00 | 244,118.00 |
| Dummy: median income > $250k | 16,926 | 0.13 | 0.33 | 0.00 | 1.00 |
| % Hispanic | 16,926 | 13.31% | 13.61% | 2.10% | 87.05% |
| % Black | 16,926 | 15.48% | 25.04% | 0.00% | 93.70% |
| % Owner occupied | 16,926 | 72.16% | 23.50% | 0.00% | 98.71% |
| Pop. density (Pop/sq km) | 16,926 | 3,448.06 | 2,935.42 | 27.94 | 15,560.81 |

*Table 2: Enterococcus counts and beach closure variables*

| | Count | Mean | St Dev | Min | Max |
|---|---|---|---|---|---|
| Ent. at closest monitor | 16,926 | 250.73 | 821.07 | 0.00 | 11,000.00 |
| Ent. at closest beach | 14,852 | 146.85 | 211.14 | 3.78 | 1,473.00 |
| Ent. at closest beach (public) | 7,910 | 218.43 | 243.10 | 3.78 | 1,453.70 |
| Ent at closest beach (private) | 6,942 | 65.28 | 124.71 | 4.35 | 1,473.00 |
| Beach days closed | 16,540 | 7.16 | 10.35 | 0.00 | 107.00 |
| Beach days closed (public) | 9,507 | 11.27 | 11.24 | 0.00 | 46.00 |
| Beach days closed (private) | 7,033 | 1.59 | 5.26 | 0.00 | 107.00 |

Note: Enterococcus measured as count of colony-forming units (CFU) per 100mL.

*Table 3. Hedonic Regression Results: Elasticities with respect to Enterococcus levels closest to Home. (Dependent variable: ln(price)).*

| | Model 1 | Model 2 | Model 3 | Model 4 |
|---|---|---|---|---|
| Home Ent 0-500m | -0.0137*** | 0.0029 | 0.0043 | 0.0047 |
| | (0.004) | (0.0066) | (0.0065) | (0.0065) |
| Home Ent 500-1000m | -0.0124*** | 0.0022 | 0.0028 | 0.0034 |
| | (0.0041) | (0.0052) | (0.0052) | (0.0052) |
| Home Ent 1000-1500m | -0.0046 | $-1.8\text{x}10^{-5}$ | -0.0007 | 0.0001 |
| | (0.003) | (0.0032) | (0.0033) | (0.0033) |
| Home Ent 1500-2000m | -0.0023 | -0.0002 | -0.0005 | -0.0006 |
| | (0.0025) | (0.0026) | (0.0026) | (0.0027) |
| Home Ent 2000-2500m | 0.0006 | 0.0015 | 0.0011 | 0.001 |
| | (0.0032) | (0.0033) | (0.0033) | (0.0033) |
| Home Ent 2500-3000m | 0.0019 | 0.0024 | 0.0030 | 0.0029 |
| | (0.003) | (0.003) | (0.003) | (0.003) |
| Home Ent 3000-3500m | 0.0047 | 0.0050 | 0.0054* | 0.0053* |
| | (0.0031) | (0.0032) | (0.0032) | (0.0032) |
| Home Ent 3500-4000m | -0.0003 | 0.0005 | 0.0010 | 0.0010 |
| | (0.0031) | (0.0033) | (0.0033) | (0.0033) |
| Home Ent 4000-4500m | 0.0050 | 0.0062 | 0.0057 | 0.0056 |
| | (0.0038) | (0.0044) | (0.0044) | (0.0044) |
| | | | | |
| rho | 0.0373*** | 0.0300*** | 0.0270*** | 0.0260*** |
| | (0.0048) | (0.0003) | (0.0003) | (0.0003) |
| lambda | 0.7810*** | 0.8020*** | 0.7850*** | 0.7720*** |
| | (0.0008) | (0.0023) | (0.0007) | (0.0008) |
| | | | | |
| Beach Ent | No | Yes | Yes | Yes |
| Beach Closures | No | No | Yes | Yes |
| Beach Attributes | No | No | No | Yes |
| | | | | |
| Observations | 16,926 | 14,852 | 14,845 | 14,845 |
| R-squared | 0.7853 | 0.7858 | 0.7867 | 0.7865 |

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.
Regressions include variables for structural, location, and neighborhood characteristics, as well as dummy variables for year and quarter. The sample is smaller in Model 2 because residential transactions where water quality measurements at the nearest beach are missing are dropped from the estimating sample. For Models 3 and 4, an additional seven transactions are dropped due to missing values for beach closures. Additional coefficient estimates pertaining to these specific regression models are displayed in Table 4. The full regression results are provided in Appendix A.

*Table 4. Hedonic Regression Results: Elasticities with respect to Enterococcus levels and Closures at the Nearest Beach. (Dependent variable: ln(price)).*

| | Model 2 | Model 3 | Model 4 |
|---|---|---|---|
| Beach Ent 0-500m | -0.0336** | -0.0187 | -0.0182 |
| | (0.0132) | (0.014) | (0.0141) |
| Beach Ent 500-1000m | -0.0141 | -0.0060 | -0.0059 |
| | (0.0095) | (0.0097) | (0.0098) |
| Beach Ent 1000-1500m | -0.0217** | -0.0167* | -0.0174** |
| | (0.0084) | (0.0086) | (0.0086) |
| Beach Ent 1500-2000m | -0.0236*** | -0.0214*** | -0.0216*** |
| | (0.0075) | (0.0078) | (0.0078) |
| Beach Ent 2000-2500m | -0.0197*** | -0.0218*** | -0.0225*** |
| | (0.0072) | (0.0076) | (0.0076) |
| Beach Ent 2500-3000m | -0.0027 | 0.0054 | 0.0058 |
| | (0.0089) | (0.0096) | (0.0096) |
| Beach Ent 3000-3500m | -0.0143 | -0.0102 | -0.0102 |
| | (0.0091) | (0.0099) | (0.0099) |
| Beach Ent 3500-4000m | 0.0011 | -0.0002 | -0.0003 |
| | (0.0092) | (0.0098) | (0.0098) |
| Beach Ent 4000-4500m | 0.0054 | 0.0069 | 0.0070 |
| | (0.0091) | (0.0099) | (0.0099) |
| | | | |
| Beach Closures 0-500m | | -0.0127*** | -0.0123*** |
| | | (0.0044) | (0.0046) |
| Beach Closures 500-1000m | | -0.0145*** | -0.0145*** |
| | | (0.0028) | (0.0029) |
| Beach Closures 1000-1500m | | -0.0105*** | -0.0096*** |
| | | (0.0022) | (0.0024) |
| Beach Closures 1500-2000m | | -0.0051** | -0.0055** |
| | | (0.0023) | (0.0023) |
| Beach Closures 2000-2500m | | -0.0013 | 0.0007 |
| | | (0.0025) | (0.0026) |
| Beach Closures 2500-3000m | | -0.0077*** | -0.0077*** |
| | | (0.0024) | (0.0024) |
| Beach Closures 3000-3500m | | -0.0056** | -0.0043 |
| | | (0.0027) | (0.0028) |
| Beach Closures 3500-4000m | | -0.0013 | -0.0001 |
| | | (0.0029) | (0.0031) |
| Beach Closures 4000-4500m | | -0.0023 | -0.0029 |
| | | (0.0028) | (0.003) |
| | | | |
| rho | 0.0300*** | 0.0270*** | 0.0260*** |
| | (0.0003) | (0.0003) | (0.0003) |
| lambda | 0.8020*** | 0.7850*** | 0.7720*** |
| | (0.0023) | (0.0007) | (0.0008) |
| | | | |
| Home Ent | Yes | Yes | Yes |
| Beach Attributes | No | No | Yes |
| | | | |
| Observations | 14,852 | 14,845 | 14,845 |
| R-squared | 0.7858 | 0.7867 | 0.7865 |

Note: Robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Regressions include variables for structural, location, and neighborhood characteristics, as well as dummy variables for year and quarter. The sample is smaller in Model 2 than Model 1 because residential transactions where water quality measurements at the nearest beach are missing are dropped from the estimating sample. For Models 3 and 4, an additional seven transactions are dropped due to missing values for beach closures. Additional coefficient estimates pertaining to these specific regression models are displayed in Table 3. The full regression results are provided in Appendix A.

*Table 5. Hedonic Regression Results: Elasticities with respect to Enterococcus levels closest to Home and Beach Closures at the Nearest Beach. (Dependent variable: ln(price)).*

| | Model 5 | Model 6 | |
|---|---|---|---|
| Home Ent 0-500m | -0.0055 | -0.0048 | |
| | (0.0042) | (0.0042) | |
| Home Ent 500-1000m | -0.0075* | -0.0063 | |
| | (0.0041) | (0.0042) | |
| Home Ent 1000-1500m | -0.0034 | -0.0026 | |
| | (0.0031) | (0.0031) | |
| Home Ent 1500-2000m | -0.0028 | -0.0027 | |
| | (0.0026) | (0.0026) | |
| Home Ent 2000-2500m | 0.0005 | 0.0007 | |
| | (0.0033) | (0.0033) | |
| Home Ent 2500-3000m | 0.0026 | 0.0028 | |
| | (0.0029) | (0.0029) | |
| Home Ent 3000-3500m | 0.0052* | 0.0053* | |
| | (0.0031) | (0.0031) | |
| Home Ent 3500-4000m | -0.0001 | -0.0001 | |
| | (0.0031) | (0.0031) | |
| Home Ent 4000-4500m | 0.0046 | 0.0045 | |
| | (0.0038) | (0.0038) | |
| | | Public | Private |
| Beach Closures 0-500m | -0.0152*** | -0.0154* | -0.0133*** |
| | (0.0041) | (0.0083) | (0.0047) |
| Beach Closures 500-1000m | -0.0140*** | -0.0147*** | -0.0121*** |
| | (0.0025) | (0.0041) | (0.0032) |
| Beach Closures 1000-1500m | -0.0103*** | -0.0146*** | -0.0086*** |
| | (0.0022) | (0.004) | (0.0025) |
| Beach Closures 1500-2000m | -0.0083*** | -0.0193*** | -0.0044* |
| | (0.0021) | (0.0038) | (0.0026) |
| Beach Closures 2000-2500m | -0.0018 | -0.0107*** | 0.0047 |
| | (0.0023) | (0.0039) | (0.0031) |
| Beach Closures 2500-3000m | -0.0073*** | -0.0187*** | -0.0038 |
| | (0.0022) | (0.005) | (0.0026) |
| Beach Closures 3000-3500m | -0.0055** | -0.0216* | -0.0047 |
| | (0.0026) | (0.0115) | (0.0031) |
| Beach Closures 3500-4000m | -0.0010 | -0.0288** | -0.0020 |
| | (0.0029) | (0.0129) | (0.0034) |
| Beach Closures 4000-4500m | -0.0037 | -0.0048 | -0.0046 |
| | (0.0025) | (0.005) | (0.003) |
| rho | 0.0260*** | 0.0259*** | |
| | (0.0003) | (0.0003) | |
| lambda | 0.7660*** | 0.7610*** | |
| | (0.0008) | (0.0009) | |
| Observations | 16,540 | 16,540 | |
| R-squared | 0.7883 | 0.7888 | |

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Regressions include variables for structural, location, and neighborhood characteristics, as well as dummy variables for year and quarter. The size of the estimating sample is slightly smaller than the n=16,926 observations because residential transactions where beach closure data at the nearest beach were missing are dropped from the estimating sample.

*Figure 1. Study area in Westchester County, NY with beaches and average enterococcus counts at monitoring sites.*

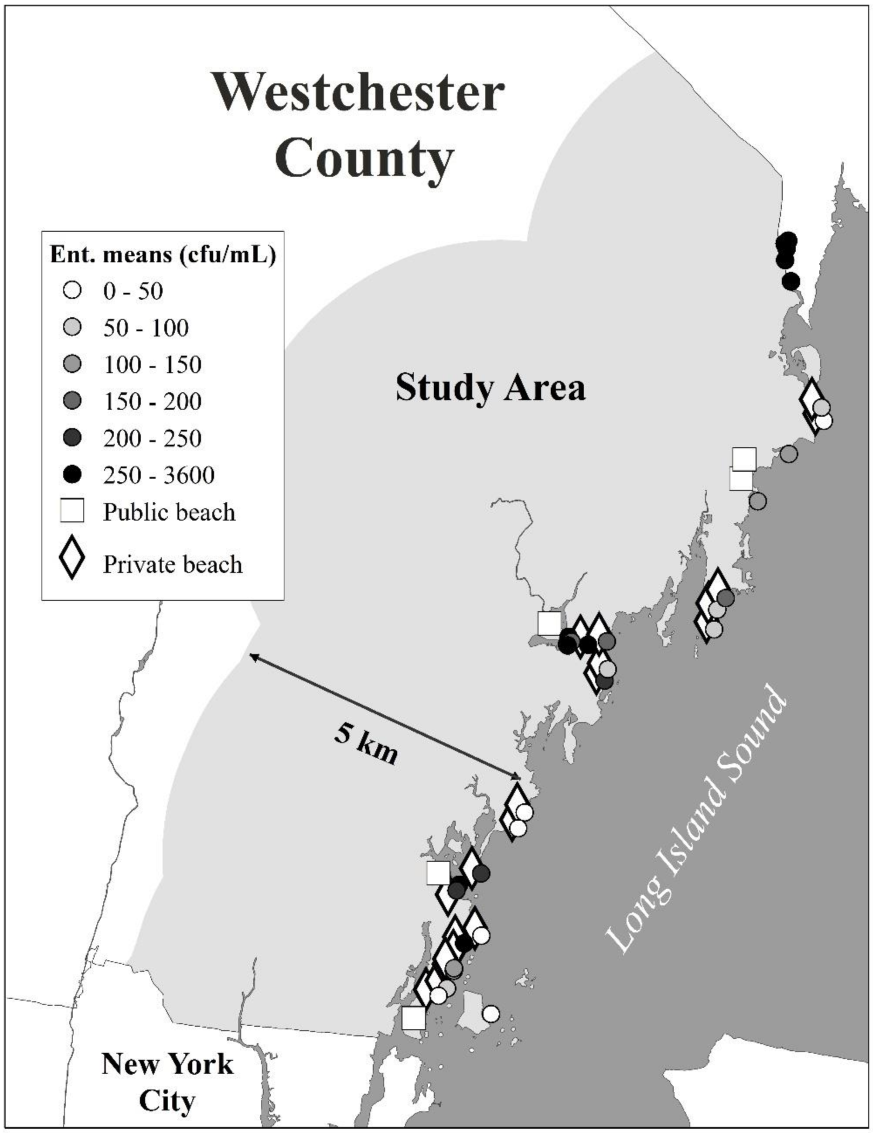


*Figure 2. Model 1 – Home WQ only with 95% confidence intervals*

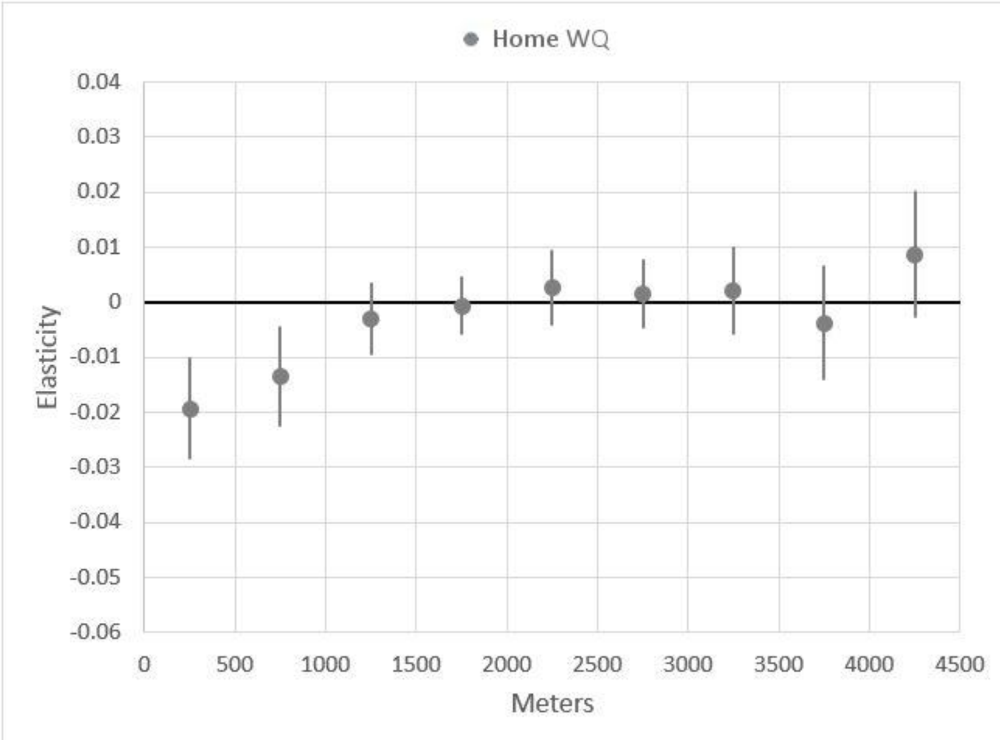



*Figure 3. Model 2 – Home WQ and Beach WQ with 95% confidence intervals*

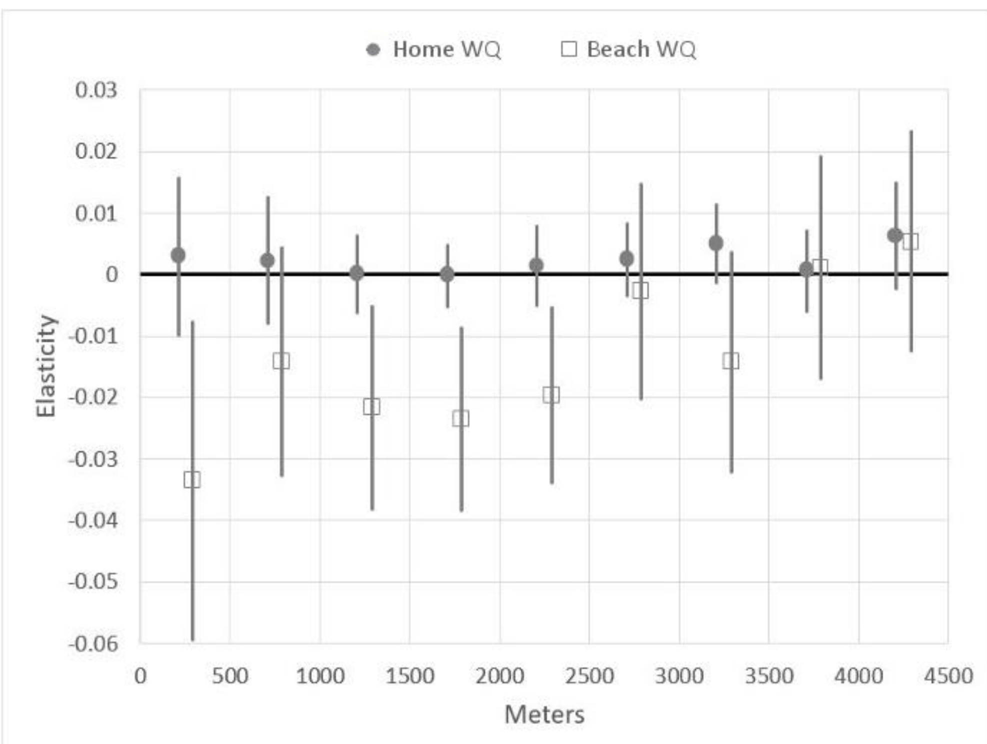


*Figure 4. Model 4 – Beach WQ and Beach Closures with 95% confidence intervals*

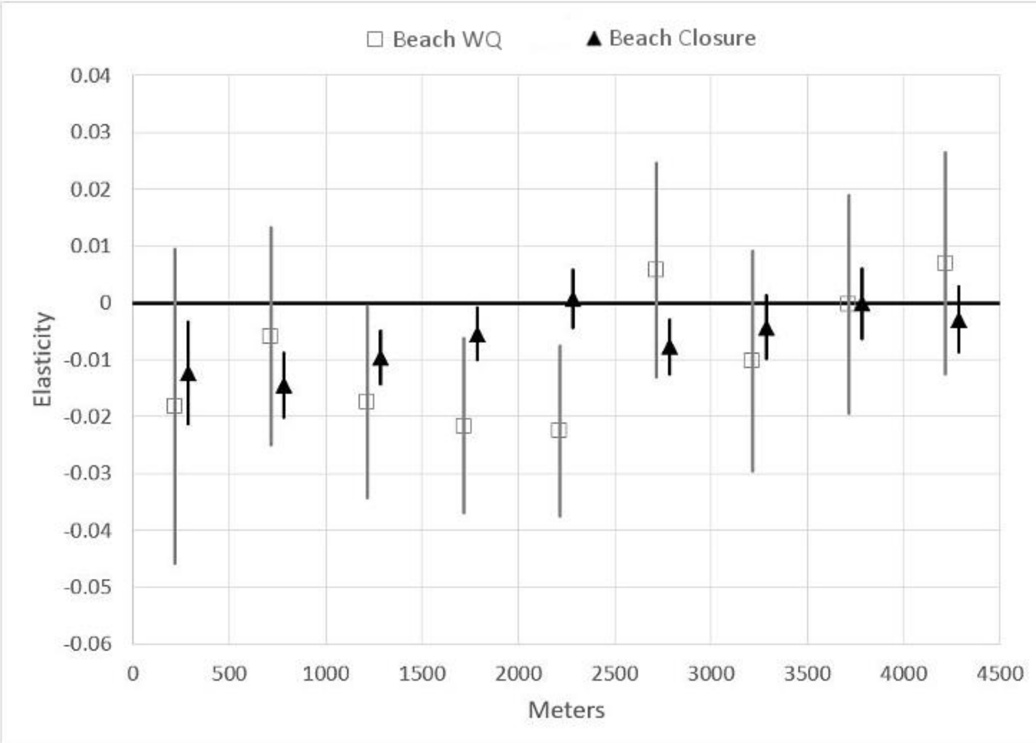
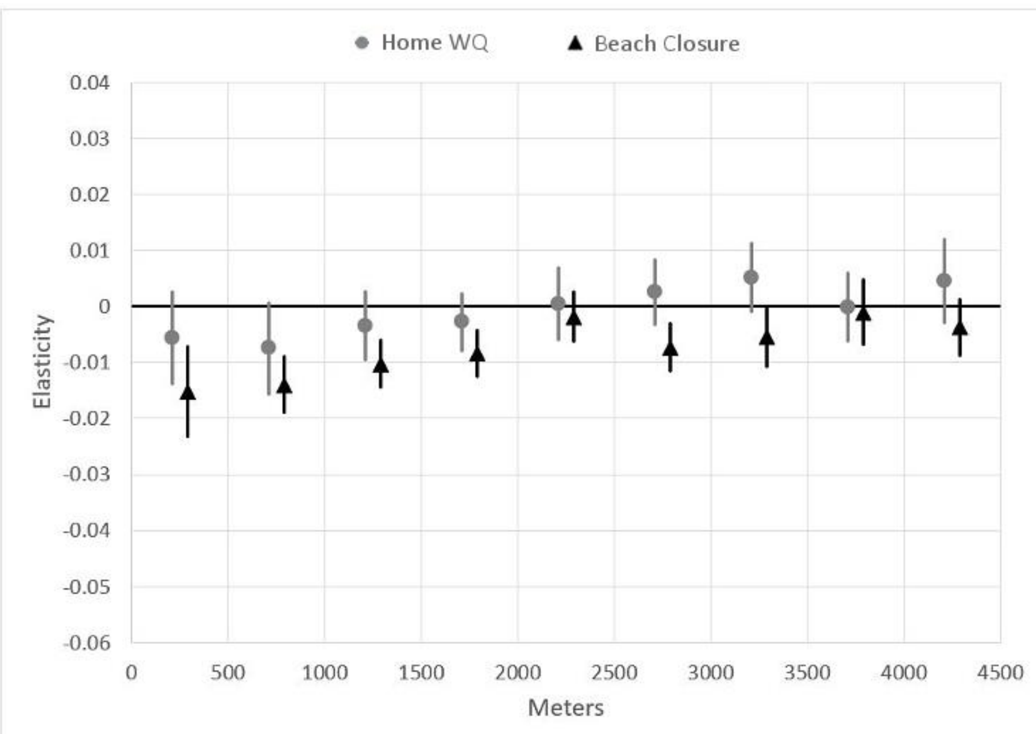



*Figure 5. Model 5 – Home WQ and Beach Closures with 95% confidence intervals*



# Appendix

## Appendix A. Full SAC Hedonic Regression Results

| | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 |
|---|---|---|---|---|---|---|
| Constant | -1.2686** | 10.2639*** | -9.9159*** | -15.039*** | -8.9912*** | -9.5185*** |
| | (0.55) | (0.0077) | (0.5682) | (0.0065) | (0.5799) | (0.0134) |
| Home Ent 0-500m | -0.0137*** | 0.0029 | 0.0043 | 0.0047 | -0.0055 | -0.0048 |
| | (0.004) | (0.0066) | (0.0065) | (0.0065) | (0.0042) | (0.0042) |
| Home Ent 500-1000m | -0.0124*** | 0.0022 | 0.0028 | 0.0034 | -0.0075* | -0.0063 |
| | (0.0041) | (0.0052) | (0.0052) | (0.0052) | (0.0041) | (0.0042) |
| Home Ent 1000-1500m | -0.0046 | -1.8x10^-5 | -0.0007 | 0.0001 | -0.0034 | -0.0026 |
| | (0.003) | (0.0032) | (0.0033) | (0.0033) | (0.0031) | (0.0031) |
| Home Ent 1500-2000m | -0.0023 | -0.0002 | -0.0005 | -0.0006 | -0.0028 | -0.0027 |
| | (0.0025) | (0.0026) | (0.0026) | (0.0027) | (0.0026) | (0.0026) |
| Home Ent 2000-2500m | 0.0006 | 0.0015 | 0.0011 | 0.001 | 0.0005 | 0.0007 |
| | (0.0032) | (0.0033) | (0.0033) | (0.0033) | (0.0033) | (0.0033) |
| Home Ent 2500-3000m | 0.0019 | 0.0024 | 0.003 | 0.0029 | 0.0026 | 0.0028 |
| | (0.003) | (0.003) | (0.003) | (0.003) | (0.0029) | (0.0029) |
| Home Ent 3000-3500m | 0.0047 | 0.005 | 0.0054* | 0.0053* | 0.0052* | 0.0053* |
| | (0.0031) | (0.0032) | (0.0032) | (0.0032) | (0.0031) | (0.0031) |
| Home Ent 3500-4000m | -0.0003 | 0.0005 | 0.001 | 0.001 | -0.0001 | -0.0001 |
| | (0.0031) | (0.0033) | (0.0033) | (0.0033) | (0.0031) | (0.0031) |
| Home Ent 4000-4500m | 0.005 | 0.0062 | 0.0057 | 0.0056 | 0.0046 | 0.0045 |
| | (0.0038) | (0.0044) | (0.0044) | (0.0044) | (0.0038) | (0.0038) |
| Beach Ent 0-500m | | -0.0336** | -0.0187 | -0.0182 | | |
| | | (0.0132) | (0.014) | (0.0141) | | |
| Beach Ent 500-1000m | | -0.0141 | -0.006 | -0.0059 | | |
| | | (0.0095) | (0.0097) | (0.0098) | | |
| Beach Ent 1000-1500m | | -0.0217** | -0.0167* | -0.0174** | | |
| | | (0.0084) | (0.0086) | (0.0086) | | |
| Beach Ent 1500-2000m | | -0.0236*** | -0.0214*** | -0.0216*** | | |
| | | (0.0075) | (0.0078) | (0.0078) | | |
| Beach Ent 2000-2500m | | -0.0197*** | -0.0218*** | -0.0225*** | | |
| | | (0.0072) | (0.0076) | (0.0076) | | |
| Beach Ent 2500-3000m | | -0.0027 | 0.0054 | 0.0058 | | |
| | | (0.0089) | (0.0096) | (0.0096) | | |
| Beach Ent 3000-3500m | | -0.0143 | -0.0102 | -0.0102 | | |
| | | (0.0091) | (0.0099) | (0.0099) | | |
| Beach Ent 3500-4000m | | 0.0011 | -0.0002 | -0.0003 | | |
| | | (0.0092) | (0.0098) | (0.0098) | | |
| Beach Ent 4000-4500m | | 0.0054 | 0.0069 | 0.007 | | |

| | | | | | |
|---|---|---|---|---|---|
| | (0.0091) | (0.0099) | (0.0099) | | |
| Beach Closures 0-500m | | -0.0127*** | -0.0123*** | -0.0152*** | |
| | | (0.0044) | (0.0046) | (0.0041) | |
| Beach Closures 500-1000m | | -0.0145*** | -0.0145*** | -0.014*** | |
| | | (0.0028) | (0.0029) | (0.0025) | |
| Beach Closures 1000-1500m | | -0.0105*** | -0.0096*** | -0.0103*** | |
| | | (0.0022) | (0.0024) | (0.0022) | |
| Beach Closures 1500-2000m | | -0.0051** | -0.0055** | -0.0083*** | |
| | | (0.0023) | (0.0023) | (0.0021) | |
| Beach Closures 2000-2500m | | -0.0013 | 0.0007 | -0.0018 | |
| | | (0.0025) | (0.0026) | (0.0023) | |
| Beach Closures 2500-3000m | | -0.0077*** | -0.0077*** | -0.0073*** | |
| | | (0.0024) | (0.0024) | (0.0022) | |
| Beach Closures 3000-3500m | | -0.0056** | -0.0043 | -0.0055** | |
| | | (0.0027) | (0.0028) | (0.0026) | |
| Beach Closures 3500-4000m | | -0.0013 | -0.0001 | -0.001 | |
| | | (0.0029) | (0.0031) | (0.0029) | |
| Beach Closures 4000-4500m | | -0.0023 | -0.0029 | -0.0037 | |
| | | (0.0028) | (0.003) | (0.0025) | |
| Beach Closures (Pub) 0-500m | | | | | -0.0154* |
| | | | | | (0.0083) |
| Beach Closures (Pub) 500-1000m | | | | | -0.0147*** |
| | | | | | (0.0041) |
| Beach Closures (Pub) 1000-1500m | | | | | -0.0146*** |
| | | | | | (0.004) |
| Beach Closures (Pub) 1500-2000m | | | | | -0.0193*** |
| | | | | | (0.0038) |
| Beach Closures (Pub) 2000-2500m | | | | | -0.0107*** |
| | | | | | (0.0039) |
| Beach Closures (Pub) 2500-3000m | | | | | -0.0187*** |
| | | | | | (0.005) |
| Beach Closures (Pub) 3000-3500m | | | | | -0.0216* |
| | | | | | (0.0115) |
| Beach Closures (Pub) 3500-4000m | | | | | -0.0288** |
| | | | | | (0.0129) |
| Beach Closures (Pub) 4000-4500m | | | | | -0.0048 |
| | | | | | (0.005) |
| Beach Closures (Prv) 0-500m | | | | | -0.0133*** |
| | | | | | (0.0047) |
| Beach Closures (Prv) 500-1000m | | | | | -0.0121*** |
| | | | | | (0.0032) |
| Beach Closures (Prv) 1000-1500m | | | | | -0.0086*** |
| | | | | | (0.0025) |

| | | | | | | |
|---|---|---|---|---|---|---|
| Beach Closures (Prv) 1500-2000m | | | | | | -0.0044* |
| | | | | | | (0.0026) |
| Beach Closures (Prv) 2000-2500m | | | | | | 0.0047 |
| | | | | | | (0.0031) |
| Beach Closures (Prv) 2500-3000m | | | | | | -0.0038 |
| | | | | | | (0.0026) |
| Beach Closures (Prv) 3000-3500m | | | | | | -0.0047 |
| | | | | | | (0.0031) |
| Beach Closures (Prv) 3500-4000m | | | | | | -0.002 |
| | | | | | | (0.0034) |
| Beach Closures (Prv) 4000-4500m | | | | | | -0.0046 |
| | | | | | | (0.003) |
| Dist. to Sound 0-500m | -0.1213** | -0.2207*** | -0.1564** | -0.1609*** | -0.1541*** | -0.1692*** |
| | (0.0534) | (0.0581) | (0.061) | (0.0573) | (0.053) | (0.049) |
| Dist. to Sound 500-1000m | -0.0864* | -0.1939*** | -0.1275** | -0.1319** | -0.1061** | -0.1215*** |
| | (0.051) | (0.0531) | (0.0559) | (0.0524) | (0.0504) | (0.0466) |
| Dist. to Sound 1000-1500m | -0.0981** | -0.1477*** | -0.0904* | -0.0912* | -0.1004** | -0.1146*** |
| | (0.0481) | (0.0482) | (0.0509) | (0.047) | (0.0472) | (0.0437) |
| Dist. to Sound 1500-2000m | -0.1478*** | -0.1811*** | -0.1483*** | -0.1368*** | -0.1341*** | -0.145*** |
| | (0.0452) | (0.0451) | (0.047) | (0.043) | (0.0438) | (0.0407) |
| Dist. to Sound 2000-2500m | -0.1456*** | -0.1586*** | -0.1367*** | -0.1196*** | -0.1286*** | -0.1374*** |
| | (0.0437) | (0.0442) | (0.0452) | (0.0419) | (0.0424) | (0.0399) |
| Dist. to Sound 2500-3000m | -0.1311*** | -0.1342*** | -0.1195*** | -0.1041*** | -0.1176*** | -0.1254*** |
| | (0.0406) | (0.0417) | (0.0418) | (0.0392) | (0.0392) | (0.0374) |
| Dist. to Sound 3000-3500m | -0.104*** | -0.1195*** | -0.1015** | -0.0885** | -0.0899** | -0.0949*** |
| | (0.0383) | (0.0403) | (0.0397) | (0.0379) | (0.037) | (0.0358) |
| Dist. to Sound 3500-4000m | -0.0605* | -0.0766** | -0.0601 | -0.05 | -0.0475 | -0.0492 |
| | (0.0355) | (0.0382) | (0.0375) | (0.0361) | (0.0344) | (0.0336) |
| Dist. to Sound 4000-4500m | -0.0408 | -1.2899 | -0.0364 | -0.0302 | -0.0294 | -0.0295 |
| | (0.0339) | (0.0374) | (0.0368) | (0.0361) | (0.0331) | (0.0327) |
| Dist. to Beach 0-500m | 0.2331*** | 0.3925*** | 0.2458*** | 0.2214** | 0.2066*** | |
| | (0.0607) | (0.091) | (0.0947) | (0.1085) | (0.0792) | |
| Dist. to Beach 500-1000m | 0.2418*** | 0.2948*** | 0.1784** | 0.1693** | 0.1735*** | |
| | (0.0544) | (0.0738) | (0.0744) | (0.0802) | (0.0641) | |
| Dist. to Beach 1000-1500m | 0.168*** | 0.2583*** | 0.1732*** | 0.1379* | 0.0784 | |
| | (0.0505) | (0.0671) | (0.0667) | (0.0719) | (0.0591) | |
| Dist. to Beach 1500-2000m | 0.0786* | 0.1727*** | 0.1234** | 0.0902 | -0.0073 | |
| | (0.0465) | (0.0618) | (0.0618) | (0.0707) | (0.059) | |
| Dist. to Beach 2000-2500m | 0.0597 | 0.1482** | 0.1335** | -0.016 | -0.1001* | |
| | (0.0427) | (0.0577) | (0.0578) | (0.07) | (0.0584) | |
| Dist. to Beach 2500-3000m | 0.1216*** | 0.1174** | 0.0511 | -0.0945 | -0.1035* | |
| | (0.0392) | (0.0575) | (0.0598) | (0.0859) | (0.0629) | |
| Dist. to Beach 3000-3500m | 0.081** | 0.1385** | 0.096 | -0.0993 | -0.1454** | |

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|---|---|---|---|---|---|---|
| | (0.0364) | (0.0559) | (0.0587) | (0.0864) | (0.0706) | |
| Dist. to Beach 3500-4000m | 0.0006 | -0.0755 | -0.0171 | -0.1497* | -0.1545** | |
| | (0.032) | (0.0527) | (0.0553) | (0.0851) | (0.0712) | |
| Dist. to Beach 4000-4500m | 0.0023 | -0.1023 | -0.0296 | -0.0538 | -0.0035 | |
| | (0.026) | (0.0493) | (0.0531) | (0.082) | (0.0643) | |
| Age of Home | -0.0027*** | -0.003*** | -0.003*** | -0.003*** | -0.0027*** | -0.0027*** |
| | (0.0003) | (0.0004) | (0.0003) | (0.0003) | (0.0003) | (0.0003) |
| Age of Home - squared | 1.2x10^-5*** | 1.5x10^-5*** | 1.5x10^-5*** | 1.6x10^-5*** | 1.3x10^-5*** | 1.3x10^-5*** |
| | (1.6255x10^-6) | (2.3108x10^-6) | (2.0490x10^-6) | (2.1775x10^-6) | (1.7386x10^-6) | (1.7328x10^-6) |
| Age Missing | -0.3858*** | -0.3870*** | -0.3940*** | -0.3947*** | -0.3876*** | -0.3867*** |
| | (0.0192) | (0.0221) | (0.0216) | (0.0216) | (0.0191) | (0.0191) |
| Home Sq. Footage | 0.0002*** | 0.0001*** | 0.0001*** | 0.0001*** | 0.0002*** | 0.0002*** |
| | (4.7344x10^-6) | (5.0812x10^-6) | (5.0970x10^-6) | (5.0868x10^-6) | (4.7230x10^-6) | (4.7327x10^-6) |
| Home Sq. Footage Missing | 0.4853*** | 0.4705*** | 0.4685*** | 0.4681*** | 0.4874*** | 0.4861*** |
| | (0.0208) | (0.0223) | (0.0223) | (0.0223) | (0.0207) | (0.0207) |
| Ln(Parcel Acreage) | 0.1470*** | 0.1396*** | 0.1392*** | 0.1389*** | 0.1437*** | 0.1430*** |
| | (0.0047) | (0.0049) | (0.0049) | (0.0049) | (0.0047) | (0.0047) |
| Townhome | 0.0799*** | 0.0807*** | 0.0811*** | 0.0805*** | 0.0816*** | 0.0819*** |
| | (0.0071) | (0.0076) | (0.0076) | (0.0076) | (0.0072) | (0.0072) |
| Bedrooms | -0.0036 | -0.0053** | -0.0057** | -0.0057** | -0.0045* | -0.0047** |
| | (0.0024) | (0.0025) | (0.0025) | (0.0025) | (0.0024) | (0.0024) |
| Bathrooms | 0.0477*** | 0.0487*** | 0.0483*** | 0.0485*** | 0.0473*** | 0.0475*** |
| | (0.0038) | (0.004) | (0.004) | (0.004) | (0.0038) | (0.0038) |
| Bathrooms Missing | 0.138*** | 0.1444*** | 0.1382*** | 0.1386*** | 0.1331*** | 0.1326*** |
| | (0.0162) | (0.0177) | (0.0177) | (0.0177) | (0.0161) | (0.0161) |
| Pool | 0.0545*** | 0.0498*** | 0.0493*** | 0.0484*** | 0.0559*** | 0.0582*** |
| | (0.0179) | (0.0187) | (0.0187) | (0.0187) | (0.018) | (0.018) |
| Porch | 0.0087 | 0.6675 | 0.0034 | 0.0034 | 0.0088 | 0.0104 |
| | (0.0081) | (0.0085) | (0.0085) | (0.0085) | (0.0081) | (0.0081) |
| A/C | 0.011 | 0.0129* | 0.013* | 0.0137* | 0.0111 | 0.012 |
| | (0.0073) | (0.0078) | (0.0078) | (0.0078) | (0.0073) | (0.0073) |
| Basement | -0.0291*** | -0.0254** | -0.0344*** | -0.0348*** | -0.0298*** | -0.0266** |
| | (0.011) | (0.0116) | (0.0116) | (0.0116) | (0.0109) | (0.0109) |
| Dist. to Primary Road | 0.0001*** | 0.0001*** | 0.0001*** | 0.0001*** | 0.0001*** | 0.0001*** |
| | (1.8083x10^-5) | (2.0256x10^-5) | (1.9154x10^-5) | (1.8547x10^-5) | (1.7641x10^-5) | (1.7397x10^-5) |
| % Developed by Block Group | -0.0021*** | -0.0021*** | -0.0020*** | -0.0020*** | -0.0021*** | -0.0020*** |
| | (0.0004) | (0.0004) | (0.0004) | (0.0004) | (0.0004) | (0.0004) |
| Dist. to NYC | 1.3018*** | 0.1758*** | 2.1367*** | 2.6194*** | 2.042*** | 2.1167*** |
| | (0.0249) | (0.015) | (0.0248) | (0.0118) | (0.0273) | (0.0119) |
| Dist. to NYC - squared | -0.0395*** | -0.0028*** | -0.0655*** | -0.0807*** | -0.0625*** | -0.065*** |
| | (0.0003) | (0.0003) | (0.0002) | (4.7911x10^-5) | (0.0002) | (0.0001) |
| Dist. to NYC - cubed | 0.0004*** | | 0.0007*** | 0.0008*** | 0.0006*** | 0.0007*** |
| | (1.6155x10^-6) | | (3.2147x10^-6) | (1.8336x10^-6) | (3.0922x10^-6) | (1.5098x10^-7) |

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|---|---|---|---|---|---|---|
| Ln(Dist. to Sewage Plant) | 0.0172 | 0.4377 | 0.0269 | 0.0400* | 0.0353 | 0.0119 |
| | (0.027) | (0.024) | (0.0287) | (0.022) | (0.0263) | (0.0204) |
| School Rating | 0.0218*** | 0.0189*** | 0.0183*** | 0.0183*** | 0.021*** | 0.0203*** |
| | (0.0035) | (0.0037) | (0.0036) | (0.0035) | (0.0034) | (0.0034) |
| School Rating Missing | 0.1059*** | 0.0944*** | 0.0899*** | 0.0934*** | 0.1038*** | 0.1012*** |
| | (0.0248) | (0.0262) | (0.0257) | (0.0251) | (0.0245) | (0.0242) |
| 100-Year Flood Plain | 0.006 | 0.5348 | 0.0096 | 0.0086 | 0.0061 | 0.0053 |
| | (0.0156) | (0.0166) | (0.0165) | (0.0165) | (0.0156) | (0.0156) |
| Median Household Inc. | 1.0x10^-6*** | 1.0x10^-6*** | 1.0x10^-6*** | 1.0x10^-6*** | 1.0x10^-6*** | 1.0x10^-6*** |
| | (9.2867x10^-8) | (7.5471x10^-9) | (8.5254x10^-8) | (8.5839x10^-8) | (9.4088x10^-8) | (9.6279x10^-8) |
| Median Household Inc. > $250k | 0.2646*** | 0.2664*** | 0.2587*** | 0.2572*** | 0.2584*** | 0.2546*** |
| | (0.0071) | (0.019) | (0.0106) | (0.0099) | (0.0074) | (0.0067) |
| Ln(% Hispanic) | -0.0131 | 0.0403 | -0.0051 | -0.0057 | -0.0065 | -0.0052 |
| | (0.0125) | (0.0135) | (0.0132) | (0.0129) | (0.0124) | (0.0122) |
| Ln(% Black) | -0.0329*** | -0.0409*** | -0.0429*** | -0.0416*** | -0.0336*** | -0.0312*** |
| | (0.0056) | (0.0061) | (0.006) | (0.0059) | (0.0055) | (0.0055) |
| % Owner Occupied | -0.1884*** | -0.1682*** | -0.1892*** | -0.1832*** | -0.1763*** | -0.168*** |
| | (0.0458) | (0.05) | (0.0483) | (0.048) | (0.046) | (0.0457) |
| Pop. Density | -8.0x10^-6*** | -6.0x10^-6** | -6.0x10^-6** | -6.0x10^-6** | -7.0x10^-6** | -6.0x10^-6** |
| | (2.7506x10^-6) | (3.0346x10^-6) | (2.7890x10^-6) | (2.7670x10^-6) | (2.8226x10^-6) | (2.7719x10^-6) |
| Year 2004 | 0.088*** | 0.0847*** | 0.0758*** | 0.0769*** | 0.0773*** | 0.0742*** |
| | (0.0088) | (0.0093) | (0.0094) | (0.0094) | (0.0091) | (0.0091) |
| Year 2005 | 0.1732*** | 0.1678*** | 0.1518*** | 0.1536*** | 0.1513*** | 0.1469*** |
| | (0.0087) | (0.0093) | (0.0096) | (0.0097) | (0.0094) | (0.0095) |
| Year 2006 | 0.1794*** | 0.1668*** | 0.1509*** | 0.1529*** | 0.1577*** | 0.1549*** |
| | (0.0092) | (0.01) | (0.0103) | (0.0104) | (0.0098) | (0.0099) |
| Year 2007 | 0.1211*** | 0.1088*** | 0.0919*** | 0.0944*** | 0.1*** | 0.0964*** |
| | (0.0101) | (0.0108) | (0.0112) | (0.0112) | (0.0107) | (0.0108) |
| Year 2008 | 0.0534*** | 0.0428*** | 0.0258** | 0.028** | 0.0338*** | 0.0312*** |
| | (0.0106) | (0.0113) | (0.0116) | (0.0116) | (0.0112) | (0.0112) |
| Year 2009 | -0.0835*** | -0.0923*** | -0.1036*** | -0.102*** | -0.0992*** | -0.1018*** |
| | (0.0114) | (0.0122) | (0.0123) | (0.0123) | (0.0117) | (0.0118) |
| Year 2010 | -0.1085*** | -0.1149*** | -0.131*** | -0.1291*** | -0.1296*** | -0.1329*** |
| | (0.0107) | (0.0113) | (0.0116) | (0.0116) | (0.0112) | (0.0112) |
| Year 2011 | -0.1489*** | -0.1624*** | -0.1785*** | -0.1774*** | -0.1692*** | -0.172*** |
| | (0.0107) | (0.0113) | (0.0115) | (0.0116) | (0.0111) | (0.0111) |
| Year 2012 | -0.1907*** | -0.208*** | -0.2286*** | -0.2272*** | -0.2149*** | -0.2175*** |
| | (0.0111) | (0.0117) | (0.0121) | (0.0121) | (0.0116) | (0.0117) |
| Year 2013 | -0.1628*** | -0.1849*** | -0.2016*** | -0.1997*** | -0.1858*** | -0.1891*** |
| | (0.0108) | (0.0117) | (0.012) | (0.012) | (0.0114) | (0.0114) |
| Year 2014 | -0.1276*** | -0.151*** | -0.1682*** | -0.166*** | -0.1478*** | -0.1507*** |
| | (0.0105) | (0.0113) | (0.0116) | (0.0117) | (0.0111) | (0.0112) |
| Year 2015 | -0.1257*** | -0.1565*** | -0.1763*** | -0.1752*** | -0.1536*** | -0.1579*** |

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|---|---|---|---|---|---|---|
| | (0.0175) | (0.019) | (0.0192) | (0.0193) | (0.018) | (0.0181) |
| Quarter 2 | 0.0261*** | 0.028*** | 0.0261*** | 0.0263*** | 0.0244*** | 0.0233*** |
| | (0.0063) | (0.0066) | (0.0066) | (0.0066) | (0.0063) | (0.0063) |
| Quarter 3 | 0.0432*** | 0.0425*** | 0.0401*** | 0.0403*** | 0.0404*** | 0.0389*** |
| | (0.0061) | (0.0065) | (0.0065) | (0.0065) | (0.0062) | (0.0062) |
| Quarter 4 | 0.0156** | 0.0182*** | 0.0156** | 0.0157** | 0.013* | 0.012* |
| | (0.0066) | (0.007) | (0.007) | (0.007) | (0.0067) | (0.0067) |
| Bch Length x Bch Dist. 0-500m | | | | 0.0002 | -3.4x10^-5 | 0.0007* |
| | | | | (0.0003) | (0.0002) | (0.0004) |
| Bch Length x Bch Dist. 500-1000m | | | | 0.0002 | 0.0002 | 0.0008*** |
| | | | | (0.0002) | (0.0002) | (0.0003) |
| Bch Length x Bch Dist. 1000-1500m | | | | 0.0003* | 0.0004*** | 0.0007*** |
| | | | | (0.0002) | (0.0002) | (0.0002) |
| Bch Length x Bch Dist. 1500-2000m | | | | 0.0003 | 0.0004** | 0.0005** |
| | | | | (0.0002) | (0.0002) | (0.0002) |
| Bch Length x Bch Dist. 2000-2500m | | | | 0.0008*** | 0.0008*** | 0.0009*** |
| | | | | (0.0002) | (0.0002) | (0.0002) |
| Bch Length x Bch Dist. 2500-3000m | | | | 0.0008** | 0.001*** | 0.0009*** |
| | | | | (0.0003) | (0.0002) | (0.0003) |
| Bch Length x Bch Dist. 3000-3500m | | | | 0.001*** | 0.0011*** | 0.001*** |
| | | | | (0.0003) | (0.0003) | (0.0003) |
| Bch Length x Bch Dist. 3500-4000m | | | | 0.0007** | 0.0007** | 0.001** |
| | | | | (0.0003) | (0.0003) | (0.0004) |
| Bch Length x Bch Dist. 4000-4500m | | | | 0.0001 | 1.1x10^E-5 | 0.0003 |
| | | | | (0.0003) | (0.0003) | (0.0003) |
| Boat Launch at Closest Beach | | | | -0.0017 | -0.0017 | 0.0217 |
| | | | | (0.0235) | (0.0244) | (0.0223) |
| Dist. to Beach (Pub) 0-500m | | | | | | -0.1037 |
| | | | | | | (0.1477) |
| Dist. to Beach (Pub) 500-1000m | | | | | | -0.0612 |
| | | | | | | (0.0994) |
| Dist. to Beach (Pub) 1000-1500m | | | | | | -0.0572 |
| | | | | | | (0.0812) |
| Dist. to Beach (Pub) 1500-2000m | | | | | | -0.0584 |
| | | | | | | (0.073) |
| Dist. to Beach (Pub) 2000-2500m | | | | | | -0.1606** |
| | | | | | | (0.07) |
| Dist. to Beach (Pub) 2500-3000m | | | | | | -0.1182 |
| | | | | | | (0.0731) |
| Dist. to Beach (Pub) 3000-3500m | | | | | | -0.1238 |
| | | | | | | (0.0812) |
| Dist. to Beach (Pub) 3500-4000m | | | | | | -0.13 |
| | | | | | | (0.0841) |

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|---|---|---|---|---|---|---|
| Dist. to Beach (Pub) 4000-4500m | | | | | | -0.0455 |
| | | | | | | (0.0702) |
| Dist. to Beach (Prv) 0-500m | | | | | | 0.1502* |
| | | | | | | (0.0846) |
| Dist. to Beach (Prv) 500-1000m | | | | | | 0.1221* |
| | | | | | | (0.0668) |
| Dist. to Beach (Prv) 1000-1500m | | | | | | 0.0495 |
| | | | | | | (0.0614) |
| Dist. to Beach (Prv) 1500-2000m | | | | | | 0.01 |
| | | | | | | (0.0618) |
| Dist. to Beach (Prv) 2000-2500m | | | | | | -0.0479 |
| | | | | | | (0.065) |
| Dist. to Beach (Prv) 2500-3000m | | | | | | -0.0361 |
| | | | | | | (0.0755) |
| Dist. to Beach (Prv) 3000-3500m | | | | | | -0.1197 |
| | | | | | | (0.0944) |
| Dist. to Beach (Prv) 3500-4000m | | | | | | -0.262** |
| | | | | | | (0.1116) |
| Dist. to Beach (Prv) 4000-4500m | | | | | | -0.1083 |
| | | | | | | (0.1012) |
| rho | 0.0373*** | 0.0300*** | 0.0270*** | 0.0260*** | 0.0260*** | 0.0259*** |
| | (0.0048) | (0.0003) | (0.0003) | (0.0003) | (0.0003) | (0.0003) |
| lambda | 0.7810*** | 0.8020*** | 0.7850*** | 0.7720*** | 0.7660*** | 0.7610*** |
| | (0.0008) | (0.0023) | (0.0007) | (0.0008) | (0.0008) | (0.0009) |
| Observations | 16,926 | 14,852 | 14,845 | 14,845 | 16,540 | 16,540 |
| R-squared | 0.7853 | 0.7858 | 0.7867 | 0.7865 | 0.7883 | 0.7888 |

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

## Appendix B. Temporal versus Spatial Variation in Observed Water Quality.

To examine the contribution of spatial versus temporal variation in explaining observed water quality levels, we estimate a simple model of summer season average enterococcus levels as a function of annual time $(\mathbf{M}_t)$ and/or neighborhood $(\mathbf{N}_j)$ fixed effects, at both the 2010 Census tract and municipality level. More specifically:

$$ln(WQ_{ijt}) = \beta_0 + \mathbf{M}_t\boldsymbol{\alpha} + \mathbf{N}_j\boldsymbol{\varphi} + e_{ijt} \tag{B.1}$$

where $WQ_{ijt}$ denotes the enterococcus level corresponding to home *i* in neighborhood *j* during year *t*. The coefficient vectors to be estimated, $\boldsymbol{\alpha}$ and $\boldsymbol{\varphi}$, capture the corresponding time and neighborhood fixed effects. Also to be estimated is the intercept coefficient $\beta_0$. The term $e_{ijt}$ is an assumed normally distributed mean zero error term. The model is re-estimated based on annual enterococcus levels observed among transactions of homes within 0 to 100 meters, 0 to 500 meters, and 0 to 1,000 meters. Model 1 includes only year fixed effects, Model 2 includes only neighborhood fixed effects[27], and Model 3 includes both. Models 1 and 2 serve as the restricted (or null hypothesis) models for Likelihood-Ratio (LR) Tests of whether the neighborhood fixed effects or year fixed effects, respectively, are jointly equal to zero. Model 3 serves as the unrestricted model.

The three models are estimated for each subsample based on proximity to the Long Island Sound. The results in Table B.1 are based on the finer resolution Census tract fixed effects. The results in Table B.2 are based on the coarser municipal fixed effects.

[27] Considering the full sample of 16,926 home transactions, the data cover 81 Census tracts and 17 municipalities.

First focusing on Table B.1, the results of the LR tests across all subsamples rule in favor of the unrestricted model, demonstrating that both the temporal and spatial dimensions provide statistically significant explanatory power towards the observed variation in enterococcus levels. Compared to Model 1, the higher R-squared values in Model 2 for all cases suggest that variation over space is a larger contributor in explaining variation in water quality. This is also suggested by the higher chi-square statistics corresponding to the null hypothesis that the neighborhood fixed effects jointly equal zero, under Model 1. These results hold across all three sub-samples (0 to 100 meters, 0 to 500 meters, and 0 to 1000 meters). We conclude that this scoping analysis provides suggestive evidence in support of excluding tract fixed effects from our primary hedonic analysis, since such fixed effects likely absorb much of the corresponding price variation of interest. We refer the reader to Abbott and Klaiber (2011) for a fuller discussion of the use of fixed effects in hedonic models at different spatial scales.

Examination of the coarser municipal fixed effect results in Table B.2, leads us to the same conclusion, but we can see that the relative difference between the R-squared and chi-square statistics suggest that municipal fixed effects do not contribute as much explanatory power, relative to the corresponding tract-level fixed effects. This is not surprising given that municipalities represent a broader spatial unit. Although spatial variation still contributes the majority of explanatory power to the overall observed variation in water quality, as a robustness check we re-estimate our hedonic regression results using the coarser municipal level fixed effects and present the results here.

Table B.1. OLS Regression of Annual Enterococcus Levels on Annual Time and Tract-Level Neighborhood Fixed Effects.

| | 0 to 100 meters | | | 0 to 500 meters | | | 0 to 1000 meters | | |
|---|---|---|---|---|---|---|---|---|---|
| | Model 1 | Model 2 | Model 3 | Model 1 | Model 2 | Model 3 | Model 1 | Model 2 | Model 3 |
| Year FE | Yes | No | Yes | Yes | No | Yes | Yes | No | Yes |
| 2010 Tract FE | No | Yes | Yes | No | Yes | Yes | No | Yes | Yes |
| Observations | 328 | 328 | 328 | 2,761 | 2,761 | 2,761 | 5,173 | 5,173 | 5,173 |
| # Year FE | 13 | - | 13 | 13 | - | 13 | 13 | - | 13 |
| # Tract FE | - | 16 | 16 | - | 23 | 23 | - | 29 | 29 |
| R-squared | 0.233 | 0.408 | 0.556 | 0.187 | 0.343 | 0.498 | 0.177 | 0.276 | 0.430 |
| Adj R-squared | 0.203 | 0.380 | 0.516 | 0.184 | 0.338 | 0.491 | 0.175 | 0.272 | 0.426 |
| LR-Tests | | | | | | | | | |
| H0: Tract FE=0 | $\chi^2_{(15)}$=179.22*** | | | $\chi^2_{(22)}$=1328.21*** | | | $\chi^2_{(28)}$=1899.62*** | | |
| H0: Year FE=0 | | $\chi^2_{(12)}$=93.89*** | | | $\chi^2_{(12)}$=741.60*** | | | $\chi^2_{(12)}$=1237.80*** | |

Table B.2. OLS Regression of Annual Enterococcus Levels on Annual Time and Municipality-Level Neighborhood Fixed Effects.

| | 0 to 100 meters | | | 0 to 500 meters | | | 0 to 1000 meters | | |
|---|---|---|---|---|---|---|---|---|---|
| | Model 1 | Model 2 | Model 3 | Model 1 | Model 2 | Model 3 | Model 1 | Model 2 | Model 3 |
| Year FE | Yes | No | Yes | Yes | No | Yes | Yes | No | Yes |
| Municipal FE | No | Yes | Yes | No | Yes | Yes | No | Yes | Yes |
| Observations | 328 | 328 | 328 | 2,761 | 2,761 | 2,761 | 5,173 | 5,173 | 5,173 |
| # Year FE | 13 | - | 13 | 13 | - | 13 | 13 | - | 13 |
| # Municipal FE | - | 8 | 8 | - | 10 | 10 | - | 10 | 10 |
| R-squared | 0.233 | 0.379 | 0.531 | 0.187 | 0.311 | 0.465 | 0.177 | 0.234 | 0.390 |
| Adj R-squared | 0.203 | 0.365 | 0.502 | 0.184 | 0.308 | 0.461 | 0.175 | 0.232 | 0.388 |
| LR-Tests | | | | | | | | | |
| H0: Municipal FE=0 | $\chi^2_{(7)}$=161.42*** | | | $\chi^2_{(9)}$=1155.77*** | | | $\chi^2_{(9)}$=1549.17*** | | |
| H0: Year FE=0 | | $\chi^2_{(12)}$=92.06*** | | | $\chi^2_{(12)}$=700.80*** | | | $\chi^2_{(12)}$=1180.74*** | |

In comparing models employing municipal fixed effects with our primary hedonic SAC models, we can see that the results are generally robust, particularly with respect to beach closures. In Table B.3, we see that, with just a few exceptions in Model 1, enterococcus levels at the waters nearest a home have no statistically significant effect on home prices. Focusing on Table B.4, for Models 3 and 4, there are no significant effects from beach closures in the 0-500 meter bins, but there are significant negative effects from beach closures in most distance bins.

Table B.6 contains municipal fixed effects results for Models 5 and 6. Regarding Model 6, the magnitudes of the effects from beach closures are generally greater for public beaches than private, but unlike the SAC hedonic results in Table 5 of the main text, the significant effects from private beach closures extend just as far as that for public beach closures. This is in contrast to our primary SAC Model 6 results discussed in the main text. The municipal fixed effects are absorbing key price variation that explains why water quality at private beaches has a more localized impact on property values. It is difficult to clearly discern whether this price variation results from causal price effects of interest, or is merely the result of time-invariant spatially correlated confounders associated with neighborhoods where private beaches tend to be located. For this reason, both sets of results are noted in the main text of section V to be as transparent as possible and to allow the reader to make their own judgement.

Table B.3. Municipal Fixed Effects Results. Elasticity with respect to Enterococcus levels closest to Home. (Dependent variable: ln(price)).

| | Model 1 | Model 2 | Model 3 | Model 4 |
|---|---|---|---|---|
| Home Ent 0-500m | -0.0123 | 0.00235 | 0.00186 | 0.00525 |
| | (0.0122) | (0.0103) | (0.00889) | (0.00832) |
| Home Ent 500-1000m | -0.0187* | -0.00163 | -0.000999 | 0.00174 |
| | (0.0107) | (0.00914) | (0.00967) | (0.00945) |
| Home Ent 1000-1500m | -0.00557 | -0.000549 | -0.00246 | -0.000730 |
| | (0.00534) | (0.00271) | (0.00267) | (0.00224) |
| Home Ent 1500-2000m | -0.00699*** | -0.00318 | -0.00447 | -0.00375 |
| | (0.00236) | (0.00252) | (0.00295) | (0.00276) |
| Home Ent 2000-2500m | -0.00156 | 0.00233 | 0.00122 | 0.000984 |
| | (0.00438) | (0.00347) | (0.00345) | (0.00325) |
| Home Ent 2500-3000m | 0.00535 | 0.00718* | 0.00679* | 0.00579 |
| | (0.00329) | (0.00391) | (0.00336) | (0.00339) |
| Home Ent 3000-3500m | 0.00651 | 0.00817** | 0.00802** | 0.00732** |
| | (0.00374) | (0.00310) | (0.00337) | (0.00333) |
| Home Ent 3500-4000m | 0.000482 | 0.00284 | 0.00270 | 0.00231 |
| | (0.00475) | (0.00357) | (0.00371) | (0.00364) |
| Home Ent 4000-4500m | 0.000674 | 0.00343 | 0.00350 | 0.00320 |
| | (0.00297) | (0.00405) | (0.00398) | (0.00393) |
| | | | | |
| Beach Ent | No | Yes | Yes | Yes |
| Beach Closures | No | No | Yes | Yes |
| Beach Attributes | No | No | No | Yes |
| | | | | |
| Observations | 16,926 | 14,852 | 14,845 | 14,845 |
| R-squared | 0.553 | 0.557 | 0.562 | 0.565 |
| Number of Municipal FE | 17 | 17 | 17 | 17 |

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.
Regressions include variables for structural, location, and neighborhood characteristics, as well as dummy variables for year and quarter.

Table B.4. Municipal Fixed Effects Results. Elasticity with respect to Enterococcus levels and Closures at the Nearest Beach. (Dependent variable: ln(price)).

| | Model 2 | Model 3 | Model 4 |
|---|---|---|---|
| Beach Ent 0-500m | -0.0316 | -0.0185 | -0.0216 |
| | (0.0194) | (0.0250) | (0.0330) |
| Beach Ent 500-1000m | -0.0134 | -0.0100 | -0.00664 |
| | (0.00950) | (0.00748) | (0.00708) |
| Beach Ent 1000-1500m | -0.0148 | -0.00141 | -0.00848 |
| | (0.0146) | (0.0143) | (0.0176) |
| Beach Ent 1500-2000m | -0.0390*** | -0.0224 | -0.0234 |
| | (0.0115) | (0.0141) | (0.0140) |
| Beach Ent 2000-2500m | -0.0247** | -0.0184 | -0.0249* |
| | (0.00948) | (0.0119) | (0.0125) |
| Beach Ent 2500-3000m | -0.0382** | -0.000740 | -0.00269 |
| | (0.0140) | (0.0113) | (0.0110) |
| Beach Ent 3000-3500m | -0.0481*** | -0.0160 | -0.0171 |
| | (0.0114) | (0.0130) | (0.0118) |
| Beach Ent 3500-4000m | -0.0120 | 0.00554 | 0.00520 |
| | (0.00999) | (0.00751) | (0.00617) |
| Beach Ent 4000-4500m | -0.0128 | 0.00854 | 0.00840 |
| | (0.0148) | (0.0119) | (0.0124) |
| | | | |
| Beach Closures 0-500m | | -0.00915 | -0.0109 |
| | | (0.0108) | (0.0113) |
| Beach Closures 500-1000m | | -0.00695 | -0.0132*** |
| | | (0.00464) | (0.00310) |
| Beach Closures 1000-1500m | | -0.0101** | -0.00833*** |
| | | (0.00348) | (0.00256) |
| Beach Closures 1500-2000m | | -0.0108** | -0.0126*** |
| | | (0.00426) | (0.00314) |
| Beach Closures 2000-2500m | | -0.00493* | -0.000985 |
| | | (0.00241) | (0.00507) |
| Beach Closures 2500-3000m | | -0.0140*** | -0.0144*** |
| | | (0.00363) | (0.00405) |
| Beach Closures 3000-3500m | | -0.0134*** | -0.00872*** |
| | | (0.00229) | (0.00288) |
| Beach Closures 3500-4000m | | -0.00903*** | -0.00720*** |
| | | (0.00271) | (0.00162) |
| Beach Closures 4000-4500m | | -0.00961** | -0.00938** |
| | | (0.00335) | (0.00356) |
| | | | |
| Observations | 14,852 | 14,845 | 14,845 |
| R-squared | 0.557 | 0.562 | 0.565 |
| Number of Municipal FE | 17 | 17 | 17 |

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Regressions include variables for structural, location, and neighborhood characteristics, as well as dummy variables for year and quarter.

Table B.6. Municipal Fixed Effects Results. Elasticity with respect to Enterococcus levels closest to Home and Beach Closures at the Nearest Beach (Dependent variable: ln(price)).

| | Model 5 | Model 6 | |
|---|---|---|---|
| Home Ent 0-500m | -0.00244 | -0.00138 | |
| | (0.0120) | (0.0125) | |
| Home Ent 500-1000m | -0.00900 | -0.00850 | |
| | (0.00937) | (0.00925) | |
| Home Ent 1000-1500m | -0.00467 | -0.00206 | |
| | (0.00391) | (0.00404) | |
| Home Ent 1500-2000m | -0.00573** | -0.00390* | |
| | (0.00206) | (0.00212) | |
| Home Ent 2000-2500m | 0.000718 | 0.00244 | |
| | (0.00404) | (0.00337) | |
| Home Ent 2500-3000m | 0.00575* | 0.00578 | |
| | (0.00292) | (0.00344) | |
| Home Ent 3000-3500m | 0.00694* | 0.00695* | |
| | (0.00351) | (0.00339) | |
| Home Ent 3500-4000m | -0.000229 | -0.000464 | |
| | (0.00483) | (0.00476) | |
| Home Ent 4000-4500m | -0.000695 | -0.00114 | |
| | (0.00296) | (0.00307) | |
| | | Public | Private |
| Beach Closures 0-500m | -0.0146 | -0.00726 | -0.0175 |
| | (0.00974) | (0.0148) | (0.0132) |
| Beach Closures 500-1000m | -0.0141*** | -0.0158** | -0.0115*** |
| | (0.00265) | (0.00710) | (0.00272) |
| Beach Closures 1000-1500m | -0.00808*** | -0.0151** | -0.0101*** |
| | (0.00214) | (0.00552) | (0.00197) |
| Beach Closures 1500-2000m | -0.0136*** | -0.0151*** | -0.0102*** |
| | (0.00253) | (0.00300) | (0.00115) |
| Beach Closures 2000-2500m | -0.00453 | -0.00732 | 0.00405 |
| | (0.00370) | (0.00519) | (0.00534) |
| Beach Closures 2500-3000m | -0.0141*** | -0.0158*** | -0.00454* |
| | (0.00311) | (0.00285) | (0.00253) |
| Beach Closures 3000-3500m | -0.0120*** | -0.0244*** | -0.00398* |
| | (0.00251) | (0.00728) | (0.00189) |
| Beach Closures 3500-4000m | -0.00729*** | -0.0330* | -0.00376* |
| | (0.00142) | (0.0185) | (0.00200) |
| Beach Closures 4000-4500m | -0.00829*** | -0.0110*** | -0.00436*** |
| | (0.00220) | (0.00312) | (0.00130) |
| Observations | 16,540 | 16,540 | |
| R-squared | 0.563 | 0.565 | |
| Number of Municipal FE | 17 | 17 | |

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Regressions include variables for structural, location, and neighborhood characteristics, as well as dummy variables for year and quarter.

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