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1. INTRODUCTION

The introduced genotype of *Phragmites australis* (Cav.) Trin. ex Steudel (or common reed, hereafter referred to as simply *Phragmites*) is an invasive wetland plant. The genotype native to North America was relatively uncommon and in recent years, the introduced genotype has become a fast-spreading nuisance (Saltonstall 2002). *Phragmites*, a warm-season perennial grass, can grow up to four meters tall and has flower clusters that are open and feathery at maturity. The State of Michigan (2017) lists *Phragmites* as an invasive species. The introduced, invasive genotype has darker leaves than its native cousin, has lighter-colored rhizomes, and forms more monotypic stands (Great Lakes Commission 2017) (Figure 1, Figure 2). Public agencies across the United States spend more than $4 million per year treating areas with *Phragmites* (Martin and Blossey 2013). The Michigan Department of Natural Resources (DNR) spent more than $126,000 between 2005 and 2012 treating *Phragmites* on public lands in the Bay City area near Lake Huron (Michigan Department of Natural Resources 2015). Though the economic costs of controlling *Phragmites* are clear, the economic benefits and financing for control programs are less clear.

Figure 1. A monotypic stand of invasive *Phragmites* along the Grand River.

Figure 2. The feathery seed head of *Phragmites*.

A thorough review by Hazelton et al. (2014) documented how *Phragmites* establishment in coastal wetland ecosystems is associated with decreased biodiversity, reduced habitat quality for fish and wildlife, and disrupted biogeochemical cycles. *Phragmites* also negatively effects human use of coastal and wetland areas. The tall, monotypic stands may impair water access and viewsheds. Additionally, a large amount of slow-decaying biomass in the form of dense standing thatch remains following every growing season, resulting in a major fire hazard accumulating year after year. Coastal residents are also becoming more educated regarding the harmful effects of invasive species and are therefore more likely than ever to pressure their neighbors into removing invasive populations before they cross property boundaries. Removing *Phragmites* and restoring native ecosystems at a watershed scale should enhance ecosystem function and service provision. The economic value of ecological benefits from *Phragmites* removal are not well understood. This paper, therefore, seeks to fill that gap by estimating the property value effects of *Phragmites* removal.

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Many studies have estimated the economic value of wetlands and the results are generally positive. For example, Brander et al. (2006) conducted a review and meta-analysis of nearly 200 wetland valuation studies, but only five of those used hedonic (property sales) models. The median wetland value from the five hedonic studies was $5/ha (in 1995 dollars) but mean value was about $8,000/ha. Other valuation methods exhibited similarly wide ranges. Wetland values were positively associated with both per capita GDP and population density.

Studies from Ohio, Minnesota, Oregon, and Australia found that home sale prices are inversely associated with distance to most, but not all, types of wetlands. That is, property prices increase as distance to wetlands decreases (Babb 2012; Doss and Taff 1996; Mahan et al. 2000; Tapsuwan et al. 2009). Associations ranged from $0.13/m (Mahan et al. 2000) to about $33.60/m (AUS$42.40/m in the original paper) (Tapsuwan et al. 2009). Metrics of wetland quality, such as size, buffer, and habitat diversity, also had a positive influence on housing values (Babb 2012). An analysis of coastal marsh along Michigan's Saginaw Bay using travel cost and contingent valuation methods found that people valued the wetlands at $756/ha ($1,870/ac) in 2005 dollars (Whitehead et al. 2009). This equates to about $928/ha ($2,292/ac) in inflation-adjusted 2015 dollars. There are few valuation studies that focus directly on *Phragmites*. One study of a Greek wetland found that people had a positive willingness to pay for reducing the area of the wetland covered by *Phragmites* (Birol, Karousakis, and Koundouri 2006). These studies suggest that people see high-quality, biologically-rich wetlands as an asset and are willing to pay to obtain the ecosystem services that flow from them. As far as we know, our study would be the first economic valuation of *Phragmites* removal using a hedonic model.

Environmental economists have developed various techniques for measuring the economic values of ecosystem goods and services. Economists often use hedonic models to estimate the willingness to pay for various attributes of consumer goods including environmental quality. In a hedonic model, the consumer good is viewed as a bundle of characteristics and sales price is regressed against these attributes. With a reasonably large sample size, the analyst can estimate the marginal effect each attribute has on the sales price. The repeat-sales model is a variation on the standard hedonic model that is often used in residential home sales. Economists can regress the change in sales price over time against the relevant time-variant characteristics, while leaving out characteristics that do not change over time. This simplifies the process considerably, although it limits the available data to those goods that have sold multiple times (Freeman 2003). The repeat-sales model was developed by Palmquist (1982) and was first used to analyze the effect of highway noise on residential properties.

Since 2007, The Nature Conservancy and other conservation entities in the Michigan Dune Alliance collaborative have implemented extensive terrestrial invasive plant control efforts throughout the dunes, wetlands, and nearshore forests of Eastern Lake Michigan, ultimately aimed at restoring and maintaining the ecosystem health, processes, and services of this globally-unique coastal system. Traditionally, financial resources for this type of ecological restoration come from public and private grant sources, a system primarily based on short-term (1-3 year) funding cycles and defined project start and end dates. While these traditional funding sources have been vitally important to both define the extent of invasive species impacts across this 500-mile stretch of shoreline and reduce those populations to a manageable level, they do not currently offer secure, long-term funding to maintain those outcomes in the future. To best maintain the ecological integrity of this system for natural habitat and human well-being, Michigan Dune Alliance members began to investigate alternative funding models that could derive resources for sustainable ecosystem management from the human-use benefits these coastal areas provide.

There are anecdotal reports that realtors in coastal areas such as Traverse City and Grand Haven, Michigan, USA were actively steering potential home buyers away from properties on which stands of *Phragmites* were established. Simultaneously, The Nature Conservancy developed a whitepaper on coastal conservation financing specifically focused on the aforementioned goal of identifying sustainable funding options for invasive species control (The Nature Conservancy 2010). Included in that document was an evaluation of multiple financing options, including tax increment financing (TIF).

Tax increment financing is based on the idea that improvements in, for example infrastructure, within a designated district can stimulate incremental growth in property assessments and tax revenues. Those additional revenues over time are earmarked to pay for the original improvements. The improvements, therefore, should be self-financing. Since its origins in California in 1952, TIF has become the most popular tool in the United States for financing economic development. It also has expanded from a tool to invigorate depressed city centers to an approach

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for financing more general public investments in infrastructure (Briffault 2010). In Michigan, TIF can be used to promote economic development in downtown districts, manufacturing and technology parks, commercial districts outside of city centers, and brownfield industrial sites (Bassett 2009).

This expansion in scope also includes the use of TIF for conservation purposes. In 2008, the Michigan legislature passed the Water Resource Improvement Tax Increment Finance Act (PA 94). The act enables local government units to create TIF districts to promote water resource improvements or access to inland lakes (State of Michigan 2008). Programs that remove invasive aquatic plants, such as *Phragmites*, could potentially be funded through TIF.

While TIF appeared to be well-aligned with the desired funding stream in terms of potential governance and timeframe, it was undetermined whether the revenue generated would be sufficient to support ongoing, long-term control of a species such as *Phragmites* in coastal areas (The Nature Conservancy 2010).

The Grand River flows more than 250 miles from its headwaters near Jackson to its mouth at Grand Haven where it empties into Lake Michigan. *Phragmites* has invaded many of the wetlands in the lower Grand River area, including the river's bayous and tributaries as well as Spring Lake (Figure 3, Figure 4). We used a repeat-sales model to estimate the property value effects of *Phragmites* removal in Ottawa County, Michigan. We hypothesize that coastal property values are negatively affected by proximity to *Phragmites* and that removing *Phragmites* will increase property values. As property values increase, so should property tax revenues. If the additional tax revenues are greater than the cost of *Phragmites* removal, then the publicly-funded management regime should be self-sustaining. This is similar to the TIF concept used to improve blighted urban and industrial neighborhoods (Briffault 2010). The results of this study will help local units of government understand the economic benefits of removing *Phragmites* and will inform TIF-style policy options.

Figure 3. The lower Grand River study area includes the city of Grand Haven at the river's mouth.

2. METHODS

2.1 Study Area and Data Sources

The study area was the lower Grand River watershed including the communities of Grand Haven and Spring Lake in Ottawa County, Michigan, USA (Figure 4). Ottawa County borders on Lake Michigan. In 2014, the Census Bureau estimated Ottawa County's population at about 276,000. The median value of owner-occupied homes (2009-2013) was $153,200 and median household income (2009-2013) was $56,453 (US Census Bureau 2014). The Ottawa County GIS Office provided parcel polygons including the property identification number (PIN) for all properties within 800 meters of the Grand River, Spring Lake, and their major tributaries. The *Phragmites* locations came from two sources: the Nature Conservancy provided point locations of *Phragmites* from their 2010 survey, and

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Ottawa County Parks provided point locations from their 2015 survey. Distances to *Phragmites* and to waterbodies were calculated from the parcel polygon edges using ArcGIS 10.1.

The *Phragmites* survey protocols, however, were not identical. This is a source of uncertainty. The absence of *Phragmites* points in Spring Lake in the 2015 survey was confirmed by Spring Lake Township Supervisor John Nash (personal communication). Spring Lake Township treated the lake for *Phragmites* in 2013, and remaining *Phragmites* stands were treated again in 2014. No treatment was necessary in 2015 because it was eradicated. *Phragmites* stands on Harbor Island near the mouth of the Grand River were also treated and eradicated. The untreated areas along the Grand River show relatively consistent patches of *Phragmites* in both 2010 and 2015. This gives us confidence that, although the data were not collected identically and systematically between the organizations, they both found the major patches of *Phragmites,* and the differences can be attributed to treatments on Harbor Island and in Spring Lake.

Ottawa County established a database and protocol that they will follow starting in 2015 so that future *Phragmites* conditions in the lower Grand River watershed can be tracked. Beginning with the 2015 survey, Ottawa County Parks is collecting not only *Phragmites* locations but also area and density. The data were categorical (Table 1). We assumed that each 2015 point location is at the top of its category and used 0.81 ha for the >0.40 ha category (the median value). The high-end values were chosen to simulate a “worst case” scenario. If the actual area of *Phragmites* is less, then the cost of treatment will likewise be lower. The high-end estimate therefore is about 36.42 ha of *Phragmites* in the lower Grand River area in 2015. Using the midpoint of the first three categories and 0.40 ha for the highest yields an estimate of 21.21 ha of *Phragmites*. The data also included a category for individual stalks, but this was ignored in the area calculation.

Table 1. The Estimated Total Area of *Phragmites* in the Lower Grand River Area in 2015 Was 36.42 ha.

Category	Number of points	High-end estimated area (ha)
<0.01 ha	22	0.20
0.01 ha to 0.20 ha	39	7.89
0.20 ha to 0.40 ha	30	12.14
>0.40 ha (assume 0.81 ha)	20	16.19
Total	111	36.42

Sales data from 2004 to August 2015 for Ottawa County were obtained through the Ottawa County (Michigan) Assessor's Office. Sales less than $10,000 were considered invalid (not arms-length transactions) and were removed from the dataset. The tabular sales data were joined to the parcel polygons through the PIN field. The extreme northern end of Spring Lake extends into Muskegon County. Sales from this area were not included in the analysis.

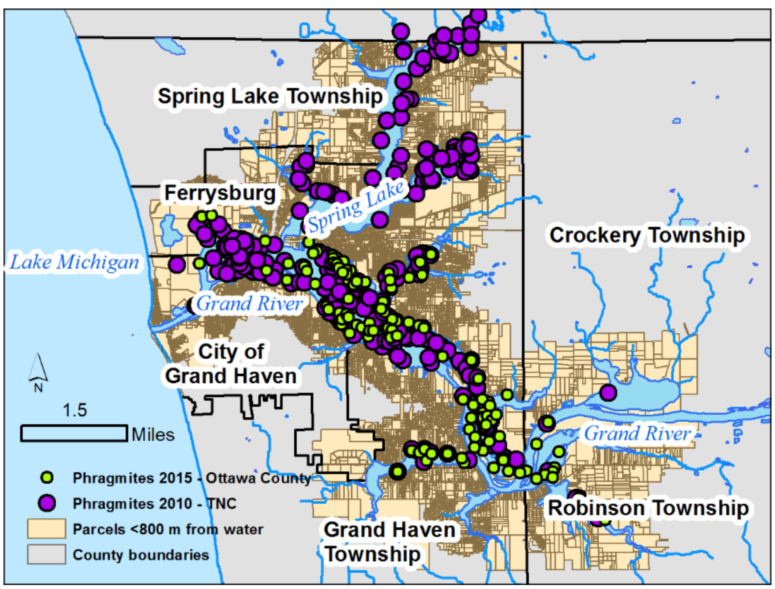

Figure 4. The lower Grand River watershed showing *Phragmites* locations in 2010 and 2015.

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2.2 Economic model

A repeat-sales model was used to measure the effect of *Phragmites* on property values. Repeat-sales models compare the change in a property's sales price with the change in the variable(s) of interest. The model assumes that all other attributes of the property, including both housing and neighborhood characteristics, are unchanged between the sales. It is important to note that homeowners do invest in renovations and some houses may violate this assumption. However, at least one study has shown that repeat-sales models provide comparable results to hedonic property value models that include a suite of home and neighborhood characteristics (Hansen 2009).

The regression model can take one of two forms: random effects or fixed effects. The Hausman test, a form of chi-square, can determine whether the unique errors are correlated with the regressors. The null hypothesis is that the errors and regressors are uncorrelated, in which case the random effects model is preferred (Greene 2008). We performed the Hausman test (χ^2 = 33.38, Prob>χ^2 = 0.00) and rejected the null hypothesis. Therefore, a fixed effects model was chosen.

The dependent variable was the natural log of the sales prices (*ln_price*). The independent variables included distance to the closest *Phragmites* location (in meters, *dist_phrag*) and a property value index for each year. The 2004 variable was withheld to prevent multicollinearity problems.

Hedonic models can be hampered by spatial autocorrelation within the data. That is, property prices for nearby houses tend to be similar and violate the statistical assumptions about independence of observations. Spatial autocorrelation can result in biased regression estimates. The sales price dependent variable was tested for spatial autocorrelation using Moran's *I* in ArcGIS 10.1. Most cases of significant spatial autocorrelation are dealt with using spatial lag or spatial error term models. With fixed effect repeat-sales models, however, this is not possible. A reasonable approach that mimics the spatial error model is to adjust the standard errors for clusters (repeated sales of the same property) (Heintzelman and Tuttle 2012). The repeat-sales model is derived from (Heintzelman and Tuttle 2012) (Equation 1, next page):

$$\ln\_price_{it} = \lambda_t + \alpha_i + \boldsymbol{z}_{it}\boldsymbol{\beta} + \epsilon_{ijt}$$

Equation 1. Repeat-sales hedonic model.

where λ_t is the annual dummy variable for year *t* (2005-2015); α_i is the fixed effects for parcel *i*; $\mathbf{z}_{it}$ is the vector of time-varying parcel-level characteristics (in this case, distance to *Phragmites*); $\boldsymbol{\beta}$ is the vector of regression coefficients; and ε_{ijt} is the error term including error clustering for group *j*.

Distance to *Phragmites* was calculated based on the year of sale. For sales before 2013 (when Spring Lake Township began removing *Phragmites*), distance was calculated based on the Nature Conservancy's 2010 points. For 2013-2015 sales, the Ottawa County *Phragmites* points were used. This allows us to capture the change in *Phragmites* distribution over time. This method assumes that the *Phragmites* stands were relatively stable in size and location from 2004 to 2010. Although it would be better to use sales that are closer in time to the *Phragmites* assessments, limiting the sales years also limits the number of observations. Including repeated sales back to 2004 was necessary to create a sufficiently large dataset for the regression model.

The sales were further restricted to properties within 100 meters of a waterbody including the Grand River, Spring Lake, or the various bayous and tributaries. The dataset comprised a total of 967 sales of 384 properties. Repeat-sales models require a minimum of two sales. The average number of sales in the dataset was 2.5 with a maximum of eight.

The average sales price for homes in the dataset was about $185,000. This is slightly higher than the median home value for Ottawa County of $153,200 (US Census Bureau 2014). This is to be expected because of the higher proportion of waterfront homes in the dataset. The total value of *Phragmites* removal was calculated using the following formula (Equation 2):

$$ValueRemoval = \#Homes \times (400 - MeanPhragDist) \times PricePhragDist$$

Equation 2. Determining the value of *Phragmites* removal.

where *ValueRemoval* is the property value generated by totally removing *Phragmites* within 400 meters of a property; *#Homes* is the number of homes with *Phragmites* within 400 meters; *MeanPhragDist* is the mean distance to the nearest

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Phragmites location; and *PricePhragDist* is the change in sales price that results with each one-meter increase in the distance to *Phragmites*. We assume that this change in value happens immediately when the *Phragmites* is removed. In reality, the change in value, and in property tax revenue, is captured when the home is sold.

Changes in the property values due to *Phragmites* removal will affect property tax revenues. Property taxes in Michigan are calculated based on millages ($1/1000^{th}$ of a dollar) and the taxable value is, by Michigan law, not more than 50 percent of the sales price. In the base case, we assumed that all homes were primary residences (homesteads). Area homestead millage rates for 2014 ranged from 26.51 in Grand Haven Township to 39.69 in the Village of Spring Lake (Michigan Department of Treasury 2015). For example, a house in Grand Haven Township that sells for $200,000 would have a taxable value of $100,000. At the millage rate of 26.51, the homeowner would pay $2,651 per year in property taxes.

The average homestead millage for the five municipalities was 32.14, which was applied to one-half of the sales price. Millages are higher for second homes, rentals, and businesses. Non-homestead millages ranged from 44.69 (Grand Haven Township) to 57.87 (Village of Spring Lake) with an area average of 50.29 (Michigan Department of Treasury 2015). The owner-occupied housing rate for Ottawa County Michigan (2009-2013) was 78.1 percent (US Census Bureau 2014). The remainder can be assumed as non-homesteads (rentals or second homes). The alternative model used a weighted average of homestead and non-homestead millages applied to one-half the sales price to estimate the property tax revenue change.

3. RESULTS

The Moran's *I* test for spatial autocorrelation showed that the log of sales price was significantly autocorrelated (Moran's I = -0.57, $p<0.01$). The negative Moran's *I* statistic indicates that high value properties are more dispersed than would be expected under a random distribution. We used error clustering to generate robust coefficients that account for the spatial effects (Heintzelman and Tuttle 2012).

Distance to *Phragmites* (*dist_phrag*) was statistically significant after controlling for the effects of the sales year (Table 2. Fixed Effects Regression Results.). The rho metric of intraclass correlation indicates that about 55% of the variance is due to difference across groups. The regression results indicate that a one-meter increase in distance to *Phragmites* is associated with a 0.0002 change in the natural log of the price, that is, a $3.90 change in the sales price (Table 3). Removing *Phragmites* from a property so that the next closest *Phragmites* patch is a quarter mile (400 m) away would lead to a sales price increase of more than $1,500. All *Phragmites* patches in the study area were less than 400 meters from the closest property.

The value of the change in distance to *Phragmites* was calculated for each house with *Phragmites* within 400 m (Equation 2). The total value of removing all *Phragmites* from the study area, found by summing all the per house values, was estimated at $837,391. This is assumed to be an immediate effect of removing the *Phragmites*. Assuming all the affected homes are primary residences and using the area average homestead millage (32.14), increasing property values by removing *Phragmites* would increase property tax revenues by $13,457 per year. Including the higher millage rate for non-homestead homes using a weighted average results in an annual property value increase of $15,121.

A report from the Michigan Department of Natural Resources (DNR) summarized the costs of *Phragmites* treatment in the Bay City area from 2005 to 2012. The DNR treated 184.54 ha of *Phragmites* at a cost of $126,866, or $687.47/ha. The treatments consisted mostly of ground-based foliar spraying and hand swipes but also included burning and helicopter spraying. Assuming there are about 36.42 ha of *Phragmites* in the lower Grand River area (Table 1), the cost of treating all of it would be $25,041 in the first year. Treatments in subsequent years would likely be less since there would be fewer patches of *Phragmites* to treat. This was the case in Spring Lake in which initial treatment in 2013 was followed by a modest treatment in 2014. In 2015, no treatment at all was needed.

Table 2. Fixed Effects Regression Results.

Variable	Regression coefficient	Standard Error
Constant	11.8401*	0.1019
dist_phrag	0.0002*	0.0001
year2005	0.0671	0.1217
year2006	0.3346*	0.1585
year2007	0.0566	0.1394
year2008	-0.1055	0.1958
year2009	-0.0562	0.1521

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Variable	Regression coefficient	Standard Error
year2010	-0.1400	0.1508
year2011	-0.0473	0.1372
year2012	-0.0584	0.1445
year2013	0.0605	0.1132
year2014	0.2819*	0.1180
year2015	0.1564	0.1406
*Coefficient is statistically significant (p<0.05) F(12, 571)=2.41, p<0.05 *rho*=0.55 N_{obs}=967 (sales) N_{groups}=384 (properties)		

Table 3. Relationship between Distance to *Phragmites* and Sales Price.

Distance to ***Phragmites*** (m)	Expected mean sales price	Difference from base case
1	$185,204	-
10	$185,239	$35
50	$185,394	$191
100	$185,589	$386
150	$185,784	$581
200	$185,980	$776
250	$186,175	$971
300	$186,371	$1,167
350	$186,567	$1,363
400	$186,762	$1,559

4. DISCUSSION

The literature shows that people are willing to pay for high-quality wetlands, as shown through housing prices (e.g. Babb 2012; Tapsuwan et al. 2009; Mahan et al. 2000; Doss and Taff 1996). Similarly, our results show that *Phragmites* has a significant effect on property values. A property's value increases by $3.90 for each meter the property is further away from *Phragmites*. The magnitude of this relationship is consistent with other estimates of the effect of wetland distance on sales prices, for example $0.35/m (Babb 2012) to $13.6/m ($21.02 in inflation-adjusted dollars) (Doss and Taff 1996). Removing *Phragmites* therefore has a positive economic benefit not only to the property owner, but the entire community. Higher property values lead to greater tax revenues which can fund additional *Phragmites* removal.

We found that removal of all *Phragmites* within the study area would increase annual tax revenues by $13,457-$15,121. Removing *Phragmites,* however, comes at a cost of about $687.47/ha. Removing all the *Phragmites*, about 36.42 ha, would cost $25,041. The cost of removal is just slightly less than two years of additional annual tax revenue. Since *Phragmites*, once controlled, does not need to be treated each year, the additional annual tax revenues can be put to other uses. These could range from lowering other taxes to improving infrastructure or maintaining key services. This suggests that TIF may be an appropriate tool for financing *Phragmites* removal.

This study has several limitations. The costs of *Phragmites* removal occur in the present, while the benefits from increased property values occur in the future after the properties have sold or are re-assessed. The full effect could take many years to be seen. The estimates of the property value impact come with some uncertainty. The years 2004-2015 included the inflation, bursting, and recovery of the housing bubble. While Michigan was spared the worst of the bubble's effects, there was substantial volatility in the Ottawa County housing market. We have taken steps to account for these swings, but the market instability could affect our estimates.

Repeat-sales models are limited to properties that have sold multiple times. It is possible that there is something unusual about a property that sells two or more times in a ten-year period. The median housing value in our dataset ($185,000) was slightly higher than that of Ottawa County as a whole ($153,000). This suggests that the properties in the dataset are representative of the county's housing stock. As noted previously, the repeat-sales method assumes that the condition of the home, such as renovation or deterioration, does not change between sales. Comparisons of repeat-sales and hedonic models that include a suite of housing and neighborhood characteristics show that repeat-sales models provide results that are consistent with hedonic models with housing attributes (Hansen 2009). We do not, however, have data that would confirm the stability in housing characteristics in our study area, and this is a source of uncertainty in the model. The temporal scope of sales, going back to 2004, assumes that the *Phragmites* stands were stable from

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2004 to 2010. Inclusion of the early sales was necessary to create a sufficiently large dataset to run the model. Limiting the temporal scope would have resulted in an unworkably small dataset.

5. CONCLUSIONS

Phragmites can quickly dominate a wetland, which displaces native vegetation and disrupts ecosystem functions and services. Communities often struggle, however, with funding *Phragmites* removal programs, and the economics benefits of such removals are unclear. This paper shows that in Ottawa County, Michigan, home sales prices are negatively associated with proximity to *Phragmites*. Removing *Phragmites* and increasing the distance to the next closest patch raised property values at a rate of $3.90 per meter. This demonstrates that *Phragmites* depresses property values and homeowners have a positive willingness to pay for properties that are farther away from *Phragmites*. The total property value benefits of removing all *Phragmites* within 400 meters of all affected properties were estimated to be $837,391 once all the benefits are internalized into sales prices, which could take a decade or more. The increased annual property tax revenues ($13,457-$15,121/year) is about half of estimated *Phragmites* treatment cost ($25,041). That is, two years of additional property tax revenues would pay for the removal of *Phragmite*s, which should last many years. The treatment would not need to be conducted annually, so treatment should have a positive net benefit to coastal communities.

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