

Navigating the Shift: Homeowner Perspectives on Managed Retreat Along Lake Michigan

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Abstract

Communities with developed shorelines face increasing negative impacts from adaptation, prompting policymakers to consider managed retreat programs. However, institutional challenges and homeowner interest raise questions about their economic and political viability. This study surveys Lake Michigan homeowners to assess the financial incentives needed for participation in a proposed on-site retreat program. Excluding relocation costs, a median payment between \$38,000 and \$77,000 is needed to participate and surrender the private option to alter lake shorelines with protective structures. These findings offer evidence of implementation strategies to minimize hardened shorelines and increase natural shoreline conservation, at costs lower than traditional retreat programs.

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1. Introduction

Coastal communities generate recreational and economic benefits through shoreline access, water activities, and tourism. Shorefront homeowners enjoy these amenities but also face unique risks like erosion. While homeowners can mitigate some risks through shoreline armoring or hardening, such adaptations can impact public benefits for others utilizing the shoreline (Beasley and Dundas, 2021). However, many shoreline policies in the United States (U.S.) tend to favor private property rights, allowing hardened adaptation through a permitting process. The public-private tension between shoreline homeowner adaptation and the public is expected to worsen with rising sea levels, rapid lake level oscillations, and increasing storm intensity and frequency (Sullivan and White, 2021; Harp et al., 2023; Taylor et al., 2023). These challenges underscore the critical need to explore all potential shoreline management options to develop socially optimal and politically viable long-term policies.

Current shoreline management options range from hardened to soft adaptation. Hardened adaptations, such as riprap revetments and seawalls, provide immediate risk reduction but can have negative public impacts. Softer adaptations, like zoning restrictions, are less intrusive but offer limited aid to existing homeowners with vulnerable properties.ⁱ Given the limitations of hardened and soft adaptation, policymakers are exploring alternative approaches to shoreline management. One such alternative is managed retreat, which involves strategically relocating at-risk development away from the environmental risks. Managed retreat provides an alternative risk mitigation option for homeowners with program benefits that may extend to a larger community by avoiding the negative spillovers of hardened adaptations and the preservation or restoration of public good aspects of natural shorelines.

Managed retreat programs often involve state or government agencies purchasing at-risk properties and retiring the land from future development. Carey (2020) suggests that retreat-based policies will likely become more common to mitigate shoreline hazards. Several regions globally and in the United States (U.S.) have already implemented managed retreat programs, including New Zealand, Louisiana (Bittle, 2023), New York (Hashida and Dundas, 2023), and New Jersey (Hashida and Dundas, 2024). However, expanding managed retreat programs face challenges with funding, logistics, and significant knowledge gaps in optimal design and implementation (Hanna et al., 2020). O'Donnell (2022) calls for greater cross-disciplinary research into managed retreat programs and compensation strategies.

Using a stated preference (SP) survey in the U.S. state of Michigan (MI), we asked 3,550 homeowners with property along Lake Michigan to respond to a contingent valuation (CV) scenario based on a hypothetical on-site relocation program.ⁱⁱ Our CV scenarios describe a program that covers homeowners' costs associated with relocating their home on the same parcel, along with offering an additional one-time payment for foregoing any current and future shoreline alterations. We received over 1,300 responses, with between 34 and 47 percent of respondents indicating they believed their property was large enough to accommodate an on-site retreat. Of that potentially eligible group, over 44 percent expressed interest in the proposed program, and the additional median payment to give up their option to harden their shoreline was between \$38,000 and \$77,000 (2022 USD). Importantly, 26 percent of respondents interested in an on-site retreat policy indicated they would not be open to traditional retreat-and-retire policies where they would have to relocate to another home elsewhere. Under current conditions, we also report that a non-trivial segment of the population with lakefront homes is unlikely to voluntarily

enroll in any form of managed retreat program, regardless of the erosion risk or the financial incentives offered.

We contribute to a broader understanding of the economic challenges of implementing managed retreat policies in four distinct ways. First, we explore on-site retreat programs in the Great Lakes Region (GLR) for the first time. The GLR, with its rapid lake level fluctuations and high population density, presents unique challenges and opportunities for managed retreat compared to oceanfront communities. Second, our analysis of on-site retreat rather than retreat-and-retire provides policy-relevant information about a new alternative option for shoreline management that may reach interested homeowners who are unwilling to leave their property or community. Third, our homeowner interest and participation analysis contributes to our understanding of barriers to alternative shoreline management plans. In regions prone to sea level rise (SLR), hurricanes, and storm surges, retreat may be inevitable. In other areas, erosion is the primary concern and may require alternative policies to balance private and public benefits provided by shorelines. Fourth, we empirically estimate the economic incentive to induce voluntary participation in a state-level retreat program. Much of the prior literature has focused on adoption characteristics (Robinson et al. 2018) and price effects from retreat-and-relocate policies (Frimpong et al. 2019), while our assessment offers insights into alternative design and payment schemes. While on-site retreat programs may not be cost-effective for all lots or structures, particularly homes with concrete slab-on-grade foundations, it may be a viable alternative that reduces erosion risk to structures and promotes natural shoreline conservation that avoids homeowner displacement in some at-risk communities. Using rough estimates for eligible home relocation costs, back-of-the-envelope calculations suggest on-site relocation could be performed for 27 to 54 percent of traditional retreat program costs without considering

additional financial incentives and restoration expenses.ⁱⁱⁱ Our findings provide valuable insights for the future design and implementation of retreat programs.

The remainder of this paper is structured as follows. Section 2 discusses shoreline adaptation, risks, and management policies in Michigan (MI), including an overview of the managed retreat literature. Section 3 discusses the survey construction, challenges with estimating willingness-to-accept (WTA) offers, and a conceptual framework for voluntary managed retreat. Section 4 provides data summaries for survey respondents, including sociodemographic and shoreline experience data. Section 5 presents econometric results for program interest and median WTA estimates. The paper concludes with a discussion of policy implications, limitations of the study, and avenues for future research.

2. Shoreline Adaptation, Managed Retreat, and the Great Lakes Region

Hardened Shoreline Adaptation

While regulated and constructed on private property, hardened adaptation can adversely affect a local community. These structures, such as riprap revetments and seawalls, may deflect wave energy to neighboring areas, exacerbating erosion on unarmored shorelines. Downward-directed wave energy can cause scouring, further eroding the shoreline in front of the structure. This negative feedback loop could lead to structural failure and more significant adaptive measures, reducing beach quality and width (Kraus, 1988; Hall and Pilkey, 1991). This type of individual adaptation decision-making has been shown to generate a cascading effect, resulting in the potential for large increases in hardened shorelines (Scyphers et al., 2015; Beasley and Dundas, 2021).

Hardened shorelines also impact local property values (Jin et al., 2015; Dundas and Lewis, 2020; Beasley, 2024) and decrease the desirability of visiting these areas compared to natural shorelines (Landry et al., 2020). They disrupt aquatic and terrestrial ecosystems (Toft et al., 2013) and lower coastal resiliency (Hamin et al., 2018). This situation exemplifies the “tyranny of small decisions,” where individual actions lead to cumulative negative social outcomes (Kahn, 1966; Odum, 1982). These adverse community impacts suggest that decentralized, reactive shoreline management strategies can shape a developed shoreline's appeal and environmental health, with potential consequences for both market and nonmarket service flows (Landry et al., 2020).

Managed Retreat

The literature on managed retreat has evolved rapidly over the last twenty years, with O'Donnell (2022) providing a systematic review of this body of work. Key studies explore program design and implementation. Kousky (2014) discusses better shoreline policy designs, including development limits in high-risk areas and using disasters as catalysts for retreat programs. Bragg et al. (2021) examine indicators of “receptive” versus “resistant” communities to managed retreat in California, addressing stigmas that may hinder policy adoption. Communities with high land values due to coastal amenities may be more averse to participating in managed retreat programs due to potential losses of property tax revenues from retired parcels (Hashida and Dundas, 2024). Siders (2019) discusses whether retreat programs can be transformative and successful, focusing on the allocation of potential benefits.

Case studies offer insight into managed retreat programs' successes and challenges. For example, Braamskamp and Penning-Rowsell (2018) evaluate a New York program's success post-Superstorm Sandy, while Hashida and Dundas (2023) show varying housing market impacts

from the same program, depending on the type of policy intervention (i.e., buyout or acquisition) and location. Ajibade et al. (2022) report a 61 percent success rate among 138 “resettlement” case studies. The success of retreat programs often depends on factors such as risk exposure, program initiation, government support, and compensation levels.^{iv}

Recent studies, such as Robinson et al. (2018) and Frimpong et al. (2019), assess factors influencing homeowners’ acceptance of voluntary buyout offers. Robinson et al. conducted a survey in Raleigh, North Carolina, testing willingness to participate in a voluntary acquisition program. Frimpong et al. examined the impact of different payment offers and timing on program acceptance in flood-prone areas of eastern North Carolina. They found that the offer amount, timing, and homeowner characteristics significantly affect acceptance rates.

Our survey describes a program to move at-risk development inland and restrict future hardened shoreline adaptations, with the latter component akin to a payment for ecosystem services program. Managed retreat is a recognized strategy within the Resilient Michigan Strategic Management Plan, even though it is not actively utilized.^{v,vi} While on-site relocation services may not be feasible for all residents given lot and structural constraints and erosion impacts, they may prove cost-effective in specific situations, preserving natural shorelines and avoiding community displacement. Additionally, there may be circumstances where less cost-effective strategies are preferred when dealing with maintaining the continuity of community for marginalized or at-risk populations.

Regional Factors

The desirability of coastal amenities combined with historical industrial development may explain why nearly 50 percent of MI's population lives in a coastal area. Michigan has over 3,200 miles of shoreline, second only to Alaska in the US.^{vii} Chronic erosion risk affects many

shoreline communities, with an estimated 24 percent of sandy beaches eroding more than 1.64 feet per year globally (Luijendijk et al., 2018). MI is no exception, with hundreds of miles of beaches, dunes, and bluffs eroding along the shores of the Great Lakes.

The Great Lakes, though non-tidal, experience erosion due to wind, wave action, seasonal changes, and fluctuating water levels. Extreme cases can see up to 17 feet of shoreline lost per year (Michigan Department of Environment, Great Lakes, and Energy, 2022). Rapid water level fluctuations in the Great Lakes exacerbate erosion risks compared to gradual SLR on ocean shorelines. From 2013 to 2020, Lake Michigan water levels rose nearly six feet, causing substantial damage to infrastructure and property. The Great Lakes and St. Lawrence Cities Initiative estimates that short-term investments will exceed \$450M, with over \$800M needed for future mitigation activities.^{viii} Climate change may lead to wider oscillations in lake levels, resulting in cycles of damage and repair.^{ix}

Michigan's 41 coastal counties, bordering four of the five Great Lakes, include over 380 municipalities that set local shoreline management strategies. Erosion is common in many areas, but the state also designates High-Risk Erosion Areas (HREAs) - eroding more than one foot per year over the last 15 years - that cover nearly 250 miles of shoreline in 36 coastal counties (Michigan Department of Environment, Great Lakes, and Energy, 2022). HREAs are subject to more stringent development setback requirements (i.e., how close homes can be built to the lake), alleviating short-term erosion issues for new development. It is estimated that as much as 83 percent of the shoreline in MI is privately owned, which amplifies the public-private tension over shoreline management as lake levels oscillate and private adaptation decisions proliferate (U.S. Geological Survey, n.d.).

Prior survey research suggests homeowners favor seawalls and revetments as durable and cost-effective erosion-management options (Scyphers et al., 2015; Smith et al., 2017). This preference helps explain why an estimated 14 percent of the U.S coastline is hardened (Gittman et al., 2015). The National Oceanic and Atmospheric Administration (NOAA) Office for Coastal Management reports increased deterioration of GLR shoreline ecosystem health due to increases in hardened areas.^x At the state level, Michigan's Department of Environment, Great Lakes, and Energy (EGLE) aims to promote natural shorelines to foster greater coastal resiliency. However, the agency also operates a permitting system for installing private hardened shorelines at or below the ordinary high-water mark. Lake conditions can often generate significant increases in applications over short time horizons. For example, over 2,200 shoreline permits were approved in the 14 month-period ending December 2020.^{xi} In the GLR, common adaptations are semi-permanent, hardened structures like seawalls and riprap revetments. Large temporary sandbags have also been used during high water periods.

3. Survey and Theoretical Construct

Survey Design and Challenges

A full copy of the survey can be found in the online appendix (Appendix Figure A1). The online survey was divided into five sections: consent, homeowner background, CV scenarios, flood risk information, and socio-demographic questions.^{xii} The consent section emphasized the voluntary nature of the survey and required respondents to confirm they were at least 18 years old. Before the retreat-and-relocate CV scenario, respondents were asked to estimate their shorefront property's fair market value (FMV) and indicate if their property was large enough for

an on-site home relocation program. Table 1, col. 5, reports the number of respondents who answered “Yes” or “Maybe” to this question.

The survey then described the hypothetical on-site relocation program for eligible respondents. In this scenario, a government agency would cover expenses related to relocating the house on the parcel inland and restoring the shoreline to a more natural state (e.g., removing hardening). In return, the homeowner would forgo the right to alter the shoreline in the future. Since the homeowners are asked to give up a private property right, a one-time payment was proposed in addition to the relocation costs to incentivize voluntary participation.

Respondents’ willingness to accept (WTA) this program offer was assessed using a stochastic payment card (SPC), which allowed them to express their confidence in accepting a specific offer (Wang and Whittington, 2005). The SPC presented ten payments in \$5,000 increments between \$0 and \$45,000, and respondents indicated their likelihood of accepting an offer on a scale from “Definitely Yes (100%)” to “Definitely No (0%)”. If the respondents did not express at least a 75% likelihood of offer acceptance at any payment level, they were asked a follow-up question to determine whether their reluctance was due to disinterest in the program or insufficient payment level. Respondents were then prompted to input the minimum payment required to participate if their unwillingness to accept an offer was based on insufficient payment.

The SPC method integrates the strengths of the payment card (PC) approach and incorporates response uncertainty, potentially providing a better reflection of individual value distributions (Wang, 1997; Wang and Whittington, 2005). Previous research has shown that the SPC yields lower estimates compared to a referendum model (Wang and Whittington, 1997). Additionally, Boyle (2017) suggests that payment cards may mitigate issues with \$0 bids and

could be preferable to dichotomous choice questions. Lloyd-Smith and Adamowicz (2018) also highlight the utility of the SPC approach, especially with smaller sample sizes.

While WTA surveys have become more common, empirical practice has historically favored willingness-to-pay (WTP) questions. However, Knetsch et al. (2020) argue that WTP is often inappropriate when WTA is the relevant measure. Whittington et al. (2017) report that WTA questions may lead to greater scenario rejection than WTP questions, likely due to low or implausible payment offers and perceived inconsequentiality. Given recent advances in WTA survey design and the nature of our hypothetical program (e.g., giving up a property right), this survey focused on WTA questions. Moreover, research by Penn and Hu (2021) indicates little to no evidence of hypothetical bias in most WTA studies.^{xiii}

Vossler and Holladay (2018) find that lack of consequentiality can result in negative hypothetical bias and under-predicting response acceptance. Michigan has a history of utilizing land acquisition programs to construct lakeshore parks (e.g., Sleeping Bear Dunes), which some survey respondents referenced. Additionally, EGLE's shoreline adaptation strategies, as listed on their public website, include language relating to "... retreat from the coastline."^{xiv} The historical use of expenditures for land in coastal settings and the contemporaneous mention of such strategies may provide Michigan respondents with a more meaningful context (consequentiality) for this survey. To test for perceived consequentiality, respondents were asked if they believed their responses would impact the future implementation of retreat policies.

Survey Testing and Rollout

The survey sample comprised of Michigan homeowners with properties bordering Lake Michigan, spanning 14 counties in the Lower Peninsula and 4 counties in the Upper Peninsula. Figure 1 (panel A) shows the 18 counties and the approximate location of surveyed properties,

while Table 1 lists each county (col. 1) and their 2020 population estimates (col. 2). Panel B of Figure 1 shows the difference between the proposed on-site relocation policy approach compared to more common retreat-and-retire programs.

<<Fig 1 About Here>>

Pre-testing involved expert reviews, cognitive interviews with shoreline property owners, and a 200-household pre-test. The survey received IRB approval from Western Michigan University's (WMU) Office of Research and Innovation (ORI) in August 2022.^{xv} An initial group of 200 homeowners was contacted using a modified Dillman survey approach (Dillman et al., 2014). A one-page introductory letter (Appendix Figure A2) was mailed in early August, followed by a postcard (Appendix Figure A3) with survey access instructions and a follow-up letter (Appendix Figure A4). The postcard and follow-up letter included a unique six-digit access PIN associated to each property address. Mailings were addressed using homeowner names, where the data was publicly available. The survey achieved a 19% response rate in the trial phase, with 47% of respondents indicating a potential willingness to participate in the retreat program. Minor adjustments were made before the full mailing of the survey to improve responsiveness and better elicit homeowner values.^{xvi}

<<Table 1 About Here>>

The main survey followed the trial with another randomly sampled 4,170 parcels. Follow-up letters were mailed by early October using the same contact strategy. Early respondents were entered into a raffle for one of four gift cards to encourage participation.^{xvii} Out of 4,370 unique shoreline homeowners, 3,550 (81.2 percent) postcards were successfully delivered.^{xviii} The sample was relatively balanced across counties and peninsulas based on the number of available shoreline parcels (Table 1, col. 4).

Theoretical Considerations

The CV scenario required homeowners to evaluate an on-site relocation program, balancing private property rights against compensation for retreat. Let each homeowner i have utility function $U_i = u^j(y_i, X_i, h_i^t, j_i^t, \varepsilon_i^t)$ that varies with income (y), household characteristics (X), property rights associated with the shoreline (h), and shoreline risks (j), where the latter two dimensions are state-varying. We assume managed retreat programs target properties with community-wide shoreline risks ($t=1$). Initially, homeowners have the right to alter the shoreline (h_i^1) and face shoreline risks (j_i^1). This results in a starting utility condition $U_i = u^1(y_i, X_i, h_i^1, j_i^1, \varepsilon_i^1)$ for all potential retreat program participants.

Retreat acceptance involves forfeiting shoreline alteration rights (h^0) but will also reduce the shoreline risk (j^0) to their home, leading to a post-retreat utility $U_i = u^0(y_i, X_i, h_i^0, j_i^0, \varepsilon_i^0)$. Willingness to accept is defined as the minimum payment that equates the utility between the two states:

$$u^1(y_i, X_i, h_i^1, j_i^1, \varepsilon_i^1) = u^0(y_i + WTA, X_i, h_i^0, j_i^0, \varepsilon_i^0). \quad [1]$$

In other words, the WTA is the minimum payment that makes homeowners indifferent between the heightened risk with property rights and reduced risk without property rights. Assuming a homeowner will accept compensation and enroll in a retreat program when such a decision maximizes their utility, the probability of acceptance is given by:

$$P(\text{Accept} = 1) = P(u^0(y_i + WTA, X_i, h_i^0, j_i^0, \varepsilon_i^0) > u^1(y_i, X_i, h_i^1, j_i^1, \varepsilon_i^1)) \quad [2]$$

If utility is additively separable between the deterministic (v) and stochastic (ε) components, then eq. 2 can be reconfigured as follows

$$P(\text{Accept} = 1) = P(\varepsilon_i^1 - \varepsilon_i^0 < v^0(y_i + WTA, X_i, h_i^0, j_i^0) - v^1(y_i, X_i, h_i^1, j_i^1)) \quad [3]$$

WTA will be the minimum amount required for an individual to switch from not accepting to accepting the program. In this framework, the difference between the stochastic components (ε_i^0) and (ε_i^1) represent the unobserved factors influencing program acceptance. By estimating the deterministic part of the utility functions (v^0) and (v^1), we can analyze how observable factors impact the probability of acceptance. Depending upon assumptions regarding linearity and error term structures, various probability models may be used to estimate the WTA from eq. 3.

4. Data and Empirical Considerations

Of the 3,550 respondents who received mailed letters and postcards, 1,306 began the survey and consented, resulting in a 36.8 percent start rate. We performed multiple exclusions, reducing the number of final respondents in our analysis. We removed respondents who did not believe their property was large enough to accommodate an on-site retreat program (n=769). We removed respondents who did not answer the contingent valuation question (n=20), those who did not believe their property rights extended to the shoreline (n=19), and respondents from the pre-test (n=16).^{xix} Finally, we removed respondents with incongruent SPC responses (e.g., probabilities that decrease as offered payments increase) (n=34). Our final respondent count consists of 448 respondents, or 12.6 percent of all invited households.^{xx}

On-site relocation response totals vary by county, with participation ranging between 6 (Charlevoix) to 18 percent (Muskegon) of responding parcels. Among respondents, Lower Peninsula counties were slightly more likely than Upper Peninsula counties to believe their properties could accommodate on-site retreat.

Summary statistics of sociodemographic data for respondents are provided in Appendix Table A1. Over 85 percent of respondents report an age of at least 55, compared to the 2020 MI

census, which reported this group as 32 percent of the population. Only 2 percent of survey respondents report a race or ethnicity other than white (86.8 percent white, 11.2 percent unreported) compared to 26.1 percent non-white per the census. While the survey respondents do not reflect a random sample of MI residents, this may be an artifact of shoreline homeowners skewing older, whiter, and more affluent than the general population.^{xxi}

<<Table 2 About Here>>

Using the responses to the SPC and the follow-up question on program interest, we codified respondents as “Interested” or “Not Interested” in managed on-site retreat programs. It is important to note that this classification is based on receptiveness to an on-site managed retreat program, not the financial incentives necessary for program participation. The “Not Interested” label arises when respondents explicitly state they have no desire to participate in a retreat program, regardless of the level of compensation. Table 2 reports summary statistics from the remaining survey questions for both “Interested” and “Not Interested” respondents.

The mean self-reported FMV of lakefront homes is \$ 1.4M, with some homes reportedly worth as low as \$ 120K.^{xxii} Table 2 reports results from questions with discrete choice responses (No = 0, Yes = 1). Over 50 percent of all respondents reported owning multiple homes, while only 29 percent of those with multiple homes reported the Lake Michigan shoreline home as their primary residence. While only 6 percent of respondents reported erosion-related damage to their house, 52 percent reported damage to ancillary structures (e.g., decks, stairwells, docks). 29 percent reported installing or repairing hardened structures (seawalls or revetments). 60 percent of respondents were at least “a bit” concerned that shoreline modifications would adversely impact their neighbors and community.

Prior knowledge levels associated with six important coastal topics are also reported in Table 2. Respondents rated their knowledge on a Likert scale from “Unfamiliar” (1) to “Expert” (5). The mean shoreline erosion score is 3.5, with 55.8 percent of respondents considering themselves very knowledgeable. Only 1.3 percent of respondents reported being unfamiliar with shoreline erosion. Seawall knowledge had a similar mean score of 3.4, with 46.2 percent reporting being at least very knowledgeable. Revetment knowledge had a mean score of 2.8, with 19.4 percent of respondents unfamiliar with the term. Coastal resiliency had a mean score of 2.5, with nearly half of respondents reporting being not very knowledgeable. Managed retreat had the lowest mean knowledge score of 2.0, with less than 8 percent of respondents considering themselves very knowledgeable. The further the topic moves from an individualized experience (erosion) to communal aspects (coastal resiliency), the less assured respondents were in their prior knowledge.

Based upon the unique survey pin for each respondent, geographic measures corresponding to shorefront homes were manually assessed. Using Google Earth and parcel map data, variables approximating erosion risk and shoreline length were constructed. Where homes were visible from satellite imagery, the distance from the edge of the housing structure to the high-water mark was recorded.^{xxiii} On average, homes were 187 feet away from the high-water mark, though some homes were as close as 31 feet, indicating significant risk variation among respondents. The mean elevation of respondents’ homes is 613 feet, ranging from 581 feet to 826 feet, highlighting development from waterfront to bluffs.^{xxiv}

Wilcoxon rank-sum tests were performed between the two groups reported in Tables A.1 and 2. Respondents’ demographics were not statistically significantly different between the two groups. However, three key differences emerged between interested and uninterested

respondents. Homeowners not interested in managed retreat had significantly higher (self-reported) property values (31.2 percent higher). They also rated their knowledge of hardened adaptation significantly higher (14.6 percent higher). Conversely, homeowners most concerned about adaptation harm to their neighbors were significantly more interested in participating in managed retreat programs (71.9 percent higher).

Respondents who reported installing (or repairing) hardened structures were asked to provide further details presented in Appendix Table A2. The perceived durability of hardened protection was very influential for 74.8 percent of respondents, consistent with findings from a survey completed by Scyphers et al. (2015). The reactive nature of protection strategies is evident, with 73.8 percent influenced by the immediacy of protection. Nearly 59 percent reported professional recommendations as very influential. Finally, just over 29.8 percent of respondents were motivated by the low costs of hardened protection installation.

Empirical Approach

Our empirical analysis consists of three main components. First, we examine the factors influencing interest in the on-site retreat program using data from all survey respondents (n=343 to 448 depending upon survey responses). Next, we estimate the median WTA based on responses to the SPC program offers. Following Alberini et al. (2003) and Kanjilal (2015), we convert uncertain responses to certain ones by applying acceptance-cutoff thresholds of 50 percent, 75 percent, and 100 percent confidence.^{xxv} We categorize responses as accepted or rejected using these thresholds and employ two methods to calculate the median WTA. Finally, we reassess the median WTA by incorporating additional financial incentive data beyond the SPC offers. For analyses quantifying the WTA, we focus on respondents who indicated an openness to financial incentives (n=204).^{xxvi} Figure 2 (Left) presents the distribution of

acceptance certainty across SPC thresholds. Figure 2 (Right Top) illustrates that using the 75 percent rule, 58 percent of homeowners accept a \$45k offer - representing 26 percent of all surveyed respondents, including those uninterested in the program. For our analysis, we consider the 75 percent cutoff as our preferred approach, although we bound this with results from the 50 and 100 percent cutoff. We also test the impact of imposing a deterministic cutoff about certainty by developing a Monte Carlo procedure to simulate program acceptance with individual probability distributions.

We exclude financial incentives to explore the factors influencing interest in the on-site retreat program. This exclusion allows us to identify motivations and underlying factors shaping support managed retreat programs. Survey responses pertaining to perceived knowledge of shoreline adaptation (*Knowledge*), experience with erosion (*Experience*), concern for the environment and community (*Concern*), sociodemographic data (*Demographics*), and physical risks based on imagery (*Risk*) are incorporated in this analysis. We specify a Logit model (eq. 4), with standard errors clustered at the county level.

$$\log\left(\frac{P(\text{Interest}=1)}{1-P(\text{Interest}=1)}\right) = \alpha^0 + \alpha_1^0 * \text{Knowledge} + \alpha_2^0 * \text{Experience} + \alpha_3^0 * \text{Concern} + \alpha_4^0 * \text{Demographics} + \alpha_5^0 * \text{Risk} + \varepsilon^0 \quad [4]$$

To estimate the median premium for program acceptance (i.e., WTA), we link the theoretical framework (eq. 3) to a discrete choice model. Survey respondents were asked about their likelihood of accepting offers at ten different compensation levels, ranging from \$0 to \$45k. Using the Welsh and Poe (1998) method, we identified the lowest bid that shifted a respondent from not accepting to accepting an offer. This bid produces the minimum bid of acceptance (X_{iU}) and the maximum bid of rejection (X_{iL}). The true WTA lies in the interval $[X_{iU}, X_{iL}]$, given the assumption of respondent acceptance. The probability of an individual WTA falling between

these thresholds is then $F(X_{iL}; \beta) - F(X_{iU}; \beta)$. Using the standard logistic function and a maximum likelihood estimation, we calculate the median WTA using the negative ratio of the intercept and the coefficient on the payment ($\frac{-\alpha}{\beta}$). The Krinsky-Robb method with 10,000 simulations is used to produce confidence intervals for the median WTA (Krinsky and Robb 1986, 1990).

The Welsh-Poe method reduces the SPC to a single bid interval. Constraints in sample size and variation in bid acceptance limit our ability to implement more advanced estimation approaches that incorporate all bids and their uncertainty levels. However, alternatives still exist that utilize more data from the SPC by stacking acceptance and rejection recoding for each respondent for each SPC offer. This creates a balanced panel of 2,040 responses and increases the efficiency of our discrete choice model. Assuming the error terms are normal, independent, and identically distributed, eq. 3 can be operationalized as a random effects (RE) probit model with respondent characteristics and risk measures (Z):

$$P(\text{Accept}_i) = \Phi(\alpha + \beta * \text{Offer}_i + \delta * Z_i) \quad [5]$$

Under our preferred approach, 58 percent of respondents accepted an offer using the Welsh-Poe method. However, only 30 percent of all SPC responses were accepted (Table 4, column 4), suggesting that acceptance was grouped around higher SPC offers. This creates challenges with the RE analysis, which we mitigate by incorporating additional data from our survey based on the follow-up question posed to all respondents who did not accept an SPC offer with at least 75 percent confidence. These respondents entered their minimum WTA using a free-form entry. With this data, we create additional payment intervals up to \$300k and assume all respondents who accepted offers from the SPC would accept higher offers, even though they were not offered these higher bids. This approach increases acceptance levels from 30 to 54

percent of responses. Figure 2 (Right Bottom) illustrates the impact on accepted response rates. We use this new data to re-estimate eq. 5.

<<Fig 2 About Here>>

5. Results

This section details the empirical findings of our investigation into the proposed on-site managed retreat program. We begin by reviewing our findings on program interest, excluding financial incentives. Next, we move into the empirical results for median-WTA across multiple specifications. We conclude this section with a series of exclusions and robustness checks, strengthening our key results.

Analysis of Program Interest

Table 3 presents marginal effects across six specifications (cols. A-F), which should be interpreted as changes to the likelihood of showing interest in a retreat offer. Column A reports the baseline model with controls for adaptation knowledge, experiences, concerns, and underlying beliefs. Column B incorporates county-fixed effects. While counties are large, relatively heterogeneous groupings, using more granular spatial controls significantly reduces the power of our analysis given the low numbers of observations in smaller spatial units (i.e., city, census block group). While counties may be heterogeneous, our data suggests that the shoreline homeowners within each county are likely more homogeneous, given ethnicity, income, and education data. Column C includes self-reported FMV data. Column D adds sociodemographic controls, reducing the sample to 317 respondents.^{xxvii} Column E incorporates parcel risk characteristics, such as the distance from the structure to the high-water mark and elevation. Column F focuses on respondents likely to face higher erosion risk where the distance to the

high-water mark is less than 200 feet (n=205). In our last specification, we drop county fixed effects to accommodate the reduced sample size.

<<Table 3 About Here>>

Home tenure, which we include to control for the strength of community ties and experience with the area, is largely unrelated to program interest. Higher self-reported knowledge about shoreline erosion does not significantly influence program interest. However, knowledge about hardened adaptation and managed retreat was significant. Homeowners who reported expertise in hardened adaptation were 35 to 51 percent less likely to be interested in the on-site retreat program than those who were “unsure” about hardened adaptation. Those with expertise in managed retreat were 39 to 44 percent more likely to be interested compared to those “unsure” about managed retreat. Respondents who believed in the effectiveness of retreat programs in shoreline management were 10 to 17 percent more likely to be interested. Additionally, those anticipating erosion impacts were 10 to 16 percent more likely to show interest. Concern for neighbors being harmed by shoreline adaptation increases interest by 21 to 26 percent, relative to those not concerned about impacts on neighbors.

Next, we turn to the impact of sociodemographic factors on retreat program interest. Higher self-reported FMV is associated with reduced interest, with each \$100K increase in FMV of the home reducing program interest by 1 percent. Survey participants using their property as a summer vacation home were less likely to show interest in ceding shoreline property rights. Multiple home ownership, which is not included in the models presented Table 3, does not influence the likelihood of program interest (though it will influence the size of the required payout). There is limited variation in the remaining self-reported sociodemographic controls. We find no evidence that income impacts the likelihood of program interest. However, nearly 30

percent of survey respondents failed to disclose annual income estimates. Amongst these respondents, we find they are less likely to be interested in program participation. While we cannot discern whether this is related to high, or low, true incomes, we do note that self-reported FMV was 27 percent higher amongst respondents not reporting their income.

Geographic measures of potential structural risk were insignificant when controlling for respondent knowledge, beliefs, and demographics. Using a model with only controls for the presence of hardened shorelines, distance from the structure to the water, and the interaction of these two terms does reveal that homeowners with properties nearer to the water are more likely interested in retreat programs. Appendix Figure A5 illustrates greater interest in retreat among property owners with unarmored shorelines for homes nearest to the water (less than 85 feet). The lack of geographical effects in our primary specification thus likely arises from the small sample and limited number of homes near the shoreline. When we restrict our sample to the most at-risk (nearest to the shore) properties, the effects of the most significant controls become even more pronounced (Column F).^{xxviii}

Median WTA

To estimate the financial incentives required for program participation, we use multiple approaches to calculate the median WTA. We begin with the Welsh-Poe method, which reduces the SPC to a single bid interval. Results using all three cutoff thresholds are presented in Table 4, col. 3. When employing the 50 percent threshold, 75 percent of respondent intervals were identified via the SPC. If employing the 100 percent threshold, this percentage of identified intervals declines to 26 percent. We report the bid amount (β) to be statistically significant across all specifications. As expected, the median WTA increases as we tighten our assumption on

acceptance from 50 percent to 100 percent. Our preferred threshold suggests the median WTA is between \$18k and \$26k.

<<Table 4 About Here>>

Next, we estimate both a naïve and full model of eq. 5 by excluding (including) additional controls related to respondent knowledge, experience, and concern for environmental damages (Z_i). Results from the naïve RE model are presented in Table 4, col. 4. This panel approach increases the sample size from 204 to 2,040. The percentage of accepted offers declines from 47 to 12 percent, indicating a significant volume of acceptance at higher offers from the SPC. Under all three thresholds, higher payment offers (β) continue to be associated with a greater likelihood of acceptance and are statistically significant. Under the 75 percent rule, the median WTA increases from \$22k to \$38k (95 percent confidence interval: \$36k to \$40k).

Lastly, we incorporate additional controls (Z_i) from eq. 5, including home tenure (years), hardened shoreline installation, concern for erosion, concern for neighbors, and belief in managed retreat. Selected results are presented in Table 4, col. 5, and are similar to the naïve results. Payment offers are again associated with a greater likelihood of acceptance and are statistically significant. The median WTA under the 75 percent cutoff rule is virtually unchanged from the naïve results. We also use this model to calculate the median WTA for varying subpopulations. For example, we assess the median WTA if the respondents believe in managed retreat programs. Under this scenario, the median payment decreases from \$38k to \$32k. If the government agency focuses on properties with existing hardened adaptation, the median WTA increases from \$38k to \$44k. Under the most favorable scenario in terms of budgetary expenditure, the median WTA decreases from \$38k to \$27k if the implementing agency can

focus on properties with homeowners having lived there for more than 30 years, with a non-hardened shoreline, who believe in managed retreat, and who are worried for their neighbors.

Expansion of Program Offers

To address the relatively low acceptance rate in our initial analysis, we incorporate additional data from our survey based on the follow-up question posed to respondents who did not accept an SPC Offer with at least 75 percent confidence. This approach allows us to create additional payment intervals up to \$300k, significantly increasing the number of accepted offers. We re-estimate eq. 5 using the expanded dataset and present the results in Table 5.

Under the naïve model specification (Table 5, col. 1), the number of accepted offers increases to 54 percent. The WTA increases from \$38k to \$64k due to the inclusion of payment offers beyond the SPC. We next present our results for the full model, incorporating additional controls (Table 5, col. 3). Results conform to a priori expectations and remain consistent with previous specifications. Higher bid levels (β) are associated with greater acceptance, while most controls are at least marginally statistically significant. The further a homeowner's property is to the water, the less likely they are to accept a retreat offer. The longer the property shoreline, the less likely the owner will accept a retreat offer. Homeowners who have lived at their property for at least 30 years are more likely to accept an offer. Homeowners with a hardened shoreline are less likely to accept a program offer. Those who believe managed retreat programs can be successful, are worried about their neighbors, and utilize the home for summer vacations are more likely to accept an offer. We extend this model by including county fixed effects and present these results in Table 5, col. 4. Including county-fixed effects results in a median WTA, with covariates held at their means, of \$77k.

<<Table 5 About Here>>

For our final specification, we focus on the subset of properties where the distance from the house to the shoreline is less than 200 feet. Results are similar to previous specifications, except lower-income homeowners are much more likely to accept a program offer among this subgroup. If the implementing agency were to focus on these properties nearest the shore, where the shoreline is unaltered and where the homeowner earns less than \$75k per year, the median WTA would fall to \$25k.

Robustness Checks

We examine the robustness of our WTA estimates by exploring a variety of impacts on our primary specification. We begin by restricting respondents to those who were attentive throughout the survey. Embedded within one of the informational questions, survey takers were asked to “Please select strongly disagree” as an attention check. Approximately 15 percent of respondents answered with something other than strongly disagree. When focusing on attentive respondents, the median WTA decreases, although there is overlap in the confidence intervals.

Next, we implement a consequentiality restriction for survey respondents. The language throughout the survey consistently states that the survey aims to inform government agencies about homeowner beliefs in designing coastal management plans. After the CV scenario, we asked survey respondents the extent to which they believed their responses would be used to determine the payment level and program location. Only 8.8 percent of respondents who answered this question believed the state would not use their answers when considering future retreat payment levels. Excluding these respondents reduces the median WTA by approximately \$5k. While lower than our original estimates, the result is within 6 percent of our initial calculation, and the confidence intervals overlap significantly.

We also assess whether respondents felt comfortable answering questions regarding their interest in retreat programs. Approximately 18 percent of respondents “Strongly disagreed” or “somewhat disagreed” that they were informed enough to make valuation decisions. Excluding these respondents reduces the participant total to 156. The estimated median WTA decreases by approximately \$21k for the assuredly informed participants. Including all three robustness restrictions simultaneously reduces the total respondent count to 120. The median WTA falls from \$77k to \$72k.

Lastly, rather than imposing a deterministic cutoff of 50, 75, or 100 percent certainty, we develop a Monte Carlo procedure that draws from the individual probability distributions. We sample (with replacement) 4,000 acceptance probabilities from the payment card responses for each offer size on the payment card. We then compare each sampled response to a random uniform draw. If the random uniform draw is lower than the reported probability of acceptance, we denote that sample as an acceptance of the offer. This simulation framework yields a synthetic dataset of 40,000 observations that preserves the stochastic nature of the choice process while avoiding arbitrary researcher-induced certainty thresholds.

We use the simulated data to plot acceptance likelihoods in Appendix Figure A6 (left). The “all respondents” category includes creating simulated data from all survey respondents, whether they were interested in managed retreat or not. Next, we re-run the simulated approach but only sample from those respondents who indicated an openness to managed retreat policies (“interested respondents”). With the interested subset of simulated data, we then re-estimate our preferred random effects specification from Table 4, column 2. Under this approach, we report a median WTA of \$66K, which falls within the range of our estimated WTA using the 75 and 100 percent threshold cutoffs.

We then show how the Monte Carlo approach could be used to understand further differences in homeowner payments. We resample among interested homeowners and separate those with one home and those with multiple homes. Acceptance rates by offer size are presented in Appendix Figure A6 (right). The figure illustrates that homeowners with multiple homes are more likely to accept offers from the lower end of the payment card. Under the preferred random effects approach, we report that multiple-home homeowners' median WTA is \$61k, relative to single-home homeowners' median WTA of \$74k.

6. Discussion, Policy Implications, and Conclusion

Shoreline adaptation options are generally limited for homeowners facing significant erosion risks to their private property. The dominant individual adaptation strategy involves the installation of hardened shorelines, such as seawalls and revetments. These methods are perceived as durable, cost-effective, and immediate solutions for risk reduction. However, the external costs associated with their installation are often not considered in the decision-making process. Once installed, hardened shorelines can exacerbate erosion patterns, alter sediment transport, limit lake access, and disrupt natural shoreline dynamics. They also sever the link between aquatic and terrestrial ecosystems, potentially degrading water quality and increasing the prevalence of invasive species. While these adaptation strategies may provide short-term private benefits to homeowners, they often come at the expense of reduced coastal resiliency for the broader community.

Alternatives to shoreline adaptation are less common and more challenging to implement. Managed retreat, a less-studied option, involves relocating structures and development away from high-risk areas. Although retreat-based programs are included in strategic management

plans, they are rarely implemented in coastal settings due to institutional barriers (e.g., Hashida and Dundas, 2024), legal hurdles, and perceived low interest from shoreline homeowners. This paper assessed a hypothetical on-site retreat program within the GLR using an online survey distributed to 3,550 homeowners across 18 counties along Lake Michigan. Interest in shoreline management was high among homeowners concerned with erosion and conservation. Over 42 percent of homeowners in our sample frame began the online survey, and more than 12 percent completed the survey and believed their property was large enough for an on-site retreat. We also report that 26 percent of respondents interested in on-site retreat programs would not be interested in traditional retreat-and-retire programs.

In the retreat scenario described in the survey instrument, the state covers the expense of moving structures away from the lake on the same parcel, stipulating that homeowners must forego the right to alter their shoreline in the future. We asked homeowners to report their WTA using an SPC to relinquish this property right. An analysis of program interest shows that homeowners who were more familiar with managed retreat, trusted the government, were worried about their neighbors, and were concerned about erosion were most likely to show interest in the program. Conversely, the homeowners who felt the most informed about hardened adaptation and those with higher property FMVs were the least likely to be interested in the program. We were unable to identify the effects of sociodemographic differences due to limited variation among shoreline homeowners. Next, we excluded 244 respondents who indicated they would never, under any circumstance, participate in a voluntary retreat program. We extend our analysis by translating free-form WTA offers into an expanded SPC, which improves the acceptance rate beyond 60 percent. Assuming a 75 percent payment certainty cutoff rule, we estimate the median WTA for program acceptance to be between \$38k and \$77k. Simulated data

from a Monte Carlo analysis suggests a median WTA of \$66k for interested respondents.

Program managers could further reduce program costs by targeting homeowners with more than one property, without a hardened shoreline, who have lived on their property for over 30 years, and those who believe that state-sponsored retreat programs can succeed. Our results suggest that program participation is heterogeneous across space, self-perceived knowledge, and faith in institutions. These differences manifest in changes to WTA that induce participation, which will significantly impact future budgetary allocations for retreat programs.

To provide context to our results, we reviewed payment options for managed retreat or buyout programs in other regions of the U.S. We find that a majority offer a pre-disaster FMV to voluntary and successful applicants to the program, with no additional incentives. This is the case for programs such as the Harris County (TX) Disaster Recovery Voluntary Buyout Program, the New Jersey Blue Acres Program, and North Carolina's Strategic Buyout Program. The lone exception we found is the New York (NY) Rising Buyout and Acquisition Program that also offers a pre-disaster FMV but provides additional incentives in areas acutely vulnerable to potential future damages. The program offers a 10 percent incentive in addition to FMV if homes are within a state-designated Enhanced Buyout Areas or if they accept buyouts in clusters of 2 - 10 homes within the 100-year floodplain. There is also an additional incentive of 5 percent if the homeowner relocates and purchases a home within the same county, likely to counter local government resistance to potential losses of taxpayers (Hashida and Dundas, 2024). According to a report from the NY State Office of Resilient Homes and Communities, the average pre-storm FMV paid for buyouts in the NY Rising program through 2018 was approximately \$370k.^{xxix} This suggests the average range of incentives offered was between \$19k and \$56k. While not directly comparable due to the differing nature of the retreat programs (i.e., other states are

retreat-and-retain, this program was on-site relocation), the magnitude of our results are fairly consistent with these incentives offered to selected areas for the NY Rising program. This suggests that regardless of the type of retreat offered, financial incentives above FMV may be a needed component of such programs to induce voluntary participation, especially in coastal areas with high levels of desirable amenities.

While retreat-and-retain programs in coastal areas are likely costly (due to high housing values) and often significantly budget-constrained, the potential for on-site relocation may present a lower-cost option for coastal retreat. Discussions with an International Association of Structural Movers (IASM)-certified contractor in MI revealed that many eligible homes may be moved on-site for less than the cost of alternative adaptations. While it is challenging to predict relocation costs without detailed parcel (i.e., grade) and structural housing characteristics (i.e., foundation type), our discussions suggest an eligible 1,500 sq. ft. home could be relocated for \$150K to \$300K, including all project expenses. When considering additional costs related to the price premium for on-site retreat between \$38K and \$77K, on-site retreat will still be 27 to 54 percent of the cost of acquiring and retiring properties at FMV under traditional retreat programs. Based on rough cost estimates, the cost per shoreline foot conserved is between \$1,305 and \$2,618, which may be competitive with some private alternative adaptation strategies. Our results suggest there will be communities in the GLR (and globally) where on-site relocation will be significantly cheaper than the outright purchase of the land where natural shorelines are restored. Additionally, on-site retreat programs would avoid the displacement of homeowners from their property. This artifact may have significant value in developing shoreline management strategies for areas with low-income residents or other vulnerable members of the community.

We caveat our results with the following limitations. Our sample was recruited from a large percentage of the population of MI homeowners with shoreline property along Lake Michigan. It is plausible that homeowners along different Great Lakes, in states outside of Michigan, and along tidal ocean coastlines may respond differently. That said, significant differences in the GLR are unlikely, given minor differences in participation and compensation estimates across counties within Michigan's Upper and Lower Peninsulas. Many of our respondents indicated no money could ever be used to induce participation, suggesting an infinite WTA. To perform a policy-relevant analysis for a voluntary program, these respondents are assessed for their lack of interest but do not factor into median-WTA calculations. WTA calculations for private goods create assessment challenges. We perform multiple checks for consequentiality, all of which reduce the reported WTA, suggesting our preferred range may be a conservative estimate. With respect to program implementation, not all respondents interested in the program would have the option to relocate structures inward on the same parcel. Relocation costs are difficult to assign without site visits and detailed parcel data, which we do not possess. As such, we use rough estimates for relocation costs and assume an a conservative average FMV as an expected traditional buy-out cost in our back-of-the-envelope cost comparison.

A variety of future avenues of research can be derived from this work. Acquiring relocation cost data may help determine regions where on-site retreat is both feasible and cost-effective, allowing development of heuristics for policy design and targeting of investments. Additionally, this data would support a more detailed benefit-cost analysis of retreat policy design. Further surveys or focus group assessments could be conducted to better understand the heterogeneous factors that drive homeowner interest in retreat programs of varying designs. Identifying how to design retreat programs best to induce participation and lower compensation

packages would provide valuable information as risks increase and interest in these programs expands. Our results also highlight the potential for imbalances in program participation and community targeting based on sociodemographic characteristics. Further understanding the differences in program participation among the at-risk would help quantify program expenses for future budgeting needs.

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Table 1: Sample Frame and Response Rates by County in Michigan

	County	Population	Surveys Sent	Responses	On-site Retreat (Y)
Lower Peninsula	Allegan	120,502	211	82	33
	Antrim	23,431	236	81	32
	Benzie	17,970	39	17	7
	Berrien	154,316	147	65	21
	Charlevoix	26,054	64	24	4
	Emmet	34,112	342	54	34
	Grand Traverse	95,238	370	125	31
	Leelanau	22,301	654	232	72
	Manistee	25,032	152	70	29
	Mason	29,052	90	36	17
	Muskegon	175,824	114	44	27
	Oceana	26,659	215	88	26
	Ottawa	296,200	336	146	54
	Van Buren	75,587	116	40	9
Upper Peninsula ^a	Delta	36,903	174	54	23
	Mackinac	10,834	98	39	9
	Menominee	23,502	132	45	11
	Schoolcraft	8,047	60	23	9
	Totals	1,201,564	3,550	1,306	448

Counties included within the sample frame (col. 1) and the 2020 population from the Census (col. 2) are listed above. The number of selected shoreline parcels (col. 3) from each county, along with survey response totals for (col. 4) and those homeowners included in the final analysis who believe their property is large enough for on-site retreat (col. 5) are provided.

Table 2: Summary Statistics

	<u>Would Participate</u>				<u>Would NOT Participate</u>			
	N	Mean	Min	Max	N	Mean	Min	Max
Self-Reported FMV (000s)	193	1,228	100	8,500	219	1,611	91	8,000
Discrete responses [Scale: 0 - 1]								
Owns multiple homes	204	0.50	0.00	1.00	244	0.53	0.00	1.00
Michigan primary residence	102	0.25	0.00	1.00	130	0.32	0.00	1.00
Tenure < 10 years	80	0.39	0.00	1.00	76	0.31	0.00	1.00
Tenure > 10 and < 30 years	71	0.35	0.00	1.00	84	0.34	0.00	1.00
Tenure > 30 years	53	0.26	0.00	1.00	84	0.34	0.00	1.00
Lost land due to erosion	204	0.67	0.00	1.00	244	0.69	0.00	1.00
House damaged due to erosion	204	0.06	0.00	1.00	244	0.06	0.00	1.00
Other damage due to erosion	204	0.53	0.00	1.00	244	0.51	0.00	1.00
Installed hardened shoreline	204	0.25	0.00	1.00	244	0.32	0.00	1.00
Concerned for neighbor	164	0.55	0.00	1.00	183	0.32	0.00	1.00
Wants Lake MI View	204	0.96	0.00	1.00	244	0.96	0.00	1.00
Swims in Lake MI	204	0.89	0.00	1.00	244	0.88	0.00	1.00
Walks along Lake MI	204	0.90	0.00	1.00	244	0.90	0.00	1.00
Boats in Lake MI	204	0.54	0.00	1.00	244	0.54	0.00	1.00
Summers along Lake MI	204	0.57	0.00	1.00	244	0.61	0.00	1.00
Rents out property	204	0.11	0.00	1.00	244	0.07	0.00	1.00
Knowledge Questions [Scale: 1 – 5]								
Shoreline Erosion	204	3.47	1.00	5.00	243	3.57	1.00	5.00
Seawalls	204	3.30	1.00	5.00	244	3.42	1.00	5.00
Revetments	204	2.61	1.00	5.00	244	2.98	1.00	5.00
Natural Shorelines	203	2.51	1.00	5.00	244	2.62	1.00	5.00
Coastal Resiliency	204	2.46	1.00	5.00	242	2.52	1.00	5.00
Managed Retreat	203	1.96	1.00	5.00	243	2.08	1.00	5.00
Shoreline Measurements								
House to high water mark (ft)	190	183	34	639	222	192	31	770
House elevation (ft)	190	613	581	826	222	614	581	784
Shore length (ft)	190	152	39	1,208	221	140	44	1,364

The first column identifies the selected question for which we present summary statistics. The next four columns present key summary statistics for respondents who indicated they would be interested in the program, if compensated appropriately. The last four columns present key summary statistics for respondents who indicated they would never be interested in the program, regardless of the payment offered. Not all respondents answered all questions and not all shoreline measurements were available, so number of observations (N) vary by question. Wilcoxon-Rank Sum tests suggest statistical differences between groups for the self-reported FMV, knowledge on riprap revetments, and concern for neighbors.

Table 3: Marginal Effects – Retreat Program Interest

	A	B	C	D	E	F
Tenure < 10 years	0.09	0.09	0.07	0.08	0.08	0.11 *
Knowledgeable: Erosion						
Not Very Familiar	-0.02	-0.07	-0.03	-0.03	-0.12	0.15
Somewhat Familiar	-0.07	-0.08	-0.04	-0.02	-0.11	0.04
Very Familiar	0.02	-0.00	0.06	0.07	-0.01	0.12
Expert Knowledge	-0.28	-0.27	-0.21	-0.20	-0.21	-0.14
Knowledgeable: Revetments						
Not Very Familiar	-0.05	-0.04	-0.09	-0.10	-0.10	-0.16
Somewhat Familiar	-0.26 ***	-0.24 **	-0.29 ***	-0.29 ***	-0.30 ***	-0.29 **
Very Familiar	-0.29 ***	-0.26 ***	-0.34 ***	-0.35 ***	-0.33 ***	-0.36 ***
Expert Knowledge	-0.39 **	-0.35 **	-0.45 ***	-0.46 ***	-0.47 ***	-0.51 ***
Knowledge: Retreat						
Not Very Familiar	0.02	-0.01	0.00	-0.00	-0.00	0.04
Somewhat Familiar	0.10	0.09	0.09	0.10	0.08	0.24 ***
Very Familiar	0.05	0.04	0.10	0.10	0.11	0.03
Expert Knowledge	0.42 *	0.43 **	0.44 **	0.44 **	0.39 *	0.43 **
Erosion Damage to Structures	0.09 *	0.10 *	0.09	0.09	0.09	0.05
Lost Land to Erosion	-0.09 *	-0.08	-0.06	-0.06	-0.04	0.01
Trust MI Government	0.15 **	0.14 **	0.10	0.10	0.11 *	0.03
State Responsibility	0.08 **	0.10 **	0.11 ***	0.11 ***	0.11 ***	0.09
Retreat Can Help	0.11 *	0.11 *	0.12 **	0.12 **	0.10 *	0.17 **
Erosion Will Impact Me	0.10 **	0.12 ***	0.13 ***	0.13 ***	0.13 **	0.16 **
Concern for Neighbors ¹	0.21 ***	0.24 ***	0.25 ***	0.25 ***	0.26 ***	0.21 ***
Summer Vacationer	-0.14 **	-0.12 **	-0.14 **	-0.13 **	-0.13 **	-0.25 ***
Self-Reported FMV (\$100k)			-0.01 ***	-0.01 ***	-0.00 **	-0.01 ***
Income Below \$75K				-0.03	0.01	-0.10
Age: 54 +				0.04	0.04	-0.01
Distance to Shore (ft)					-0.00	
Elevation House (ft)					0.00	
N	343	343	317	317	303	205
County Fixed Effects	No	Yes	Yes	Yes	Yes	No
Pseudo R2	0.16	0.21	0.23	0.24	0.23	0.22

Marginal effects for on-site relocation interest. Column A excludes county indicators and sociodemographic data. Column B adds county indicators. Column C adds self-reported fair market value (FMV) for the property under consideration. Column D adds sociodemographic responses, excluding respondents who declined to answer these questions. Column E adds estimated geographic measurements, including the distance from a visible house to the high-water mark. Column F restricts respondents to those with structures less than 200 feet from the shoreline and drops the county effects. * p < 0.10, ** p < 0.05, *** p < 0.01.

¹ - Only 343 respondents answered this question. Interpretation of remaining variables is unchanged through inclusion.

Table 4: Median WTA for On-Site Retreat among Interested Respondents

		Welsh-Poe	RE Naïve	RE Full
50% Cutoff	# Accept	154	962	744
	α	-1.120 ***	-6.223 ***	-13.187 ***
	β	0.797 ***	0.267 ***	0.396 ***
	Median	14,055	23,342	26,030
	WTA			
	WTA CI	10,423 – 17,598	21,760 – 24,980	23,420 – 28,660
75% Cutoff	# Accept	118	604	454
	α	-1.981 ***	-12.105 ***	-14.936 ***
	β	0.892 ***	0.321 ***	0.318 ***
	Median	22,214	37,664	37,990
	WTA			
	WTA CI	18,431 – 25,751	35,740 – 39,660	34,610 – 42,430
100% Cutoff	# Accept	53	254	166
	α	-1.867 ***	-20.401 ***	-13.687 ***
	β	0.781 ***	0.266 ***	0.179 ***
	Median	23,914	76,808	64,370
	WTA			
	WTA CI	17,183 – 30,082	71,840 – 83,120	60,080 – 69,860
	N	204	2,040	1,640

Three cutoff acceptance rules (50, 75, and 100%) appear in rows 2-6, 7-11, and 12-16. Column 3 results correspond to Welsh-Poe (WP) method. Column 4 results correspond to a naïve (intercept and offer only) random effects (RE) probit model. Column 5 results extend the RE Naïve model with controls for tenure at property, hardened adaptation installation, worry about erosion, belief in retreat programs, concern for neighbor, and property uses in the summer.

Table 5: Median WTA for On-Site Retreat among Interested Respondents with Extended Offers

	Naïve Model	Full Model 1	Full Model 2	Full Model Near Shore
α	-8.137 ***	-8.775 ***	-7.599 ***	-8.212 ***
β	0.0001 ***	0.0001 ***	0.0001 ***	0.001 ***
Income Below \$75K		1.068	1.365	5.536 ***
Distance Water		-0.008 **	-0.003	0.001
Shore Length		-0.006 *	0.003	-0.014 ***
Tenure > 30 Yrs		2.174 *	1.462 *	0.728
Hardened Shoreline?		-2.471 ***	-1.022 +	-1.300 +
Retreat can Succeed		1.745 **	1.625 ***	1.865 **
Worry for Neighbor		2.066 **	2.234 ***	1.619 *
Summer Vacation Home?		0.995 +	0.996 **	0.439
County Effects	No	No	Yes	No
N	3,800	3,610	3,610	2,413
# Accepted	2,039	1,934	1,934	1,327
Median WTA	64,638	85,459	76,578	77,813
WTA CI	61,447 – 67,887	79,124 – 92,018	66,342 – 86,997	67,351 – 88,697

Figure 1:

Top (A): Survey participant locations. Bottom (B): Illustrates the differences in retreat-and-relocate programs (top), which displace homeowners, relative to on-site relocation programs (bottom) that move development inland.

Figure 2:

Left: Responses by payment card offer. Right-Top: Recode “Always” or “Often” as acceptance among interested respondents. Right-Bottom: Extends payment beyond the payment card based on self-reported minimum thresholds.

ⁱ Other forms of adaptation are used elsewhere (such as beach nourishment), but are less common in the Great Lakes Region.

ⁱⁱ This contrasts with the more commonly used retreat-and-retire program, where at-risk land is purchased and retired from future development.

ⁱⁱⁱ Discussions with a member of the International Association of Structural Movers located in SW Michigan provided anecdotal evidence for on-site relocation expenses. While true costs vary significantly from site to site, an average, eligible, 1,500 sq. ft. home could be moved for \$150K to \$300K. This estimate includes excavation, new foundation, and mechanical expenses associated with relocation. While the average fair market value of homes in our sample is \$1.4M, we conservatively utilize the 25th percentile (\$700K) as a buy-out expense for traditional programs. Thus, on-site retreat program costs of \$188K to \$378K (estimated relocation expenses plus premium payments) are 27 to 54 percent of a home's FMV.

^{iv} See Robinson et al. (2018) Table 1 for a summary of historical participation rates in voluntary acquisition programs, which range between 10 and 89 percent.

^v <https://www.michigan.gov/egle/about/organization/water-resources/coastal-management/michigans-resilient-coast>

^{vi} Land acquisition programs have been utilized in Michigan for conservation or state parks.

^{vii} <https://coast.noaa.gov/states/michigan.html>

^{viii} <https://www.pewtrusts.org/en/research-and-analysis/blogs/stateline/2020/09/30/rising-waters-threaten-great-lakes-communities>

^{ix} <https://scientificamerican.com/article/climate-change-sends-great-lakes-water-levels-seesawing/>

^x <https://coast.noaa.gov/states/stories/great-lakes-shoreline.html>

^{xi} <https://www.mlive.com/public-interest/2020/12/a-submerged-high-water-mark-upends-michigans-control-of-the-beach.html>

^{xii} We estimated that respondents should be able to complete the survey in 20 minutes. Respondents could save their progress within the Qualtrics platform and return at a later date. Per Internal Review Board requirements, responses to any question in the survey were not mandatory.

^{xiii} Following Lloyd-Smith and Adamowicz (2018), we ask a follow-up question to the CV scenario to reveal internal motivations. The respondents were asked whether their responses were motivated by ensuring payouts were worth it for themselves, a desire to ensure their community would be considered, or by maximizing the payouts to the community.

^{xiv} <https://www.michigan.gov/egle/about/organization/water-resources/coastal-management/michigans-resilient-coast>

^{xv} WMU IRB confirmation # 2022-145

^{xvi} Revised IRB approvals were secured in the second week of September 2022. Phase-one respondents are not included in the final analysis since they were assessed with a different SPC.

^{xvii} In this study, we offered a chance to win up to a \$500 Visa gift card if the homeowner completed the survey by a specified date. While raffles are not considered the most effective way to boost participation, budgetary constraints necessitated their inclusion over leading alternative methods, like direct payments (e.g., \$2 included with the survey). Four different raffle winners were selected for gift cards ranging between \$500 and \$200.

^{xviii} During this process, a significant number of mailed items were returned with an "NMR" (No Mailing Receptacle) USPS code. Upon investigation, it was revealed that many homes along the shoreline do not accept parcels due to a lack of mailboxes. Where secondary addresses for shoreline property owners were available, we mailed new correspondence to these addresses. Approximately 17 percent of homeowners were sent the survey information at an alternative, or secondary, address not located at the shoreline.

^{xix} These respondents utilized an alternative SPC, with lower bounds.

^{xx} This calculation does not correspond to a Survey Response Rate, given the removal of 769 respondents who felt their property was too small. An estimated survey response rate is 34.2 percent.

^{xxi} We do not weight our sample based upon differing demographics from state census data.

^{xxii} We exclude home values reported under \$ 10K and over \$ 10M due to potential data entry errors.

^{xxiii} This measurement may not be reflective of the risks at the time of the survey, given varying lake levels. However, it should still capture a relative risk of survey participants.

^{xxiv} The 1985 ordinary high water mark for Lake Michigan is 580.5’.

(<https://www.michigan.gov/egle/about/organization/water-resources/submerged-lands/ordinary-high-water-mark-ohwm>)

^{xxv} For example, when using the 50 percent cutoff acceptance rule, we code all SPC responses with at least 50 percent certainty as an acceptance ($P(\text{Accept}) = 1$).

^{xxvi} Excluded respondents indicated there was not payment level high enough to induce acceptance, suggesting an infinite WTA. This exclusion limits the interpretation of the WTA to those homeowners who are willing and able to discuss managed retreat programs. Given the voluntary nature of such programs, this is the most relevant data point when considering program design and costs.

^{xxvii} Sociodemographic questions were more likely to be “undisclosed”, which reduces sample size when including in the assessment.

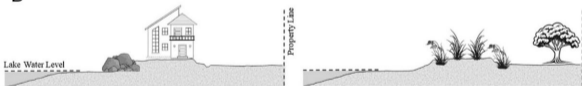
^{xxviii} Using publicly available information, we also explore the effect of the property age. There are only 208 properties with a recorded construction date from 1914 to 2020. Our listed models have no permutations in which property age is a relevant indicator for program interest.

^{xxix} The report is available here: https://hcr.ny.gov/system/files/documents/2023/11/20230921_managed-retreat-paper.pdf

A



B



Panel A: Retreat-and-Relocate

Pre-Policy



Policy Outcomes



Panel B: On-Site Relocation

