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Managed retreat in response to climate hazards

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Managed retreat in response to climate hazards

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What are you doing in my swamp? A case study of a community-led buyout and ecosystem restoration program in Staten Island, NY, from 2012 to 2024

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Introduction

Hurricane Sandy hit the New York City region on October 29th, 2012. Various coastal communities recorded extensive damage, including Oakwood Beach, a small community on the southern coast of Staten Island (McNeil et al., 2015). Under a New York State-led buyout program, funded by a Community Development Block Grant (CDBG) provided by the U.S. Department of Housing and Urban Development (HUD) (2023), the majority of the residents of this community agreed to and advocated for a community relocation (Salles, 2022; Shailer, 2022). The Oakwood Beach Buyout Program is significant, as it is considered to be one of the first in the country to take advantage of a state-led managed retreat buyout program. The ways in which this program was implemented are now considered a critical case study for buyouts across the United States (Spidalieri et al., 2017). Parties that laud the project's success largely attribute it to the high level of community involvement and engagement in the form of a community-led Oakwood Beach Buyout Committee. In total, 180 out of 184 homeowners were approved for this buyout program, and the majority of the community was relocated (Spidalieri et al., 2017).

As a condition of the Oakwood buyouts, parts of the land were intended to be ecologically restored to provide a natural buffer against storm surges and flooding caused by superstorms and hurricanes (Spidalieri et al., 2017; Governor's Office of Storm Recovery, 2023; Kensinger, 2022). However, key terms such as "*natural*" and "*restoration*" are often left too open for policymakers and practitioners to interpret. Significantly, the legislation introduced shortly after the buyouts, such as New York State Assembly Bill A05499A (2015), includes wording that categorizes recreational areas under the broad umbrella of *natural ecosystems*. Consequently, a clear example of the misuse of this phrasing and interpretation is that it currently permits soccer fields, laid with concrete foundations, to be constructed in areas that were originally reserved for natural floodplain functions by the Staten Island Youth Soccer League (Shailer, 2022; Kensinger, 2022). Furthermore, according to documents from a City Planning Commission Review (2017), land originally purchased by the state from residents was eventually sold to New York City, and later sold to unidentified, private entities in 2023 (CountyOffice.org, 2024).

Due to this outcome, views about the program's long-term success have diverged sharply. While both experts and community members view the short-term program as a success, in recent years, Oakwood Beach community members who participated in the Buyout Committee have expressed disappointment at a mixed-use outcome that deprioritizes the true efforts at ecosystem restoration (Spidalieri et al., 2017; Shailer, 2022). Comments from community members include, "I thought they were going to let everything grow. I envisioned swamp," "People could have seen all the nature here; it would have been beautiful," and "I don't see where the success is…" (Shailer, 2022).

The progression of missteps in long-term program implementation in this case study that contributed to many discrepancies in program outcomes raises important questions about how to 1. Define, communicate, and implement the concept of nature-based solutions (NbS) among experts, and 2. Advocate for the prolonged administration, involvement, and accountability of managed retreat programs by experts.

Although the nature of this article primarily reflects the viewpoints of its authors, a literature and document review were required to piece together the program timeline and experience of Oakwood Beach residents. Sources for this article were found on Google Scholar (scholar.google.com) and google.com. Search terms used on Google Scholar included "nature-based solutions", "NbS", "managed retreat", "Oakwood Beach", "Oakwood Beach buyout program". Search terms used on Google.com included "managed retreat", "Oakwood Beach", "Oakwood beach buyout program", "Oakwood Beach nature-based solutions". Public records were accessed through the Automated City Register Information System (ACRIS) at https://www.nyc.gov/site/finance/property/acris.page and County Office Property Records https://www.countyoffice.org/ny-property-records/.

Nature-based solutions

Currently, Nature-based Solutions (NbS) are defined by the Federal Emergency Management Agency (FEMA) as: "...sustainable planning, design, environmental management and engineering practices that weave natural features or processes into the built environment to promote adaptation and resilience" (United States, 2023). This definition is also utilized by HUD when implementing Community Development Block Grants such as the Oakwood Beach Buyout Program (U.S. Department of Housing and Urban Development, 2023).

The FEMA definition would therefore include the aforementioned recreational areas, suggesting that such recreational areas act as effective mitigation against flooding as more biodiverse and efficiently-selected ecosystem restoration measures (United States, 2023). Both recreational areas and ecological areas are encompassed by Community Development Block Grants. The widespread assumption that recreational areas and ecological areas are equivalent in addressing community needs is also reflected in the definition established in the New York State Assembly Bill A05499A in 2015. However, the loose practical definition of NbS raises questions about whether high-maintenance recreational monocultures, such as soccer field turf, should be considered as effective a hazard mitigation strategy as floodplain restoration based on the location provided (Ferreira et al., 2022; Li and Guo, 2024; Lo et al., 2021). NbS must show effective hazard mitigation, but due to a lack of data it is difficult to ascertain whether recreational areas are effective flood mitigation in this case (Lo et al., 2021). Given the diverse array of definitions from academic and governmental sectors, practitioners and communities are likely to come to the conclusion that recreational areas with concrete foundations are considered successful hazard mitigation strategies (Frantzeskaki et al., 2019). The specific location requirements, as a result, may not be considered or analyzed adequately with potential consequences for NbS functionality (Ferreira et al., 2022).

Community-led buyout program

This case study also raises questions about how subject matter experts and policymakers may better communicate nature-based solutions with vulnerable communities and manage the long-term protection of coastlines from more extreme storms. Oakwood Beach residents initially understood and agreed that a more traditional restoration approach would be implemented in their community. However, due to the wording in the established policy, this was not the case.

In September 2017, vacant lots in Oakwood Beach were rezoned to minimize future developments (Spidalieri et al., 2017). Some lots that were not passed to the Staten Island Youth Soccer League were later passed from the state to the city government in 2021 and then sold to unknown entities in 2023 (CountyOffice.org, 2024). A long-term environmental plan for the lots purchased by New York State after Hurricane Sandy has not been located by the authors of this paper.

Case synthesis

There is a major divide between how experts and residents view the outcomes of the Oakwood Beach buyout program in terms of balancing and contrasting program theory and residents' lived experiences. While experts originally lauded this case as a successfully managed retreat, residents currently see it as returning to an unprepared pre-disaster status quo. Due to climate change, future storms are expected to hit New York City more frequently and intensely. The solutions that experts employ and endorse must be led by a community and include nature-based restoration to reduce damage.

The solutions required to protect communities warrant long-term project plans that protect such communities before, during, and after a disaster. Solutions to these types of existing and emerging climatic challenges are difficult; often, the creation and sustainment of NbS does not exist in a vacuum, and projects must fit into the built environment while also enhancing a community landscape using an ecosystem's maximum capabilities. These high expectations for NbS as a panacea, combined with a lack of communication and management, can lead to negative outcomes that can cause further harm to a community and distort understanding of NbS and its use cases (Frantzeskaki et al., 2019; Seddon et al., 2021; International Union for Conservation of Nature (IUCN), 2020).

Key questions for alignment on nbs within communities

Our analysis determined three key objectives that, when addressed, may prevent barriers to NbS implementation similar to those faced by the Oakwood Beach community. These objectives may support a variety of subject matter experts for future project collaboration, management, and implementation of vital NbS practices. From these objectives, a table of guiding questions (Figure 1) was developed. These guiding questions aim to support academics, subject matter experts, practitioners, and policymakers as they help communities navigate a post-disaster landscape. In addition, recommendations are given that may assist various academic, subject matter, policy, and practitioner experts in their long-term goals of protecting communities from future hazards.

The guiding questions for academics, subject matter experts, practitioners, and policymakers in Figure 1 will address the three following objectives:

1. How to identify current gaps in the communication of Nature-based Solutions between technical and non-technical audiences,
2. How to establish a better working definition of Nature-based Solutions in hazard mitigation for use by policymakers and practitioners; specifically, how to define and operationalize "ecosystem function" as a hazard mitigation practice, and
3. How to establish a protocol for longer-term Monitoring and Evaluation (M&E) involvement by practitioners, academics, and subject matter experts in the ecosystem restoration aspects of managed retreat practices, in order to ensure that communication with the community remains at the forefront of the project during its entire lifecycle.

The majority of these questions follow a similar track, focusing on the equitable aspects of involving a community in its long-term restoration. When restoring a community in a post-disaster environment, experts in the field act out of good conscience; however, bad actors or mistakes may severely affect the outcome of a project or potentially harm a community. These questions intend to reduce harm by increasing communication and consideration between experts.

When addressing current gaps in the communication of Nature-based Solutions between technical and non-technical audiences (Objective 1), it is imperative to identify barriers that exist in a community that may be exacerbated by an NbS project. For example, the creation of a park that protects a community against storm surges or wildfires may raise property values for homeowners, yet push lower-income residents out. Not only must communities be involved in decision-making processes and long-term plans, but they must also be given the capacity to continue management and maintenance long after the experts conclude the project (Li and Guo, 2024).

It is difficult to measure how well a functioning ecosystem can mitigate the effects of a hazard or disaster on a community (Buma et al., 2024; Li and Guo, 2024). To expand upon this concept, it is even more challenging to measure how well a functioning ecosystem works when in comparison to a more managed, less diverse ecosystem as no two projects are alike or exist in a vacuum (Li and Guo, 2024). Therefore, when identifying a better working definition of NbS in hazard mitigation for use by non-scientists, Objective 2, a variety of factors must be considered. The term, "Nature-based Solutions" is used in multiple different contexts and has many different meanings depending on the field. However, we suggest that a new definition of Nature-based Solutions across academic, governmental, and policy contexts contain the following parameters:

- Improves community physical health through scientifically sound practices (via hazard mitigation, pollution reduction, and sustainable food and water access) while minimizing harm.
- Can be managed by a community over a long term, and if the community is unable to manage it, then overseen by local, Tribal, or territorial government.
- Contains a portion (>50% of the patch) that is a self-sufficient, healthy, and biodiverse ecosystem with predominantly native species.
- A farm that uses permaculture practices ("biodiverse" farm) may fit these criteria

The continuity of a project through Monitoring and Evaluation (Objective 3) is seemingly the most difficult issue to address. When practitioners, academics, and subject matter experts are involved in the implementation of a multidisciplinary project such as an NbS, continuity is essential, but momentum is limited. Professionals may make mistakes, switch jobs, or retire; companies may be shut down, or governmental departments may be merged or dissolved. It should be at the forefront that teams, not single experts, work with the community on a project. Funding is limited, and projects may prove difficult to balance. Experts must keep in mind that they have the ability to leave a project. A community does not necessarily have this ability.

Discussion

As practical and effective Nature-based Solutions are more incorporated by communities, acknowledging realistic project implementation becomes more and more imperative. Academics, subject matter experts, policymakers, and practitioners must ensure that funding, capacity, and support can be secured for long-term projects. By identifying key communication gaps, standardizing crucial definitions, and establishing long-term protocols, project implementation can be more consistent and streamlined. Managing proper communication and expectations between experts and community members is perhaps one of the most important skills any expert may possess and must be incorporated into best practices. Experts tend to "shoehorn" themselves into one subject. However, with the climate crisis causing increased disaster risk, experts must fill interdisciplinary shoes.

As authors, we acknowledge that these solutions are idyllic but necessary. In a perfect world, the current residents of Oakwood Beach would be living beside effective Nature-based Solutions that provide storm surge protection for the next hurricane season. However, it must be acknowledged that hazard mitigation is a constant game of chasing perfection and balancing tradeoffs. There will never be a "perfect storm" or a "perfect solution", but for the good of the communities that benefit from Nature-based Solutions

Objective 1: Identify current gaps in the communication of Nature-based Solutions between technical and non-technical audiences
Academic
How can we reach and interact with communities that can aid in the communication of NbS projects?
How can we use this project to increase values of belonging and equity?
How do we better collaborate with practitioners to aid in better project outcomes?
What barriers exist that cause issues in communication? (Including differences in education, language barriers, education, access to transportation or Internet, or community mistrust)
Policymaker
How do we best facilitate a community's success through policies?
How do we ensure that loopholes are omitted in policy wording?
What social and natural context is needed to understand this community?
How do we set up policies to ensure that long-term management is upheld?
What barriers exist that cause issues in communication? (Including differences in education, expertise, language, or mode of communication)
Practitioner
How do we advocate for better NbS terminology in the government?
How do we better advocate for NbS within and for a post-disaster community?
How do we educate a community about NbS before a disaster strikes?
What barriers exist that cause issues in communication? (Including differences in education, language barriers, education, access to transportation or Internet, or community mistrust)
What potential harms does the community predict for this process?
How can we support and advocate for a community during a long-term NbS project?
Subject Matter Expert
How can we use this project to increase values of belonging and equity?
How do we better communicate what NbS are to policymakers?
How do we better collaborate with practitioners to aid in better project outcomes?
What barriers exist that cause issues in communication? (Including differences in education or expertise, language, or mode of communication)
Objective 2: Establish a better working definition of nature-based solutions in hazard mitigation for use by policymakers and practitioners
Academic
How do we communicate a novel scientific NbS definition to policymakers and practitioners?
How do we ensure that projects are accessible to and managed by the entire community?
How do we work with communities to communicate more efficient NbS practices?
What practices should we omit or discourage from the 'Nature-based Solutions' phrase and why?
How do we define 'Nature-based Solutions' in the context of hazard mitigation?
Policymaker
How do we ensure our wording is equitable and inclusive?
How do we define nature-based solutions in the context of hazard mitigation?
In what stage of the policy-writing process do we involve academics, subject matter experts, and practitioners?
Practitioner
How do we enhance our knowledge of the theoretical and practical aspects of nature-based solutions?
How do we ensure that we are adequately providing a community with the best possible natural improvements?
Subject Matter Expert
How do we identify the best NbS practices for a whole community?
What setbacks should we foresee that could prevent a community from creating or sustaining NbS?
Objective 3: Establish a protocol for longer-term Monitoring and Evaluation (M&E) in managed retreat
Academic
How do we create and measure an assessment for the longevity of this project?
What is the long-term plan (10+ years) for this project?
What funding is available for a long-term plan?
Policymaker
How do we ensure that loopholes are omitted in policy wording?
What funding is available for a long-term plan?
How do we prepare and discuss how inflation will affect funding?
What laws and policies are in place that can protect nature-based solutions from future re-development?
Practitioner
What is the short-term plan (1-3 years) for this project?
What is the 5-year plan for this project?
What is the long-term plan (10+ years) for this project, including potential long-term practitioner involvement?
What funding is available for a long-term plan?
What strategies do we have in place to ensure long-term community management, financial and otherwise?
How can we work with local politicians to ensure that natural projects are protected from future re-development?
Subject Matter Expert
How do we assess and measure the long-term equitability and inclusion of this project?
What evidence can be shown to practitioners to encourage better outcomes?
How do we collaborate with practitioners, non-profits, and the community to ensure long-term management?
How do we create and measure an assessment for the longevity of this project?

FIGURE 1
Nature-based solutions community alignment checklist. A list of key questions that various parties involved should consider in order to assure better outcomes for a managed retreat program within a community affected by a disaster. An academic is noted as any scientist affiliated with a university; a subject matter expert is noted as any other academic expert not affiliated with a university; a policymaker is noted as any governmental or legislative employee that may write or aid in the creation of policies; a practitioner is noted as any community worker or community-facing official that serves or advocates for the community.

and investments, it is essential to gain alignment and commit to communities' long-term hazard mitigation.

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Senses of justice after managed retreat in New York city

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Sea level rise and increasing frequency and intensity of coastal storms are driving the need for managed retreat and relocation for at risk coastal populations. Managed retreat through voluntary buyouts is typically studied either from the perspective of the buyouts' process or focused on those who leave, but little attention is given to who and what is left behind. How do buyouts impact those staying behind, and their *senses of justice*? We examine this question for the low-lying majority-minority neighborhood of Edgemere, Queens in New York City where Superstorm Sandy buyouts and a long history of failed urban renewal have led to large amounts of vacant land. This study analyzes ongoing and intersectional conditi ons of residents' flood vulnerability. It grounds this analysis in 18 in-depth interviews with local residents capturing their perceptions of vacant land and its reuse, flood risk and neighborhood needs. The analysis is complemented with field observations, semi-structured interviews with city agencies involved in resilience planning initiatives and analysis of historical urban planning and open space plans in this area. Findings reveal the importance of elevating residents' understanding of place to inform possible land uses after retreat in historically disinvested neighborhoods. Furthermore, they reveal both the injustices of and attachments to living in flood prone, disenfranchised coastal neighborhoods. They also show how these experiences entangle with the citywide housing crisis. In conclusion, if retreat and post-buyout efforts aspire to be just, they need to center how past and present contextual injustice shapes the relationships between distributive and recognitional injustice.

KEYWORDS

contextual justice, recognitional justice, distributive justice, managed retreat, property buyout, land restoration, New York city

1 Introduction

With increasing extreme events such as cloudbursts, hurricanes and storm surges, coastal and riverine neighborhoods are at the forefront of the climate emergency. Managed retreat through voluntary buyouts is no longer "America's last-ditch strategy" (Flavelle, 2018) in disaster management, due to the astronomical economic impacts of flooding (NASEM, 2019) rising cost of flood insurance (FEMA, 2023) and the challenge of rebuilding (Atoba et al., 2021). The process of property buyouts is however marred in procedural hurdles, heightening anxiety and opposition to it (Lynn, 2017; Dundon and Abkowitz, 2021; O'Donnell, 1854). Many scholars raise concerns about the equity implications of buyout processes and outcomes (Maly and Ishikawa, 2013; Muñoz and Tate, 2016; Lynn, 2017; Baker C. K. et al., 2018; Siders, 2019; Shi et al., 2022), especially for those who receive a buyout and relocate (Hino et al., 2017; McGhee et al., 2020) but less so for those who stay, exceptions include Koslov (2021) and

Kimbro (2021). Buyouts tend to occur more often in pockets of high social vulnerability and racial diversity within majority-white neighborhoods (Mach et al., 2019) and while some of the conditions under which people decide to retreat are known (Robinson et al., 2018; Seebauer and Winkler, 2020), the historical oppression of black and brown people and its implications for residents perceptions of retreat, land restoration, and group place attachment receives little attention (Phillips et al., 2012; Lieberknecht and Mueller, 2023).

Land in North America's floodplains often remains vacant after retreat (Zavar and Hagelman, 2016) despite government-led buyout programs promising floodplain restoration. Maintenance costs and land use requirements often get in the way of restoration (BenDor et al., 2020). When restoration is considered, this typically happens through the language of ecosystem services, stressing that land in floodplains be restored to its ecological functions (Baker, 2004; Gourevitch et al., 2020; Worley et al., 2023). More recently some scholars argued that buyout processes need to recognize and invest in socio-ecological relationships for residents who either remain or relocate (Dascher et al., 2023; Shi et al., 2023). Only focusing on ecological and hydrological functions neglects the experiences that people have with their surroundings, and how histories of devalued urban black and brown life (Barron, 2017; Pulido, 2017) influence these experiences. Centering these issues within managed retreat processes can reflect a concern for both human and ecological health that may lead to more just retreat and post-buyout land restoration.

Furthermore, staying in place often means being still exposed to flood risk, which is dynamic and uneven (Collins et al., 2018; Herreros-cantis, 2020). Determinants of social vulnerability, such as income, age, and sex, intersect with pre-existing contextual justice (McDermott et al., 2013) relationships of class and racial (dis) advantage, which leads to higher flood vulnerability for black and brown communities (Bautista et al., 2015; Maldonado et al., 2016; Bakkensen and Ma, 2020). For instance, in NYC people living in flood risk zones are older, predominantly renters and of black and brown descent compared to the city average (Dixon, 2013). Pre-existing contextual injustices are the result of institutional actions and policies that over time have systematically undermined the wellbeing and ability to thrive of black and brown communities by reducing opportunities for intergenerational equity (Elliott and Pais, 2006; Chen, 2021). Lesser intergenerational equity can affect the ability to meet rising insurance costs (O'Connor, 2023) and to find a comparable property when accepting a buyout (Greer and Binder Brokkop, 2017).

Here, we advance an intersectional and thick framing of equity in land restoration as an important, but often overlooked process, in managed retreat in already disenfranchised coastal neighborhoods. Empirically investigating the grounded understandings and relationalities of recognitional, distributive and contextual justice, we argue for a historically and racially sensitive approach to climate adaptation broadly and managed retreat in particular. We examine the case study of Edgemere in Queens, New York City, centering everyday black and brown residents' experiences of remaining in place, despite the combined threats of flooding events, floodplain development, and future retreat. This study accounts for the racial ecologies of housing and urban development that continue to shape many urban low-lying coastal neighborhoods in the United States (Hardy et al., 2017; Paganini 2019; Moga, 2020).

Edgemere is a predominantly black and brown neighborhood of the Rockaway Peninsula (Queens, NYC) where decades of neighborhood disinvestment, institutional racism, and failed urban renewal generated large amounts of vacant land and mistrust in government institutions. Racial linked housing practices included redlining and blockbusting (see 6.1). Following Superstorm Sandy in 2012, the city planned and implemented 7 property buyouts, adding more vacant land to the existing (see 3.1), as well as prohibiting and/or limiting new developments on lots within a new established Hazard Mitigation Zone (HMZ). We review how contextual, and distributive equity can aid in understanding disinvested neighborhoods facing managed retreat and characterize the need for focusing on recognitional equity as the expression of *senses of justice* or how residents subjectively perceive, evaluate, and narrate their positions vis-a-vis managed retreat and land restoration in the context of their neighborhood. Then, we provide a background to Edgemere's flood vulnerability and current adaptation programs and methods to elicit residents' perceptions. We address how city agencies justify the production of more housing in Edgemere despite ongoing vulnerability, counterposing this to residents' views of housing and vacant land and examining feelings of misrecognition (disrespect, neighborhood stigma and betrayal) as well as relationships to place and belonging. We illustrate how these feelings are rooted in the material socio-economic harms brought by present and past histories of racial dispossession in the Rockaway Peninsula. Finally, we discuss how a *senses of justice* approach and the relationality that exists between recognitional equity, distributive equity and contextual justice can inform more equitable post-buyout land restoration.

2 Dimensions of justice in the aftermath of managed retreat

In this section we lay out the theoretical embedding of our case study work. While typically justice and equity are used mostly synonymously (Walker et al., 2024), when we use the word equity, we mean it as a principle of justice, a normative criterion for the implementation of justice (Grasso, 2007). We keep the main focus on the processes leading to injustices, their sources of material and symbolic harms and their subjects (see 2.2.2). We begin by introducing contextual justice and its importance in disinvested neighborhoods, subsequently highlighting the equity implications for those who stay in post-buyout neighborhoods and how these lead to issues of recognitional justice. Finally, we propose understanding recognitional justice through the lens of *senses of justice*, to bring forth the way black and brown people understand environmental interventions and broader neighborhood needs.

2.1 Contextual justice

Climate adaptation plans frequently direct post-disaster investments toward "resilient" housing, infrastructure, and public spaces, yet are frequently driven by neoliberal capitalist agendas lacking a nuanced comprehension of the entangled nature of equity, adaptation, and climate vulnerability (Karki, 2021; Camponeschi, 2023). Environmental justice scholarship however insists on the importance of three interacting dimensions of justice in evaluating resilience plans: recognitional justice (the well-being, knowledge and perspectives of affected groups), procedural justice (the meaningful

inclusion of affected groups in decision-making), and distributive justice (the distribution of costs, risk and benefits; Schlosberg, 2002). Because of their interaction, recognition for marginalized groups may be limited or enhanced by the way procedural concerns are negotiated (Harris et al., 2017) while greater participatory equality may enhance chances for equity or distributive justice (Fraser, 1995; Schlosberg, 2003). Few studies actually tease out how these relationships work in practice (Walker, 2023) and how they can be traced to differential valuation of land rooted into ongoing processes of racial dispossession in the US coast (Hardy et al., 2017; Paganini 2019; Lamb, 2020). Rather than treating vulnerability as something attached to individual characteristics, we seek an approach that is attentive to the "historical and multi-causal production of harms" (Ranganathan and Bratman, 2021, p. 132).

In this vein, the 2019 NYC Panel on Climate Change acknowledged that dimensions of justice must be understood within the context of the culture in question and defined contextual equity as the pre-existing socio-economic conditions and the "root causes" of social vulnerability (Foster et al., 2019). In this paper we move the focus to contextual justice as the underlying socio-political processes and urban development patterns shaped by racism, classism, power and privilege, that create zones of neighborhood disadvantage and prosperity (Van Zandt, 2012; Hendricks and Van Zandt, 2021). Examples include policies promoting segregation, redlining, blockbusting, and planned shrinkage (Aalbers, 2014) as well as urban renewal plans of the 1960s and 1970s (Pritchett, 2003) resulting in excess vacant land (Pagano and Bowman, 2000) and built environments in disrepair. To some extent, the segregation of certain populations in urban low-lying areas is the product of patterns of neighborhood investment and disinvestment (Gerken, 2023).

In NYC, almost half of today's urban renewal programs are located in prior redlined areas (Winkler, 2017), and across the US buyouts are more likely to happen in communities that experienced white flight and redlining (Loughran and Elliott, 2022). Targeted buyouts can then be used to invest in historically underserved neighborhoods (Wolch et al., 2014), where relatively poorly maintained housing stock in predominantly black and brown communities frequently qualifies as 'substantially damaged' under FEMA buyout programs (Siders, 2019). In low-income and marginalized neighborhoods, however, residents may have less ability to participate in or push back against buyouts (Lynn, 2017; Schumann et al., 2021) when they are undesired. The option of retreat can be rejected based on deep seated government distrust (Ajibade, 2019) and can be seen as an outright threat to black and brown livelihoods (Doberstein et al., 2020). In some cases, faced with increasing flooding impacts, some people may feel they are being betrayed by agencies that are supposed to protect them and fail to do so (Askland and Bunn, 2018).

2.2 Equity in post-buyout neighborhoods and the importance of recognition

The process of buying out properties can lead to several distributive inequities for those who decide to stay (Kraan et al., 2021). First, the decision to leave a place is almost never a consideration people take lightly, but motivated by fears of living in a disaster zone, including losing insurance or witnessing the dissolution of their community (Baker C. K. et al., 2018; Koslov, 2021). Those who stay, may similarly not do so out of will but rather out of the inability to do otherwise (de Vries and Fraser, 2012; Cardwell, 2021). Moreover, since the property is given priority in the retreat process, what happens to the land once the property is demolished remains entirely in the hands of local governments. Studies investigating land restoration dynamics following retreat are scant, but existing research suggests most land following retreat remains vacant (Zavar and Hagelman, 2016) because maintenance is rarely part of a retreat program. For instance, if a post-buyout land use plan is not made part of flood mitigation management, this can lead to distributional inequities due to suboptimal use of space (Zavar, 2015). People may feel their social environment is deteriorating when parcels are left vacant (Seebauer and Winkler, 2020) because either land regulations require so, or because the social and ecological values of vacant land are not acknowledged by planners (Anderson and Minor, 2017; Atoba et al., 2020). In addition, urban vacant land's association with blight, crime, and illegality can generate neighborhood stigma and negative feelings leading to health impacts (Garvin et al., 2013). Considering how those who stay behind feel about their changing neighborhood and their viewpoints on post-buyout land re-use becomes a crucial recognitional justice issue that deserves attention by adaptation scholars and policy makers alike.

2.2.1 Recognition in climate adaptation

Recognition is a relatively understudied issue in urban climate adaptation and resilience compared to procedural (Hill, 2008; Holland, 2017; Rudge, 2021) and distributional dimensions of justice (Collins et al., 2018; O'Hare and White, 2018; Ashley et al., 2020). More broadly, less than 5% of studies on equity and justice in adaptation do empirical work and even fewer address recognition implicitly or explicitly. Of the articles included in the systematic review (68 out of 1,391) investigated justice or equity empirically (Coggins et al., 2021). This study aims at meeting both the need for more attention to empirical evaluations of recognitional justice but also its relationality to the occurrence overtime of distributive and contextual injustices.

Recognitional justice consists of symbolic elements related to whether individuals or groups are treated with respect (Honneth, 1995) as well as material inequities related to the uneven distribution of risks and benefits (Fraser, 1995). In post-disaster landscapes recognitional justice is often at the mercy of state and non-state agencies who get the liberty "to define the affected community's lifeworld" (Joseph et al., 2021, p. 10) without understanding how risk and recovery are actually embedded into everyday life. Misrecognition in climate adaptation is expressed through "racialized exclusion" from decision making process that focuses on professional and educational affiliations instead of community groups' voices that advance self-determination (Grove et al., 2020). Some climate adaptation literature approaches recognition by assessing plans and strategies to understand whether they include relationships of power, contexts, vulnerabilities, knowledge, narratives (Preston and Carr, 2018; Meerow et al., 2019). Others, empirically show whether and how residents' participation in resilience and adaptation visioning and plans accommodates for difference, while accounting for past injustices influencing current conditions of vulnerability (Grove et al., 2020; Joseph et al., 2021). The term "color blind adaptation" refers to plans and policies proposing one-size-fit-all adaptation or resilience strategies that

ignore certain groups' perspectives, knowledge, and ways of life; and bypass claims of suffering (Haldemann, 2008) and the burden of race-linked housing, planning, and health practices (Maantay, 2002; Paganini 2019; Lamb, 2020). In the interest of seeking a grounded approach to aspects of recognition, researchers should not just represent the interests of marginalized groups but investigate how these are expressed by and within marginalized groups themselves (Svarstad and Benjaminsen, 2020).

2.2.2 Grounding recognition through senses of justice

Svarstad & Benjaminsen coined the term *senses of justice* as the "ways in which affected people subjectively perceive, evaluate and narrate an issue, such as their perspectives on an environmental intervention" (2020:4). *Senses of justice* is a way of putting in the spotlight the lived experiences and knowledge of groups whose framing of normative ideas about justice is overshadowed by those of more resourced and powerful actors (i.e., project funders; Massarella et al., 2020). Moreover, variations within communities in what recognitional justice criteria matter for implementing environmental policies are common. Differences stem from whether recognitional justice is discussed at individual or community level, the type of overseeing institution, and people's different roles and activities (Lecuyer et al., 2018). Overall, these studies underline the need for more nuanced and localized understandings of recognitional justice. *Senses of justice* is empirically evinced through residents' narrations of subjects, harms and processes (Martin et al., 2016). Subjects have to do with who holds moral rights and is deserving of political attention, whether individuals or communities, present or future generations and non-human species. Subjects can also shed light on place attachments or the affective bond between people and places (Manzo and Perkins, 2006), where social relations and nature interact with the meanings, we give to various elements of place to produce everyday experiences of place (Burley et al., 2007). Harms are the kinds of inequities suffered by subjects, and they can be eminently material resulting from distributive inequities, or symbolic, caused by personal injuries to one's self-esteem or a group's identity and culture. Processes are the structural explanations for both distributive and recognitional inequities. This tripartite formulation seems particularly useful to engage with the relationality that exists between recognition (subjects), distributional (material harms) and contextual dimensions (processes) of justice. Here we use *senses of justice* to investigate how neighborhood residents perceive vacant land and how they would like to see it repurposed, as a springboard to discuss broader issues about present, past, and future flood risk and urban development in their neighborhood.

3 Methods

We use an in depth case study approach to study *senses of justice* after managed retreat. In-depth interviews were conducted to understand residents' *senses of justice* after retreat on the one hand, and city officials' perspectives on retreat on the other. The first author spent several months in the neighborhood volunteering for a community garden and a grassroots organization, which allowed for recruiting possible interviewees (see Supplementary materials). Document analysis of contemporary and historical zoning and planning documents provided insight into relevant dynamics. Neighborhood walks and a vacant land survey were used to identify lot conditions.

3.1 Study area

Toward the end of a long subway ride starting in dense and bustling Brooklyn and crossing Jamaica Bay, the Rockaway shoreline appears. As the train arrives at Beach 44th Street, Edgemere's stop, there are no cafés and stores to greet you, but the sea view is still unencumbered by new development. The neighborhood of Edgemere is on the Rockaway peninsula of Queens (Figure 1) and has a population of 8,885 people (ACS, 2015–2019). Edgemere is a diverse and majority-minority low-lying waterfront neighborhood, where 59.4% of the population is African American, 35% is Hispanic, 26% is Caucasian, 2% Asian, and 12% are other races. During Superstorm Sandy (2012), flood depths of over six feet were recorded along the shoreline, while homes and infrastructures were destroyed, leaving thousands without heat, electricity, and/or with water damage leading to mold in their homes (Moore, 2014). The vulnerability of Edgemere's population is nuanced. American Community Services (ACS) estimates for 2015–2019 show that vulnerable categories like elderly living alone (88%), female headed households (70%) and renters (80%) are high here and that there are significant increase in low to moderate income people suffering from rent burden (from 13 to 49%) compared to pre Sandy estimates (2008–2012). There are significant reductions in households living with people with disabilities (from 70 to 50%) as well as in owner occupancy (from 17 to 11%).

Many recovery programs were launched in the area, including the 2015 Resilient Edgemere Community Planning Initiative (RECPI). This multi-agency effort aimed to reduce flood risk, help with disaster recovery and bring infrastructural, housing and retail developments that 19 years of active Urban Renewal Area (URA) had not been able to deliver (see 6.1). The RECPI instituted the Edgemere Resilient Plan Area (see Supplementary materials) that through the Build it Back program channeled funds for property buyouts and acquisitions. The RECPI also introduced several zoning changes aimed at eliminating or limiting housing developments along a hazard mitigation area. For instance, the RECPI designated 119 vacant city-owned lots, which include 7 buyout and acquisition lots, to be managed by a Community Land Trust (CLT) as well as mixed-use housing developments (see 4.1 in this paper and Supplementary materials).

3.2 Qualitative interviews: rationale, recruitment, analysis

Between May 2021 and September 2022, the lead author maintained a continued engagement with the neighborhood of Edgemere by volunteering in two places: one community-based organization (CBO) and one local community garden. The lead author helped the CBO conduct land parcel surveys, lots mapping, and community outreach for land visioning workshops (see last paragraph), in exchange for being able to observe the workshops. The CBO and the garden provided opportunities to meet residents to be interviewed. Focusing on people's accounts of living in their neighborhood, these interviews serve as a process of alternative knowledge production,

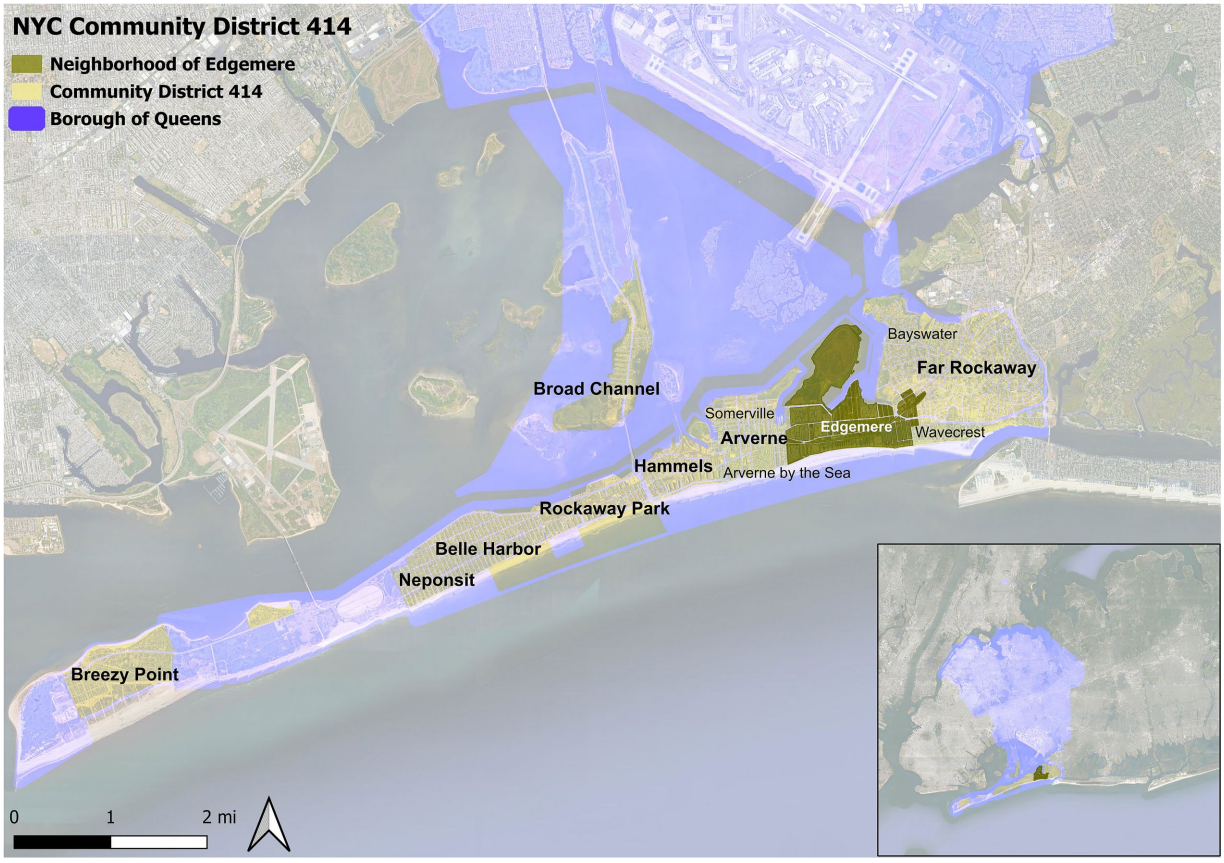


FIGURE 1
Edgemere's location on the Rockaway Peninsula.

which can fulfill affirmative politics of recognition (Barron, 2017). By talking to people about their personal feelings, opinions, and experiences, the interviews elicited past and lived experiences of recovering in the wake of Sandy and elevated people's personal accounts of living with vacant land in a post-buyout and disinvested neighborhood (see Supplementary materials for interview protocol). Interviewees were representative of Queens in terms of their diversity, largely female and in adult age. As is typical of the Rockaways, all interviewees except four came from elsewhere in the city or other states and countries. Most were homeowners and employed at the time of the interview (Table 1). The 18 in-depth interviews were recorded and transcribed using a combination of AI powered software and manual corrections in MaxQDA. Keeping anonymity in mind, all interviewees' names were changed to fictional names. Subsequently, we use a modified iterative four stage approach for coding analysis inspired by Lecuyer et al. (2018) who studied feelings of justice in conservation management (see Supplementary materials).

Furthermore, four semi-structured interviews with staff from the NY Housing Preservation and Development (HPD) (3) and the Mayor's Office of Resilience (MOR) (1) were key to understanding perspectives on urban development, climate adaptation, and retreat in Edgemere and New York City. Finally, in 2023 an analysis of all the online publicly available documents was conducted, describing the zoning changes and urban development project documents in Edgemere since 1997, the date of the Urban Renewal Area was established. It utilized search engines as well as specific searches on official NYC portals (Table 2).

Between November 2021 and March 2022 three community visioning workshops were held in Edgemere as a first step toward a resident-led definition of possible land restoration actions (see Olivotto, 2024). Residents interviewed for this study offered insights that were mostly aligned with the outcomes of the workshops and added a more nuanced understanding of the importance of engaging residents living adjacent or in front of a vacant lot.

4 The present and future of Edgemere's vacant land

In the following we illustrate city plans for building new housing on existing vacant land in Edgemere and reflect on its implications for flood risk and affordability for current residents. We contrast this with the position of some residents and community board vis-a-vis the developments, accompanied by our observations of the status of buyout lots and related residents' perceptions and wishes for vacant land use.

4.1 Fighting the housing crisis, building out the floodplain

City and federal authorities used "*a novel kind of angle*" (MOR, Pos. 42) to deal with the simultaneous challenges of coastal flood risk, neighborhood disinvestment, and housing shortage in Edgemere. From

TABLE 1 Descriptive statistics of Edgemere interviewees.

Ethnicity	Gender	Age range	Years lived in Edgemere (average)	Last place lived before Edgemere	Housing occupancy status	Job status
7 (African American)	11\u00B0F	2 (65–74)	19	2 (Bedstuy, Brooklyn)	14 Owners/ 4 Renters	14 (employed)
1 (mixed: African American/Hispanic)	7 M	6 (55–64)		1 (Crown Heights, Brooklyn)		3 (retired)
1 (African)		4 (45–54)		2 (The Bronx)		1 (unemployed)
5 (Hispanic)		3 (35–44)		2 (St. Albans, Queens)		
3 (Carribean)		3 (25–34)		4 (Far Rockaway)		
1 (mixed: Caucasian/ Hispanic)				1 (Coney Island, Brooklyn)		
				1 (South Carolina)		
				2 (from Edgemere)		
				1 (from Edgemere but lives elsewhere in Rockaway)		
				1 (from Edgemere but lives upstate)		
				1 (Trinidad, The Carribean)		

TABLE 2 Criteria for urban development policies analysis.

Zoning and urban development documents in Edgemere (since 1997)	
Inclusion Criteria	Exclusion Criteria
• Available to the public • Have a listed author - Author can be an individual or the name of the publication or organization • Be specific to HPD land acquisition program facilitation of flood buyouts in the case community or the land acquisition program, more broadly • Can include but is not limited to policy documents, program evaluations, funding agreements, public communications, online press articles, etc. • Documents published in or after 1997 or later (after Superstorm Sandy)	• Drafts of a document • Email exchanges • Documents published prior to 1997

their perspective, the RECPI provides a long-term land use strategy that aims to freeze development on city-owned land in areas beyond FEMA's line of wave action, while allowing for waterfront recreational activities and areas of limited development. Amid a citywide housing crisis fueled by a combination of opposition to and restriction of affordable housing construction (Morris, 2021), the RECPI recognizes Rockaway and Edgemere as "*the last bastions of affordable home ownership opportunities*" as a member of the Mayor's Office of Resilience put it (MOR, Pos. 69). This other quote by a former Housing Preservation and Development (HPD) officer summarizes the dilemma:

> *"There are parts of New York City that get tidal flooding. There's a little bit of it in Edgemere, but [elsewhere], it's truly a daily problem. You shouldn't be building a new multifamily building in Broad Channel. But that's a different question than what to do with tidal flood risk that's not starting in 2030 but coming sooner. How do you manage that disruption and that preparation? How do you create an out valve, so there's housing somewhere else. Right now, there's no housing anywhere. So like, you can't disassociate those things. If you say, we're not gonna do anything in the Rockaways, we're not going to build housing. Well, that was not serving anyone there. Like no one was happy with that solution. That disinvestment begets further racism and disinvestment."* (Former HPD Officer, Pos. 68).

That one of the most low-lying areas in New York City, should be touted as the last remaining place for affordable housing is astounding and points to the ongoing double jeopardy—the double threat of gentrification and flood risk—occurring in many New York City coastline neighborhoods (Herreros-cantis, 2020). The former officer explained that building high rises here would be a way to improve building quality and provide Edgemere's predominantly renter population living in one-and-two story homes, the option to live in an elevated building where water damage will not affect their apartments. But when fully built, the REPCI will bring 1,201 residential units (approximately 38% as affordable housing) and almost 150,000 square feet of retail space, and as many as 549 new parking spaces (City of New York, 2020). This plan stoked fears of gentrification among residents and was voted against by the local community board (see 4.2).

Much of the housing slated to be built under the REPCI is not affordable either. Figure 2 below shows all the residential units currently under construction as part of the RECPI as well as the

Arverne East development. It is hard to get precise rates of affordable housing in relation to Area Median Income (AMI), but the largest developments should range between 30 and 130% of AMI (REW, 2019). At this rate many of Edgemere's extremely low-income renters (earning $33,625 for a family of three, ACS, 2015–2019) will not be able to afford the new developments. The only truly affordable option may be the CLT, which lawyers, activists and a few renters strongly advocated for during the formulation of the RECPI in 2015.

In the eyes of municipal officers, the construction of all this new housing in Edgemere is seemingly justified by the extent of its vacant land, itself a product of municipal disinvestment and housing foreclosure (see 6.1). According to NYC's database MapPluto, the census tracts corresponding with Edgemere have the highest amount of vacant land in the Rockaway peninsula, 391 vacant parcels (Table 3). When this number is turned into square feet, 16% of Edgemere is occupied by vacant land (compared to a NYC average of 8%).

4.2 Residents' views of housing and vacant land development

The municipal view of the future development of Edgemere is contrasted with the concerns voiced by residents through the local Community Board 14 as well as the actual desires for vacant land and larger neighborhood needs. In June 2022, the Community Board 14 presented a unanimous resolution imposing its rationale for a moratorium on all upzoning requests until an environmental impact study addresses concerns that new developments are not aligned with existing services and low density neighborhood character (Schwach, 2022b). While some residents questioned adding more housing to the floodplain "*if the threat of flooding is real, why are you bringing more people to live here*" (Ana, Pos. 34), others also questioned the need for commercial space that does not serve the community. As Sara put it:

> *"When you have commercial space attached to a mixed use development the owner/landlord dictates what retail is going to come in, rather than thinking about the entire zip code. It's easier to rent out spaces with no residents, because if there were already residents, they'd be "well I don't want an Indian restaurant under my house". I agree with the Community Board motion. [..] The thrift way and supermarket that was there are not coming back and these are the things we need."* (Sarah (part III), Pos. 12).

Sarah who was born in Edgemere, saw what the mixed-use housing development on neighboring Arverne East brought to the area, mainly commercial eateries that satisfy the surfer community in the Rockaway Peninsula and not the working class. Existing need for a proper number of school seats, transportation options, emergency routes, parking spots and medical service on the peninsula are compounded by the state of vacant land.

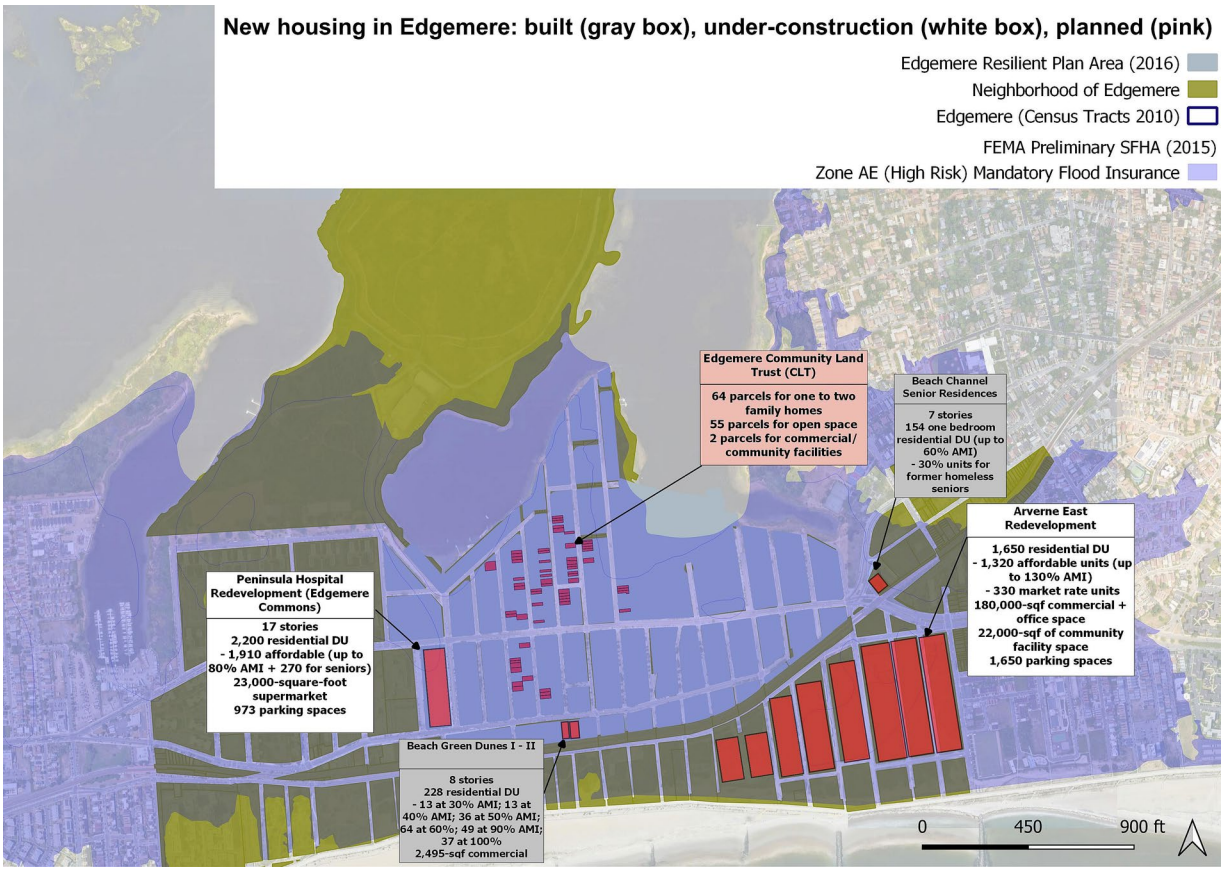


FIGURE 2
Current and future housing developments in Edgemere.

TABLE 3 Vacant parcel lots in the rockaway peninsula (by neighborhood).

Vacant parcel lots in the rockaway peninsula (by neighborhood)	Neighborhood	N vacant lots (MapPluto, 2021)
992/972.04/972.03/972.02	Edgemere	391
1010.02/1010.02/1032.01/1032.02/1008.01/1008.02/998.01/998.02	Far Rockaway/Wavecrest/Bayswater	374
1072.01	Broad Channel	207
964/954	Arverne/Arverne by the Sea/Somerville	170
942.02/942.03/942.01	Hammels	87
934.02/934.01/928	Belle Harbor	38
938	Rockaway Park/Seaside	35
918/916.01/916.02	Breezy Point/ Roxbury	12
Total in Community District 414*		1,314

*MapPluto's land use column contains 56 blank cells therefore the total vacant land is approximate.

Vacant land surveys done on foot in July 2021 showed a patchwork of vacant land conditions. Some lots have been encroached upon by adjacent residents and used as parking spots (L7 Figure 3) or garden extensions; others have overgrown vegetation (L707-79 in Figure 3); yet others are fenced with a "no trespassing" sign from HPD, who owns most of the vacant land in Edgemere. To date, as per NYC's tax lot database, 4 buyouts and 3 acquisitions were completed in Edgemere and they are all still vacant (L59, L94, L92, L14, L42, L37, L34 in Figure 2). As of September 2022, 6 of the 7 buyout and acquisition lots are property of HPD and are fenced off. Two have still undemolished structures on them, some with vegetation but mowed, and one is unfenced and bushy. One more, at the tip of the bay, is asphalted and its ownership transferred to the Department of Parks and Recreation in June 2022.

Most interviewees who mentioned their concerns for vacant land surrounding their homes felt it was neglected (9/18) or expressed feelings of unsafety (3/18). Among residents who perceived neglect the majority had concerns about infestation by city rodents or poison ivy (9/9), while others had concerns about uncollected trash (3/9) and tall grasses and bushes (2/9). The only positive perceptions of vacant land came from two interviewees who recollected their childhoods in Edgemere. Alvin recalled how there "*was always something to explore, whether it was out in the Bay Area or the beach area or, you know, the open land itself made for wonderful opportunities to become playing fields*" (Alvin, Pos. 54). Three interviewees manifested the need for an option to purchase the vacant lot next door with the intention to use it as a vegetable or ornamental garden or simply to have direct control over how often it is mowed. They cited concerns about nuisance and noise should these lots be repurposed for residential or open public space. Vacant land purchasing programs tend to significantly improve the condition and care of lots (Santo et al., 2016; Gobster et al., 2020) but purchasing options are only created if an institution such as a City Land Bank is established to acquire, catalog, and transfer title deeds.

The majority of residents (10/18) expressed the desire for recreational land uses. For instance, mentioning children compatible uses (such as playgrounds) but also a place to store kayaks and fishing infrastructure. These desires are in line with the contextual observation and anecdotal evidence collected while walking the streets of Edgemere. For instance, it is not unusual to see make-shift basketball scores equipment next to curbsides, as well as for parents turning their backyards into spaces for their kids and their neighbors' kids to play safely. This underscores a need that is not met by public infrastructure. Along with the rest of Rockaway, Edgemere is known for its fishing scene, especially for striped bass. Local resident fishermen as well as fishermen coming from other parts of Rockaway and NYC, frequent Edgemere's north shoreline. Yet there's no equipment to facilitate this activity, such as benches or wood canopies to provide shade. This microcosm of concerns and wishes for vacant land underlies some of the material neglect that this neighborhood has been subjected to for at least two decades and should be framed within a broader set of feelings of misrecognition that fuel institutional distrust.

5 Feelings of misrecognition: recognitional justice as senses of justice

Recognitional injustices in Edgemere manifest through feelings of misrecognition, specifically the feeling of being disrespected as a community (mentioned by 7/18 interviewees), through outsiders' perceptions of their neighborhood (mentioned by 6/18), and as betrayal by government authorities (mentioned by 4/18).

5.1 Group disrespect

Residents mentioned the feeling of community disrespect in relation to perceived differential treatment by institutions on several development decisions relating to the city's housing crisis as well as human/nature conflict in ecological preservation. A telling example of the experience of group disrespect is captured by the issue around La Quinta hotel on Beach 44th street. Only 1 year after the hotel's opening in 2016, the Department of Homeless Services (DHS) informed locals that half the rooms would be used to house homeless women with children who are victims of domestic abuse; despite the De Blasio administration's expressed ambition to scale back on the use of commercial hotels for such purposes. A mere 5 years later, the hotel was to transition once more into an all men shelter hosting former prison inmates. Anticipation of these kinds of changes made residents protest the

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FIGURE 3
Edgemere vacant and post-buyout lots.

proposed hotel construction already back in 2012 (Shain, 2020). These forced changes were seen as a sign of disrespect rooted in systemic racism. As Lorraine put it:

> "*This city is so disrespectful to minority communities. It's unbelievable. I mean, again, I do not want to portray these men as the boogeyman, but we also have a right to be safe. We also have a*

> *right to know who's in our community, especially coming through the shelter system.*" (Lorraine, Pos. 43).

While residents understand the necessary function that this hotel now performs for New York City, they are angered by the surreptitious way in which these decisions were made: "*Our community board district manager got an email from a Department of Homeless Services person, she sent the email from her iPhone! Her iPhone! No community meetings, no public meetings, no regards to us as a community.*" (Lorraine, Pos. 43) Unlike other types of locally unwanted land uses (LULUs; Popper, 1983) such as mental health hospitals, hotel rooms turned to shelters maintain a certain façade of being good for the community while bringing the same assumptions of nuisance and negative externalities.

Residents believe their community of Edgemere, and more broadly Eastern Rockaway, is disproportionately targeted as a place to host homeless shelters, because it is predominantly a community of color. This ties into feelings of being treated differently from the Western portion of the peninsula. As Lorraine voiced: "*you would have never done that to the West and you would never done that to Rockaway Park, Belle Harbor, Breezy Point, Howard Beach. They would have never detected the disrespect that they have shown this community.*" (Lorraine 17, Pos. 47). The heaviest burden of sheltering the homeless normally falls on neighborhoods that are predominantly black and brown and with high rates of poverty, and the Rockaway Peninsula is no exception to this (Smith and Bhat, 2022).

Community level disrespect is also experienced by homeowners who perceive their neighborhood is disproportionately a target for lower-income people depending on Housing Choice Vouchers (HCV) such as CityFHEPS, a rental assistance supplement program, associated with documented challenges (Tegeler, 2020). Landlord discrimination against accommodating HCV families in well-off neighborhoods is widespread (Cunningham, 2018) leading to economic and racial segregation in poorer areas like Edgemere and fueling neighborhood divisions (Graham et al., 2016). As Alvin explained:

> "*But one of the benefits of CityFHEPS for a lot of folks is that if you have a vacant home and if it passes CityFHEPS inspection, you could actually get four months advance payment of rent. So, you know, it's $11,000 that the city pays you upfront to get the home. So, you are getting paid that much more in advance. One of the benefits for a lot of slumlords is anytime they have a new family through CityFHEPS, you are getting that money coming in. And if they leave in a year, it does not matter. You put in for more CityFHEPS, you get new tenants. That's an additional bonus.*" (Alvin, Pos. 210).

There are also perceived ecological injustices in Edgemere. Two meaningful examples are the interrupted access to Edgemere's closest beach point from mid-May to August to safeguard the piping plovers nesting grounds and the fight over including evening lighting in a newly built 35-acre nature preserve. The Edgemere Community Civic Action (ECCA), a coalition of homeowners, led a petition in 2022 to reinstate access to the beach, calling it a form of environmental racism and of community neglect (Schwach, 2022a). ECCA also fought the real estate developer's decision to exclude lighting from the preserve, addressing it as an issue of wildlife versus human wellbeing issue:

> "[.] *is that fair to the people that live in this community? [..] What is more valuable? The lives of humans so that they can have adequate recreation.. because that nature preserve.. Yes, it is to protect bird life but what about human life? The community of Arverne and Edgemere is predominately people of color who are suffering from hypertension, diabetes, heart disease. What's the problem of having bike trails and trails for people to be able to take that evening walk? How much inconvenience would that be for people to come in and say, you know what, we can make this more people friendly and maybe their lifestyles will change. Maybe they'd be more inclined to get out and exercise.*" (Lorraine, Pos. 61).

Eventually lighting was added but only along one path cutting across the preserve leaving much of it in the dark after sunset (Dunning, 2022). The nature preserve, like the conservation area for piping plovers, emphasizes white ideals of nature, such as vegetation and non-provisioning green spaces that do not include recreational spaces valued by black and brown communities and cultures (Mullenbach et al., 2022). Preserving wildlife and ecological features without meaningfully addressing decades of injustices will only amount to more injustice in the minds of those who are oppressed.

5.2 Neighborhood reputation

Residents mentioned the issue of neighborhood reputation as a matter of recognitional justice, referring to three geographical layers of "bad" reputation: how neighbors from Long Island perceive Queens, how outsiders perceive Rockaway's past, and how other residents of the Rockaway peninsula perceive Edgemere.

Darren, who attended community board meetings in Long Island said referring to how the members would react to a developer's proposal to increase density "*and without fail before that meeting ends, somebody is going to say, we do not want our community to become like Queens. That's a code word for a lot of things. You do not want to become like Queens, you know, that's code word for density, that's code word for traffic, that's code word for diversity, that's code word for public housing, poverty. Every fear that drove people out to Long Island in the first place.*" [Darren (part II), Pos. 136–138].

Darren also referred to Rockaway's boom and bust history, when around the 1950s the summer bungalows and hotels for white middle-class New Yorkers were repurposed for migrants from the South and for low-income residents who were evicted from Manhattan by Moses's slum clearance programs:

> "*You know, once it stopped being a vacation spot, it became a place where people did not want to move to. I remember in the nineties when I came to the U.S., the Rockaways had a terrible reputation. It was a place where people would get carjacked, it was poor, the robberies. So, people did not want to move here. And then over time a lot of immigrants settled in the United States, and wanted to purchase a house, Rockaway really became the only place where you could afford to buy a house.*" [Darren 12 (part I), Pos. 47].

Neighborhood reputation, following (Otero et al., 2022, p. 22) can work "as a collective imaginary leading to a socially constructed stratification" influenced by the general perceptions held by outsiders to the neighborhood, peninsula and borough. Negative geographical reputation is a spatial inequality outcome of cultural inequalities, which can lead to very tangible loss of social opportunities (e.g., jobs) for less favored groups (Massey, 1990).

5.3 Betrayal

Unfulfilled promises over the span of several decades manifest in feelings of betrayal. These feelings are directed toward city authorities, in particular Housing Preservation and Development (HPD), the Department of Education (DOE), and the Department of Transportation (DOT). Following the first Edgemere Urban Renewal in 1997 and its amendments, which created homeownership opportunities for low-to middle-income families, these city agencies failed to bring services and infrastructure to the neighborhood (see 6.1). As Lorraine put it:

> *"And I get angry because I feel that if we bought our homes under a bait and switch, there was no support, infrastructure for the homeowner. They brought in moderate and middle income families where there was nothing. No new schools, no recreation centers, no shops. Even though this is what was promised to us. And the most disheartening thing that really bothers me, [..] when they did the reconstruction of the boardwalk, a $5.5 million dollar reconstruction [..] for the two miles where Edgemere lies, from Beach 32nd Street to Beach 59th Street, not one single thing came into the community. No bathrooms, no recreational activities, no concession stands. $126 million was left over from the reconstruction of the boardwalk, and they didn't see fit to put anything in."* (Lorraine, Pos. 17)

The bait and switch that Lorraine refers to are incentives that different real estate developers offered to teachers, nurses, and doctors to come live in the Rockaways. Half of our interviewees came from other neighborhoods of Queens, from the Bronx, and from Brooklyn because they could not find affordable homeownership opportunities that satisfied their needs. In Edgemere they found DOE signs advertising new schools, new parking spots under the A line, and new commercial opportunities. But none of it has materialized over the past 19 years, which is the average time my interviewees lived in Edgemere. What they found was less congested streets, less density, and homes with front yards and proximity to the sea.

Furthermore, Lorraine does not just voice disappointment at what was promised in the urban renewal area plan but also how little visible improvement occurred since the millions of dollars that poured into the Rockaway following Superstorm Sandy were spent in this neighborhood. Of the $120 million in FEMA funding left after the boardwalk reconstruction, the NYC Parks Department put out a call for spending preferences among nine projects initially conceived under the Rockaway Parks Conceptual Plan. Seven projects were approved and matched by $25 million from Queens Borough's public and private entities: one project included in the RECPI, allocated $14 million to raise Edgemere's bay shoreline and Rockaway Community Park (Rose, 2017) and another financed a new playground (The Wave, 2023). But only the latter was completed in 2020.

5.4 Subjects of recognitional justice and place attachments

A theme emerging from the interviews was how despite being neglected, Edgemere is a place where people enjoy living. Interviewees mentioned community strength resulting in mutual care, activism, and volunteerism. Although more strongly perceived in the months following Superstorm Sandy, some of the connections made through mutual care groups that sprang up then, are a source of encouragement to be an active community member still today. For instance, Ana said:

> "*Before the hurricane I was trying to be involved in different organizations but after the hurricane I stopped going to meetings and caring. My neighbor started a Civic Association for homeowners at that time, she really helped me during the hurricane and sometimes when we get discouraged today, we encourage each other to be more involved.*" (Ana, Pos. 11).

Community gardening at local urban gardens such as the Garden by the Bay and Edgemere Farm, was also mentioned as a space for both individual and collective healing for African American and Latinx women as well as intergenerational and intercultural learning about caring and cooking with different vegetables. The Garden by the Bay is a community garden led by Lorraine and Mercedes founded by a group of black and brown women in 2013 with the help of the community land access advocacy organization 596 Acres. Today the garden is a place where mostly women and increasingly their children come to learn about practical gardening skills, seeds, harvest and eat together, celebrate festivities, tell personal stories and to discuss what's happening in the neighborhood. Interactions with Edgemere's open spaces stimulated many positive feelings, especially proximity to the bay's water and its recreational opportunities, such as fishing, crabbing and sports like jet skiing, as well as the sight and sound of water. Access to two parks to the East (Bayswater Park) and West (Rockaway Community Park) of the neighborhood was mentioned less, probably because either park is further than a 10 min walk from Edgemere's central streets and accessibility to one of them (Bayswater Park) was only improved in 2020.

Renters' voices are not adequately represented in this study, but one of them mentioned something crucial for the future of managed retreat policy in this neighborhood. Elizabeth lives in a small apartment with two children and her husband and has been relying on rental assistance to get by. She recognized her ancestors who suffered from generational trauma and for whom the weight of generational homelessness is a daily fight and her goal of homeownership is to honor her grandmother who fought to get into a NYCHA apartment. The trauma of generational homelessness was also paired with the need for affordable housing that can be handed down to their kids for wealth building. Studies suggest that especially among black and brown people, buying a home represents a marker of their success and achievement (McCabe, 2018) because it addresses the issue of equalizing homeownership and reducing the racial wealth gap (Baker J., 2018). But in a community of renters with a history of disinvestment generating recognitional inequities like Edgemere, homeownership may be interpreted more as a sign of stable tenure and belonging in the context of anti-blackness and brownness and racial capitalism (Woods, 2002; Pulido and De Lara, 2018).

For this reason, when achieved, homeownership becomes a source of place attachment (Oh, 2004). Place attachment is an affective bond between people and places (Manzo and Perkins, 2006) where social relations and nature interact with the meanings we give to various elements of place to produce everyday experiences of place (Burley et al., 2007). Dawn and Randall, who own a waterfront property, said they'd never give up the privacy of their water-facing patio, and that they felt particularly connected to the views and the fresh air. They migrated from the Caribbean islands and found in Edgemere's bay a place that reminded them of home. Others took pride in having a yard where they could garden or host friends and neighbors' children. Ten out of eighteen interviewees moved to Edgemere around 2007, and this created a feeling of belonging around first time homeownership. As Mercedes said:

> "*We were all coming together because this was our first time owning a home, and we shared phone numbers. Whoever had a cookout, a party, we got invited. So, this felt, you know, like a real community.*" (Mercedes, Pos. 43).

Although homeowners are a minority in Edgemere, their voices speak the loudest. The Edgemere Community Civic Action (ECCA) consistently lobbies with the city council about several of the environmental, flooding and services inequities. ECCA is a crucial counterpoint to a history of organizations, like the Rockaway Council of Civic Associations and the Rockaway Chamber of Commerce, that back in the 1960s predominantly represented the interests of white homeowners organizations, advocating for market-rate housing (Kaplan and Kaplan, 2003).

6 Contextual justice: the processes and material harms underlying recognitional justice

Feelings of misrecognition presented in section 5 are the result of material harms that can be contextualized within the history of Edgemere's urban planning and broader forces shaping housing production in Rockaway and NYC. These processes represent structural explanations for distributional and recognitional harms.

6.1 Urban disinvestment: failed urban renewal and unfulfilled promises

Edgemere's history cannot be disentangled from that of human intervention and control over streams, inlets, sands, currents, sediments and fauna of the Rockaways. Several development processes made Edgemere ultimately vulnerable to flooding: indigenous land expropriation (The Rockaway Review, 1948), land filling of surrounding marshlands due to a booming real estate market (Dawson, 2017), hosting the largest city landfill (1938–1981) now a superfund site, and delayed extension of the sewer and drainage system and road pavement. Despite investments in sewer and drainage infrastructure in 1997 and 2019, Edgemere still suffers from blue sky flooding today. These floods occur around old creeks that were built over, but still contribute to high groundwater and ponding in this area. This history of ecological overhaul and environmental degradation is important to consider in parallel with uneven disinvestment and disenfranchisement of Rockaway rooted in racial linked housing and planning discrimination.

Following WWII, a wave of migration to NYC put pressure on the housing supply across the city. In the 1950s, the City Planning Commission (CPC) approved a Master Plan identifying new areas for slum clearance and redevelopment, the latter especially low-rent housing in Rockaway, which had plenty of vacant and cheap land. Meanwhile, in the late 1930s exclusionary housing policies, such as redlining, enacted by the Federal Housing Administration (FHA) had assigned a C (or: hazardous conditions) to most of the east side of the Rockaway Peninsula. Black and brown people had to pay higher mortgage rates for homes in Rockaway and had difficulties (re) financing them (Taylor, 2019). These same banks received local deposits and invested them outside of the community, draining its economic base. In NYC, redlining was accompanied by practices, like blockbusting, which led to homeowners being harassed by brokers' phone calls asking to sell in East Rockaway (Kaplan and Kaplan, 2003).

Initially, the Department of Welfare repurposed Rockaway's beach bungalows to accommodate displaced populations (Callahan, 2010). Soon after, areas like Edgemere became targets of slum clearance, but instead of being relocated within Rockaway, residents were only offered the option of moving to other boroughs. In 1961, the city constructed the first and largest public housing complex in Rockaway. Meanwhile on the West side of the peninsula, organized in civic and commercial associations, local white people did whatever was in their power to evict "undesirable" tenants of color and to prevent any public housing projects or public open space projects that would disrupt their white enclaves (Kaplan and Kaplan, 2003).

Between 1963 and 1974, NYS Urban Development Corporation built a total of 1,300 units of affordable housing between Edgemere and other neighborhoods of East Rockaway. During the 1960s, public housing became increasingly exclusively available for families on welfare programs. The most difficult family cases from Manhattan and other Boroughs were sent to the Eastern portion of the Rockaway, where city housing agencies failed to make provisions for necessary supporting services.

At the same time, a series of court rulings gave New York City extensive eminent domain powers and authority over what land could be condemned to advance urban renewal plans (Soomro, 2019). When the Edgemere Urban Renewal Area plan was adopted in 1997, several housing and commercial uses were added. HPD acquired 89 parcels, only a small fraction of those not already owned by the city, but only built 200 out of 800 housing units and delivered none of the 100,000 sq. ft. of retail space (CPC, 1997). The 2007 mortgage foreclosure crisis brought the renewal plan to a standstill leading to more abandoned homes, with East Rockaway experiencing double the NYC rate of foreclosure in 2011 (FRB, 2011). Many 1997 amendments never materialized in actual homes or commercial spaces created yet kept resurfacing in subsequent amendments.

Interviewees who moved into the neighborhood around 2007 remember signs of abandonment and decay in the form of "*dirt roads*" and "*zombie houses*" on their block – an informal term for boarded up abandoned homes. Ultimately, individual citizens and community groups typically do not have the resources to be watchdog organizations that can keep track and attempt to hold the city and developers accountable for broken promises. Urban renewal projects last decades, and politicians who negotiated these agreements leave

office by the time the planned development is complete (Schiller and Thill, 2023).

6.2 Present harms and race-linked housing and planning practices

Disinvestment in some of the eastern portions of Rockaway continues today. Interviewees highlighted three main areas of concern: access to services, abandonment and decay, and diminished neighborhood economy. In terms of services, half of the interviewees mentioned how hard it is to get urgent care, including maternal care and trauma care in the area, since the Peninsula Hospital shut down in 2011 due to bankruptcy. Since its closure residents have had to rely on expensive private hospitals or clinics or travel farther away. According to Sarah, who rallied to bring back the Peninsula Hospital, "*nobody wanted to step in to save it*" when it ran out of money.

Other residents mentioned the paucity of transportation options to reach other boroughs and neighborhoods. The A train is the only subway line, and while two buses were introduced in 2017, they mostly run on major roads. The situation is a long-standing concern in Edgemere, as well as other transit deserts (Jiao and Dillivan, 2013) in Rockaway (The Wave, 2020) especially for elderly and disabled people living far from the subway.

Easy access to healthy food options is another major concern, frequently understood as having fruits and vegetables available within walking distance (Rahkovsky and Snyder, 2015). The only large supermarket is however two subway stops away from Edgemere and there are no other grocery stores for fresh produce in the vicinity. In the Rockaways, only 34% of residents live within a 5 min walk to fresh produce compared to 49% citywide (New York City Food Policy Center, 2017).

A few interviewees connected disinvestment in their neighborhood with the visible lack of commercial spending opportunities, youth employment, and banking services. For instance, Lorraine noted:"*I have to shop outside of my community. My neighbors have to shop outside of our community, our dollars do not mature in our community. We do not have an economic base in our community because all of our money goes out to support other communities* […]. *So we are taking our disposable income, our discretionary income out of this community. And it's not being put back into our community. So apathy exists among residents, whether you are a homeowner or you are a tenant living in public housing or living in a private home, your dollars are not coming back to your community.*" (Lorraine, Pos. 41). Indeed, Edgemere has very little local multiplier effect (CDC, 2014) which worsened when many businesses shut down in the aftermath of Sandy.

6.3 Immediate post-Sandy recovery harms

Within immediate post-Sandy recovery, half of interviewed residents brought to the fore the nuisance caused by city sponsored programs like Build-it-Back (BiB) and Rapid Repair (RR). None of the interviewees elevated their homes, mostly because when the property is attached, this means agreeing with their neighbor to do so, and agreement wasn't reached. The general feeling was that, at best, the RR program and the elevation programs were not serving residents' needs, and at worst, scams occurred. The RR program assisted residential owners with emergency repairs to their private properties to alleviate emergency conditions and allow them to return to their properties. Residents spoke out about how shoddy and slow the work was and that there were "*antagonistic relationships*" with the workers hired by the program and the contractors, who seemed to be cutting costs whenever possible to the detriment of quality repairs. Some residents ended up getting their own electricians or continuing the work by themselves, incurring extra costs.

These episodes are backed by a 2017 report by the NYC Department of Investigation confirming that contractors overstated the quantities of items being installed in homes, including electrical wiring and additional problems with reimbursement from damage assessments, saving millions of dollars. The document cites "poor oversight of the approval process" and "poor procedures in place by contractors to calculate construction items installed in homes" (Struzzi and Urso, 2015, p. 3).

Flood insurance coverage was another source of immediate post-storm harm for 25% of the interviewees. Indeed, there is evidence that even homeowners, like Mercedes, who had flood insurance prior to Sandy, did not receive enough payment to rebuild without taking on debt and having to use their own savings. Other studies confirmed this occurrence in other parts of Rockaway and Staten Island (Madajewicz, 2020; Koslov, 2021). Also, as risk heightened following the storm, Mercedes and Christine were dropped by their flood insurance provider and had to organize a class action lawsuit and find a new insurer. Furthermore, in order to minimize the risk of homeowners walking away after cashing a flood insurance payout, FEMA set up a system of phased payments with the guarantee of issuing another after receiving receipts for how the money was spent on the first check issued. But homeowners like Melanie, who regularly paid for flood insurance and had no intention of cashing and leaving, were upset by the time-consuming burden of this bureaucratic measure.

6.4 The threat of present and future flooding and perceptions of managed retreat

The threat of present and future flooding was mentioned by 75% of the interviewees but the degree to which flooding is perceived as a threat is very nuanced. Two respondents felt they had no control over it; one thought it wasn't a responsibility for homeowners but rather for city agencies; others said future flooding was a concern but that another storm of such magnitude was unlikely to occur again. All the above responses recall fatalism, denialism and wishful thinking and are considered non-protective responses to perceived risk in flood mitigation behavior literature (Bubeck et al., 2013).

Of the six interviewees who addressed managed retreat, only Christopher contemplated the idea of accepting a buyout depending on "*what was offered*" as compensation, which is an important variable of buyout acceptance (Seebauer and Winkler, 2020). One other stated they would not leave because theirs is a prime location by the water. A resident said they would come back again and repair their home, like they did after Sandy. Studies show that location is a promiscuous factor in buyout acceptance because it can indicate multiple things to a homeowner, some positive (water proximity) some negative (risk of future damage; Robinson et al., 2018). Ana said that Edgemere is

"*where they can afford to live*," which points to residents' concerns over their ability to secure an alternative housing solution (Greer and Binder Brokkop, 2017). Lorraine felt that city and federal agencies needed to fulfill their duty to protect people in place:

> *"If the proper resiliency infrastructure was in place, community members wouldn't need to move or relocate. Give us the same resiliency investments as Battery Park City. They are not buying out or displacing wealthier communities. I sincerely hope more communities and their residents start pushing back on these so-called buyouts and force the Government to do the necessary resiliency building needed."* (Lorraine, Pos 74)

Lorraine is pushing back on the city's Coastal Land Use Framework narrative of protecting people in place where land use factors are conducive to growth (see 7.4). Although the US Army Corps of Engineers (USACE) plans to invest $252,544,000 in measures to reduce flood risk in mid-Rockaway (USACE, 2019) many citizens do not yet know about this plan because it is still in design phase (USACE, 2023).

7 Discussion

7.1 Reading post-buyout land restoration through Edgemere's contextual justice and senses of justice

The analysis of subjects reveals that children and youth more broadly, homeowners' rights, community solidarity and belonging according to Edgemere residents need moral and political attention. Land restoration opportunities should then account for high quality uses such as playgrounds, athletic fields and create uses conducive to block or garden parties, collaboration in yard or vacant lot work—that foster collective activity with neighbors and have the potential to create social cohesion and enhance awareness of how to steward vacant land (Stewart et al., 2019). When it comes to homeowners' rights, some expressed fear that some land uses on vacant lots next to their property may cause nuisance or vandalism, which other studies also recognized (Anderson and Minor, 2017). Although civic engagement in vacant land restoration is important for anyone living in high vacancy areas (Kim et al., 2020) it is even more essential that homeowners living adjacent to a vacant lot partake into decisions about its potential uses and be given the right of refusal of interim public uses and the options to purchase the land. Ownership of land increases the chances that communities will put in time and other resources to steward it when they know it will not be taken away (Németh and Langhorst, 2014).

The analysis of *senses of justice* also revealed how black and brown people make place amidst and in spite of oppressive realities as Hunter et al. (2016) put it. Hosting cookouts, having neighbors' children over to play in one's yard, and community gardening are sources of belonging and liberation in wounded places like Edgemere (see 5.4). Sites of belonging, liberation, endurance and resistance often start from homely practices of black and brown place making that are usually discounted, but which are crucial to heal from historic trauma and form kinship to withstand stressors (Smith, 1989; Carroll, 2015; Heynen and Ybarra, 2021) caused by institutional neglect and racism and more frequent climate induced disasters. The opportunity to rethink vacant lots in floodplains, may initiate a process of undoing past harms (Dascher et al., 2023) as well as sites for the practice, articulation and enactment of resistance (Scott, 1990) to unjust treatment. Climate change practice as well as post-buyout land restoration cannot be divorced from harm done to black and brown spaces and bodies through histories of colonialism and contemporary race linked housing, planning and health, but they also should not be only confined to analyzing and retelling stories of injuries (Hunter et al., 2016). As McKittrick (2021, p. 50) put it when addressing the importance of a black sense of place, this kind of practice also "re-orients what we know by honoring where we know from. We choose to know from the perspective of black and brown folks because we believe in black and brown humanity."

7.2 Interactions between contextual, distributive and recognitional justice

Though much of the scholarly literature focuses on distributional and procedural justice sometimes together, but more often separately, research poorly integrates recognitional and contextual justice together with these other dimensions. This study provides empirical evidence of how key dimensions of justice are perceived in land restoration after retreat. Results highlight both the interconnections and vicious cycles that exist between justice's dimensions and provide a few concrete examples of how they unfold in the case of Edgemere. Figure 4 illustrates these relations in graphic form. For instance, the data suggests a clear link between contextual and distributional injustices (the blue plain intersects with the red cone in Figure 4), where systemic structural injustices in housing, food security, and healthcare make climate vulnerability and recovery incredibly difficult and a source of sustained trauma. They also make acting toward land restoration almost trivial compared to other livelihood needs. But these structural injustices also make losing homes or new land easements, a threat multiplier for a community that is been neglected through time. Many scholars emphasize that retreat is not just about property, infrastructure, market value and individuality (Marino, 2018) and it will result in social failure if place attachments, livelihoods, cultural integrity, sense of belonging and humanity go unaddressed (Burley et al., 2007; Agyeman et al., 2009; Felipe Pérez and Tomaselli, 2021).

The data also points to the influence that distributive harms can have over generating injustices of recognition (the pink and red cone intersecting with each other and with past and current policies plains in Figure 4). Unmaintained promises of urban renewal can be linked to feelings of betrayal, while group disrespect was more strongly mentioned toward local authorities' practices of 'welfare dumping' and the policy of retreat. Neighborhood reputation is connected to past and present histories of crime, illegality, poverty and overall perceived quality of life in Edgemere. Distributive justice was closely related to the principle of need as well as equality, or the wish by Edgemere residents to have equal access to services, homes, safety and protection from climate risks. Recognitional injustice expressed as reputation, disrespect and betrayal may be linked to the idea of recognition as respect, or that individuals must enjoy the same fundamental rights in order to fulfill their autonomy (Thompson, 2006). These

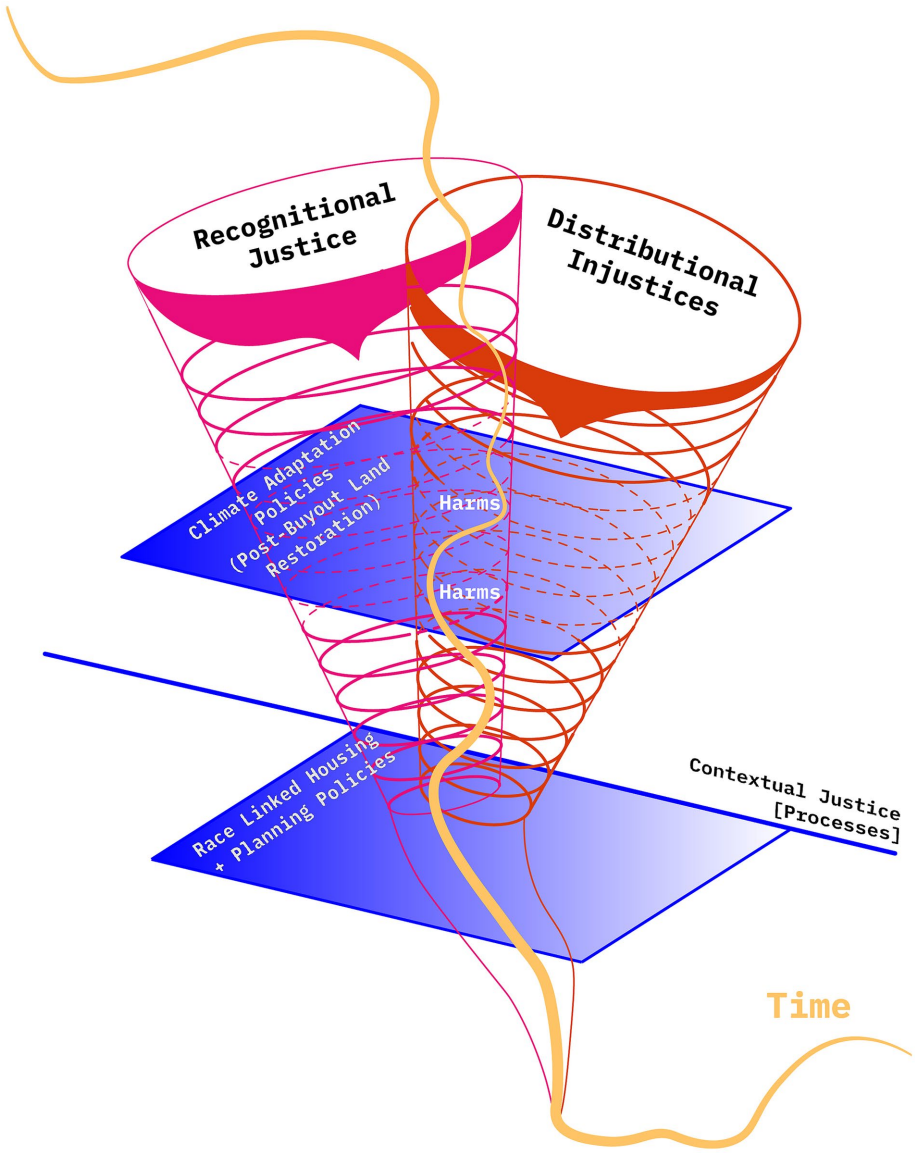


FIGURE 4
Analytical framework showing how recognitional and distributional injustices (symbolic and material harms) interconnect and arise from unjust contextual processes across time.

associations between dimensions of justice and underlying principles are confirmed in one other study (Lecuyer et al., 2018) while the interconnections between contextual, distributive and recognitional justice align with observations made by Walker (2023) who studied retreat in New York State's rural communities.

This study shows how group mistreatment rooted in contextual injustices generates community divisions with possible implications for community organizing. Group mistreatment becomes a sign of recognitional injustice, which can arise from individual experiences of injustice that may become typical of an entire group (Honneth, 1995) meaning that personal experiences of suffering are understood as affecting others too (Honneth, 1995; Pilapil, 2013). These feelings can fuel collective struggles for recognition through shared meanings and resistance. If Edgemere residents are splintered, as this study suggests (see 5.1), also the practicing, articulation and enactment of organizing is fractured. Existing homeowners and renters' divisions make it hard for Edgemere residents to organize and advocate around common harms, such as prompt flood risk reduction, housing affordability, environmental racism and availability of services. Social sites set apart from domination are needed for such meaning and practices to rise safely and land stewardship on Edgemere's vacant lots should emphasize opportunities for such sites of self-determination to emerge (Shepard, 2022).

7.3 The implications of Edgemere's contextual justice for retreat policy

Landscapes of race and deep histories of colonialism and racism shape the socio-ecological formations of US low-lying coastal areas (Hardy et al., 2017). Edgemere's history is rooted in the fundamental lack of interest in protecting and in the thriving of black and brown

spaces, which is of course not just a Rockaway history, but symbolizes the greed, opportunism, bigotry, racism and indifference to the poor in general and, to poor black and brown people in particular, that characterized much of the postwar decades (Sugrue, 2005; Cebul, 2020).

One may read Edgemere as part of what McKittrick and others called "urbicide"—killing of the city—where place, poverty and racial violence converge (McKittrick, 2011). A place where this violence not only manifests in undelivered services or letting key structures like hospitals go bankrupt, but also through extensive amounts of vacant land. As a marker of "urban decline" in popular discourses, where the state of urban infrastructure is linked to community character, representations of property vacancy can "calcify the seeming natural links between blackness, underdevelopment, poverty, and place" (McKittrick, 2011, p. 951). While New York City did not suffer from the same scale of de-industrialization as Detroit, Philadelphia and St. Louis, and it has infinitesimal amounts of vacant land compared to these cities, the borough of Queens and especially Eastern Rockaway, has historically had the largest density of vacant land, mostly characterized by small and medium sized lots (Kremer et al., 2013). As this study shows, Edgemere's depressed landscape did not happen by chance, but it was the result of the little interest politicians had in the land and people living on it and where failed renewal befell through both local (city council running out of funds) and cascading international market failures (the mortgage crisis).

A contextual justice approach reveals how the contemporary racial geographies of Edgemere (of segregation, disinvestment and displacement) are the outcome of planning policies (housing, zoning and urban renewal) sorting out who lives where and under what conditions (Stein, 2019) effectively continuing the racial differentiation and domination and settler colonial style dispossessions (Porter, 2016). Contextual justice also shows how terraforming, and development are used to tame the sea and to make space for habitable land that today is some of the most vulnerable land to the effects of sea level rise. To most black and brown communities of Edgemere who took part in this study the idea of retreating is just another form of betrayal and should represent an equity dilemma to city officers proposing it. Retreating is difficult for any community independently of class and race, but communities that are repressed in many other ways experience retreat as a new form of neglect. When group feelings of injustice, such as betrayal, group disrespect and differential treatment go unsolved for so long these can generate renewed distrust in government agencies tasked with building urban climate adaptation (Rudge, 2021; Teirstein, 2022) and land restoration.

Should more retreat be proposed in the future, this study shows that existing in-community divisions (between renters and homeowners) could be detrimental for groups that are least able to navigate retreat plans (whether homeowners or renters). As Lynn (2017) suggested after studying the retreat of Kashmere Gardens in Harris County (Texas), retreat requires that homeowners to take upon themselves to stay informed of developments, communicating with other affected households and sharing information. It also requires pooling resources and hiring lawyers and appraisers familiar with public agency-sponsored retreat. This kind of organizing in Edgemere may be possible if ECCA steps up and other civic associations are formed to become a reference point with both public agencies, appraisers and homeowners. Renters, however, may still need to rely on public officials ramping up education and outreach campaigns about risks and insurance or implementing advanced door-to-door information campaign as part of FEMA's Credit Rating System (CRS; Dundon and Abkowitz, 2021) of which the city of New York is part.

7.4 Dilemma in the making: retreating, reducing flood risks and green climate gentrification

Edgemere is an example of the present dilemmas of the concomitant climate and housing crises in New York City, where more housing gets built in floodplains at risk without also bringing adequate neighborhood infrastructure. New planned developments in Edgemere exemplify two dynamics. Firstly, that although the REPCI was successful in proposing permanent affordable housing and community stewardship of the land through the Edgemere CLT, the new mixed use developments currently being built are largely an attempt at mobilizing the resilience script to further neoliberal capital agendas for economic gains at expense of climate change risks (Karki, 2021; Camponeschi, 2023). Instead of addressing decades of disinvestment as city officers seem to think, developments may bring climate gentrification upon Edgemere and other eastward neighborhoods of Rockaway (Ehrenfeucht and Nelson, 2020; Shokry et al., 2020).

Edgemere is also an example of a mixing of adaptation strategies to simultaneously retreat, accommodate (home elevation) and reduce flood risk through hard engineering. This way of thinking is summarized in the city's Coastal Land Use Framework proposing the advancement of multiple climate adaptation strategies at the same time (Mayor's Office, 2022). This framing makes it clear that the city will prioritize flood protection projects where coastal risk till 2050 can be "practically managed and where land use factors are conducive to growth" (p.69) but it will limit residential development "where residential populations do not exist today and where support for a new population would require infrastructure to be extended and maintained at significant public cost" (p.69). One can see these two strategies simultaneously in action in Edgemere. On the Atlantic side, the city's promoting high rise buildings, while on the Bay side prohibiting or limiting residential uses. While at the moment there is a "soft, delayed retreat philosophy" (Scott, 1990, p. 143) surrounding the idea of retreat in Edgemere's bay area, the future may be different. By changing zoning no new developments or home elevations will be possible in the Hazard Mitigation Area, meaning that in the event of a new catastrophic flooding, the only option for residents still living within this area will be retreating. Given Edgemere's history of unmet promises it remains unclear whether all these housing units will be built and, more importantly, whether the CLT will find a developer willing to build one-two story housing in an area of such great flood risk with a likely short mortgage cycle, as well as necessary funding to maintain open space lots.

8 Conclusion

In the United States, the policy of managed retreat is implemented on a voluntary basis and largely through buyouts and acquisitions.

Restoring land after buyouts is an important phase of the practice of managed retreat because it can lead to suboptimal use of space and distributive inequities for the communities who remain in place. While existing literature stresses restoring ecological and hydrological functions of land in floodplains, this study stresses the need to consider how people staying in place experience their surroundings and how this experience may be affected by historical processes that over time have devalued black and brown life in the city. Our findings show how integrating residents' experiences of living with vacant land in post-buyout neighborhoods can lay the ground to inform decisions over open space uses, without bypassing crucial histories of tensions between government agencies and residents in disinvested neighborhoods. The study also provides insights into the empirical connection and vicious cycles between dimensions of justice that can help adaptation practitioners think through the justice implications of their work and hopefully design better land restoration processes as a result.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by The Human Research Protection Program (HRPP) at The New School. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

KW: Conceptualization, Writing – review & editing. TM: Conceptualization, Supervision, Writing – review & editing. VO: Writing – Original draft.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fclim.2024.1481919/full#supplementary-material

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Finding mobility in place attachment research: lessons for managed retreat

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Climate change will affect many global landscapes in the future, requiring millions of people to move away from areas at risk from flooding, erosion, drought and extreme temperatures. The term *managed retreat* is increasingly used in the Global North to refer to the movement of people and infrastructure away from climate risks. Managed retreat, however, has proven to be one of the most difficult climate adaptation options to undertake because of the complex economic, social-cultural and psychological factors that shape individual and community responses to the relocation process. Among these factors, place attachment is expected to shape the possibilities for managed retreat because relocation disrupts the bonds and identities that individuals and communities have invested in place. Research at the intersection of place attachment and managed retreat is limited, partially because these are complicated constructs, each with confusing terminologies. By viewing the concept of managed retreat as a form of mobility-based climate adaptation, this paper attempts to gain insights from other mobility-related fields. We find that place attachment and mobility research has contributed to the development of a more complex and dynamic view of place attachment: such research has explored the role of place attachment as either constraining or prompting decisions to relocate, and started to explore how the place attachment process responds to disruptions and influences recovery from relocation. Beyond informing managed retreat scholars and practitioners, this research synthesis identifies several areas that need more attention. These needs include more qualitative research to better understand the dualistic role of place attachments in decisions to relocate, more longitudinal research about relocation experiences to fully comprehend the place attachment process during and after relocation, and increased exploration of whether place attachments can help provide stability and continuity during relocation.

KEYWORDS

climate adaptation, climate migration, disaster recovery, forced relocation, managed retreat, mobility, place attachment, sense of place

1 Introduction

In 2010 at COP16 (Conference of the Parties), the International Panel on Climate Change (IPCC) recognized that one of the effects of climate change would be the increased mobility of people (UNFCCC, 2010). It has been estimated that disasters triggered about 24 million new internal displacements in 2023, most of which were due to storms and floods (IDMC, 2024). These numbers are expected to increase according to researchers working to predict

displacement patterns and trends (de Sherbinin et al., 2019; Rossi et al., 2024). For example, under low emissions scenarios 190 million people are predicted to be living below the high tide line by 2100 (Kulp and Strauss, 2019). Accordingly, moving people away from places at high-risk of becoming uninhabitable due to the effects of climate change (high-risk places) is no longer seen as a last resort but as a smart and necessary form of risk management that will reduce residents' hazard vulnerability and emergency response costs, while promoting restoration of land and ecosystem function (Hino et al., 2017; Siders, 2019). As well, moving people can avoid the high costs of structural protection measures that will increase with more severe and frequent climate change impacts (Doberstein et al., 2020). This "strategic relocation of people, assets and activities to avoid and reduce natural hazard risks and to adapt to impacts of climate change" (Hanna et al., 2019, p. 2) is known, in research and policy, as managed retreat.

Managed retreat is one of the most difficult climate-induced adaptation options to undertake because there is a complex nexus of economic, social-cultural and psychological factors that together shape individual and community responses to the relocation process (Esteban et al., 2020; Hanna et al., 2019; Hino et al., 2017; Steimanis et al., 2021; Thistlethwaite et al., 2018). Even the language of retreat, with its military connotations, can be interpreted as defeatist and intimidating (Koslov, 2016). If managed retreat is to be successfully implemented at the scale that is required due to increasing sea level rise, flooding, drought, and wildfires, then more understanding about the psycho-social dimensions of managed retreat is required (Agyeman et al., 2009; Brunacini, 2023; Fresque-Baxter and Armitage, 2012; Pucker et al., 2023; Raymond, 2013).

Understanding more about the psycho-social aspects of disruptions to place or because of relocation, such as place attachment, is highlighted as a future priority in the emerging research area of climate mobility (Dandy et al., 2019; Seeteram et al., 2023; Simpson et al., 2024). Place attachment merits exploration because relocation will disrupt the bonds and the identities of individuals and communities that are grounded in place (Brunacini, 2023; Devine-Wright, 2014; Relph, 2008; Simpson et al., 2024). Ruptures to people-place bonds create physical and emotional losses that can cause grief (Kothari, 2020) and threaten mental health and well-being (Solecki and Friedman, 2021). Research at the intersection of place attachment and managed retreat is in its infancy, but there are increasing calls to understand how place attachment may inform human responses to retreat (Agyeman et al., 2009; Devine-Wright and Quinn, 2020; Low and Altman, 1992; O'Donnell, 2022; Quinn et al., 2015). There are several potential connections between the two concepts that can be further explored including how place attachments can change over the course of managed retreat; how managed retreat can affect place attachment and vice versa; and how place attachment can impede managed retreat or help in recovery. Increased understanding of these processes has the potential to inform policy and planning initiatives that will ease transitions and limit the negative impact to individual and community well-being (Agyeman et al., 2009; Binder et al., 2019; Cox and Perry, 2011; Fresque-Baxter and Armitage, 2012; Jamali and Nejat, 2016).

The contribution of this paper is to articulate and synthesize the research at the intersection of place attachment and managed retreat. Since research that connects place attachment and managed retreat is limited, in order to obtain useful insights, we take a broader view of managed retreat as a climate-induced mobility, as it requires the movement of people and infrastructure. This has motivated us to conduct a targeted review that incorporates neighboring scholarly fields. For example, the fields of personal mobility, migration and displacement, and forced relocation and resettlement have all incorporated place attachment research and offer insight into the dynamism of place attachments, the role of place attachment in the decision to relocate, and the role of place attachments in recovery. Improved understanding of place attachment and how it may inform human responses to retreat in general will be helpful at both the theoretical and practical levels (Agyeman et al., 2009; Devine-Wright and Quinn, 2020; Low and Altman, 1992; Quinn et al., 2015).

2 Background

The literatures of managed retreat and place attachment show us that both concepts are incompletely conceptualized. Both fields suffer from multiple constructs that are often used interchangeably, and from a wide variety of related research fields which produce an abundant amount of literature about various philosophies, approaches and methods. These issues have been identified in the literature by many researchers and can result in difficulty compiling an accurate body of knowledge that reflects the current state of our understanding (Bukvic, 2015; Nelson et al., 2020).

2.1 Managed retreat

Many terms are used interchangeably in the literature to describe *the movement of individual people and communities* (Bukvic, 2015). Terms vary in whether they describe movements that are fast or slow, forced or voluntary, planned or unplanned, state-led (managed) or self-governed. For example, the term *evacuation* describes an abrupt and temporary movement, whereas *abandonment* may take more time to reconcile but is more permanent. *Migration, abandonment*, and *displacement* are seen as primarily un-planned and self-driven, but only *displacement* is seen as being forced (Burkett et al., 2017; Paul et al., 2024). Likewise, *relocation, retreat*, and *resettlement* also tend to refer to forced relocation, but also imply state-led, planned, and the more permanent movement of people (Ajibade et al., 2022; Burkett et al., 2017; Ferris, 2015; Imura and Shaw, 2009; Marter-Kenyon, 2020). Relocation and retreat are also more likely to include the relocation of assets and activities along with people.

Within the climate-induced adaptation literature there are also multiple terms used specifically to describe climate-induced, or climate-related relocation (CRR). For example, in the Global South, the term *planned resettlement* is most often used, in the United Kingdom and Europe the term *managed realignment* is often used, and in the United States, Canada and Europe, the terms *planned, strategic or managed retreat* are used (Doberstein et al., 2020; Hanna et al., 2019; Rupp-Armstrong and Nicholls, 2007). This does not mean you cannot also find references to planned or forced relocation, or resettlement in the CRR literature. Furthermore, newer terms like *climigration* (climate + migration) are entering the lexicon (Ajibade et al., 2020). Unfortunately, many of these terms have been used interchangeably over the years which is problematic for gathering an accurate state of knowledge in the field. For example, although much

of CRR research occurs in the Global South (Ajibade et al., 2022; Marter-Kenyon, 2020), searching for the terms planned or managed retreat will deliver more cases from the Global North (Marter-Kenyon, 2020). Many authors call for more standardized terminology in order to provide consistency in the literature, especially as interest in dialog about climate-related relocation continues to increase (Bukvic, 2015; Paul et al., 2024). New terms like *transformative adaptation* have been proposed to provide one, all-encompassing term, that invokes fewer negative connotations, and focuses on the positive aspects of relocation (Dundon and Abkowitz, 2021; O'Donnell, 2022). The debate continues about which term to use and when. In this paper we focus on the term managed retreat to represent the forced relocation of individuals, communities and infrastructure due to climate risks, because the term has been widely adopted in academia and policy spheres at this time. This decision however, does affect our search results. Given the linguistic bias discussed above, the focus of this paper is on the movement of people and assets in the Global North.

The construct of managed retreat builds on a long history of both involuntary and voluntary human movement from forced residential relocation as a result of urban expansion and renewal, large infrastructure projects, establishment of protected areas, unsustainable land use patterns that expose people to risks, and man-made and natural disasters (Doberstein and Stager, 2013; Hanna et al., 2019; Marter-Kenyon, 2020; Piggott-McKellar et al., 2020; Wilmsen and Webber, 2015). Some of the earliest managed retreat cases were due to riverine and coastal flooding in the United States and Europe (Koslov, 2016; Pinter, 2021; Pinter and Rees, 2021; Siders, 2019; Tubridy et al., 2021). More recently however, managed retreat has differentiated itself from other types of forced relocation as primarily being driven by climate change hazards. There continues to be managed retreat literature as a result of riverine and coastal flooding (Abel et al., 2011; Dundon et al., 2023; Mayr et al., 2020; Okada et al., 2014; Rupp-Armstrong and Nicholls, 2007), but now, there are also documented responses to extreme weather-related events and sea level rise. For example, there has been much written about relocation after Hurricanes Katrina and Sandy in the United States (Binder et al., 2019; Braamskamp and Penning-Rowsell, 2018; Koslov, 2016; Pinter et al., 2019), and about retreat from low-lying coastal communities (Marter-Kenyon, 2020; Pinter, 2021; Simms et al., 2021). Some of the most well-known cases of managed retreat include the relocation of the island Pacific communities of Kiribati and Fiji, and Indigenous coastal communities in Alaska and the southern United States (Pinter, 2021). Climate change caused wildfires, extreme heat, and permafrost melting are emerging reasons where managed retreat may also be considered necessary (Dundon et al., 2023; Siders, 2019).

Managed retreat may need to occur quickly, such as after a disaster, or may happen more slowly, such as in the case of gradual sea level rise. It is typically a planned, coordinated, and mostly an involuntary process that is overseen by the state through regulations and financial incentives. Depending on the circumstances surrounding the managed retreat, a variety of positive and negative consequences can occur (Simpson et al., 2024). In the best-case scenarios, managed retreat can protect lives, reduce costs related to staying in place, reduce stresses and uncertainty associated with living in high-risk areas, free up land for ecosystems (Ajibade and Siders, 2021; Hanna et al., 2019; Koslov, 2016; Siders, 2019), change historical marginalization (Simpson et al., 2024), and potentially present other life opportunities (Jamali and Nejat, 2016; Siders, 2019). In the worst cases, managed retreat can disconnect people from their communities, culture and livelihoods, exacerbate social inequalities and increase socioeconomic vulnerabilities (Ajibade and Siders, 2021; Koslov, 2016; Simpson et al., 2024), negatively impact mental health and well-being, and disrupt place attachments (Ajibade and Siders, 2021). These positive and negative outcomes may occur simultaneously and fluctuate over time (Ajibade and Siders, 2021).

Despite the increased urgency of needing to move people away from high-risk areas there is still resistance to the use of managed retreat, and considerable difficulties with its implementation (Lawrence et al., 2020; Mallette et al., 2021). Several recent reviews of managed retreat literature address questions about how to undertake managed retreat in ways that deal with the complexities arising from implementation costs, compensation of relocatees, maladaptations from urban and rural planning and the insurance industry, and jurisdictional issues under the law (Ajibade et al., 2022; Dundon and Abkowitz, 2021; Kousky, 2014; Marter-Kenyon, 2020; O'Donnell, 2022; Pinter, 2021; Siders, 2019). Furthermore, finding an equitable or just approach to managed retreat is of increasing interest since it is often the economically, politically, and socially disenfranchised people who are the most vulnerable, and will suffer the most as a result of retreat (Ajibade and Siders, 2021; Loughran and Elliott, 2022; O'Donnell, 2022; Pinter, 2021; Simms et al., 2021; Thaler, 2021). This includes the loss of place.

2.2 Place and place attachment

Interest in place was led by the disciplines of human geography and environmental and social psychology (Williams and Miller, 2020), but it is now studied in almost all aspects of social science and the humanities (Devine-Wright, 2013b; Nelson et al., 2020; Patterson and Williams, 2005). This has resulted in the production of a large and growing body of literature, and a reputation that the field is complex (Relph, 2008). Several reviews—including those by Duggan et al. (2023), Edensor et al. (2020), Erfani (2022), Manzo (2003), Nelson et al. (2020), Patterson and Williams (2005), and Raymond et al. (2021)—capture many of the theories, methods and applications in place research. Here we only give an overview.

The concept of place evolved through several key societal movements that bred a diversity of philosophies and approaches, many of which continue to be practiced concurrently (Cresswell, 2009; Morgan, 2010; Williams, 2014a; Williams and Miller, 2020). The humanism movement of the 1970s was one of the most impactful periods in place research. During this time, humanists pushed back on modernistic ideas that neglected human-environment relations, in favor of prioritizing human experiences and meaning (Lewicka, 2011a; Raymond et al., 2021; Williams, 2014a; Williams and Miller, 2020). Later, critical constructivists focussed on how place was socially constructed through narratives, and shaped by politics, power, and social and cultural processes (Manzo and Pinto De Carvalho, 2020; Williams, 2014a; Williams and Miller, 2020). More recently, globalization, migration, and the increased mobility of people in general has resulted in what social science researchers Sheller and Urry (2006) coined the *mobilities turn*. The mobilities turn has challenged the view that mobility is a threat to place (Di Masso et al., 2019; Lewicka, 2020). Through these historical movements, place has evolved from being considered solely a geographic location, to

becoming *a place* comprised of physical attributes, experiences and meanings (Relph, 2008), to more recently being thought of as complex and dynamic networks of things and connections (Edensor et al., 2020; Raymond et al., 2021; Williams and Miller, 2020). The fact that place research is not grounded in a single research tradition is often blamed for the lack of progress in theoretical coherence and maturity in place research (Herandez et al., 2020; Nelson et al., 2020; Patterson and Williams, 2005; Stedman, 2003).

Many terms have been used in the literature to capture the nature and meaning of *connection to place* (Masterson et al., 2017; Patterson and Williams, 2005) (Table 1). *Sense of place, place attachment, place identity*, and *place dependence* are the main terms used (Manzo, 2003; Stedman, 2003). There are however, many other terms and phrases representing this connection to place found in the literature including *topophilia* (Tuan, 1974), community sentiment and identity (Low and Altman, 1992), the ancient Roman term *genius loci* (Patterson and Williams, 2005), sense of belonging, (Nelson et al., 2020), community attachment (Hernandez-Santin et al., 2020), and perception of place (Duggan et al., 2023). There is widespread criticism in the literature about the lack of conceptual clarity about the concept of place attachment. This could be due to the use of so many different terms and the lack of consensus about how they relate to each other (Devine-Wright, 2020; Manzo et al., 2023). Like with managed retreat, this makes it difficult to compare or accumulate research findings because disciplines frequently use different definitions for the same construct (Giuliani and Feldman, 1993; Masterson et al., 2017; Trentelman, 2009), or use terms interchangeably, despite subtle differences in meaning (Nelson et al., 2020; Williams and Miller, 2020).

For the purposes of this paper we adopt the term place attachment because it is the most frequently used term in the literature to represent connection to place (Hernandez-Santin et al., 2020; Nelson et al., 2020; Nicolosi and Corbett, 2018; Trentelman, 2009). Place attachment at its most basic is a bond between humans and their environment (Low and Altman, 1992). Common characteristics found in various definitions include that bonds are affective (emotional), evaluative (positive or negative), and between individuals and or groups and their environment (Lewicka, 2020; Masterson et al., 2017; Scannell and Gifford, 2010).

3 Methods

This review takes a narrative approach, in part due to the challenges of language described above. An initial search for research at the intersection of place attachment and managed retreat using those terms yielded very few results, so conducting a systematic review did not seem beneficial. Knowing there was relevant literature about place attachment and relocation available, we proceeded to broaden the search and consider managed retreat as a mobility-based concept. This allowed us to expand our search and explore other fields related to the movement of humans and assets in relation to place. We conducted our search on the Scopus database using the terms discussed in Section 2.1 to describe the movement of people and assets, and paired them with the main terms used in the literature for connection to place (as discussed in Section 2.2). Over 400 resources were captured in the search which included book chapters, but not books or conference papers. We also found many sources through the reference lists of other papers.

Screening focused on including the literature on relocation that shared similarities to managed retreat. Therefore, of particular interest to our review was literature about place attachment and climate-related relocation, and relocation that was permanent, planned or forced, and state-led. As a result, this excluded some results that focused solely upon human movement, or that was voluntary and self-motivated. The latter results correlated primarily with human movement literature on the Global South, so the reviewed literature ended up being heavily focused on the Global North. However, we did not exclude research about the Global South, nor did we exclude non-climate related relocation, particularly if it referred to how place attachment responded to relocation or place change. The remainder of the paper will review the literature found in these targeted domains.

TABLE 1 **Frequently used place terms and definitions.**

Place terms	Descriptions and definitions
Sense of place (SOP)	• First term to appear along with 'place attachment'; often used interchangeably (Nelson et al., 2020) • Broadest, most encompassing term; incorporating meanings and attachments to a setting by individuals or groups (Cresswell, 2009; Duggan et al., 2023; Masterson et al., 2017)
Place attachment	• Used more than other terms in the literature (Hernandez-Santin et al., 2020; Nelson et al., 2020; Nicolosi and Corbett, 2018; Trentelman, 2009) • A bond between humans and their environment (Low and Altman, 1992) • Common characteristics found in definitions include: bonds are affective (emotional), evaluative (positive or negative), and between individuals and or groups and their environment (Lewicka, 2020; Masterson et al., 2017; Scannell and Gifford, 2010)
Place meaning	• Descriptive statements about what a place is, what it is like, and the images it conveys • Is subjective and individualized (Masterson et al., 2017)
Place identity	• A sub dimension of an individual's personal identity developed in relation to their physical environment (Devine-Wright, 2013b; Fresque-Baxter and Armitage, 2012; Manzo et al., 2023; Masterson et al., 2017; Trentelman, 2009) • Plays a role in personal sense of belonging and how one defines themselves (Fresque-Baxter and Armitage, 2012; Nicolosi and Corbett, 2018)
Place dependence	• A functional attachment between a person and place that is perceived as a strength of association (Manzo et al., 2023; Nelson et al., 2020; Trentelman, 2009) • Development of strong attachments and identities causes reliance on a place that suits a person's needs and desires (Nicolosi and Corbett, 2018; Pucker et al., 2023)

4 Research fields at the intersection of place attachment and mobility

By taking a broader view of managed retreat as a climate-induced mobility, our search found several neighbouring mobility-based fields that have incorporated place attachment research, including migration and displacement, personal mobility, and forced relocation and resettlement. A brief discussion follows of these fields and how they may be similar or different than managed retreat.

4.1 Migration and displacement

Millions of people migrate within, or between countries each year. Migration can be driven by individual choices, such as seeking better opportunities, or in less voluntary ways, because situations are risky or untenable due to war, politics, or natural hazards (De Sherbinin et al., 2011; Hanna et al., 2019; Paul et al., 2024). Migration is typically unplanned, uncoordinated, and is the result of complex relationships between perceptions, needs, desires, real or perceived risks and benefits, and financial or legal ability to move (Barcus and Brunn, 2010; Koslov, 2016). Involuntary migration is often referred to as displacement and typically affects more vulnerable populations who frequently live in poorer, high risk areas (Paul et al., 2024). Conversely, lack of financial or social resources can lead to immobility, causing some people to be trapped in place (Koslov, 2016; Upadhyay et al., 2024).

Interest in migration caused by climate change is increasing so rapidly it has made its way into popular discourse with recently published non-academic books about the displacement of people away from areas of climate risk (Bittle, 2024; Vince, 2022). The current literature about climate change and migration, or *climigration* as it is often referred to, mainly focuses on determining the extra impact that climate change contributes to existing socio-economic drivers of migration, how and when climate change will affect which places, and how many people will migrate in the future (Upadhyay et al., 2024). However, the literature also illustrates the similarities between migration and managed retreat, such as when the drivers are climate-driven (Pinter, 2021).

Although there are many opportunities to learn from the field of migration, there are many distinctions between it and managed retreat. Ajibade and Siders (2021) point out that migration is primarily about human mobility and focuses on people in the Global South, whereas managed retreat is a withdrawal of people and the resources they value (e.g., homes, infrastructure, ecosystems, and other assets) (Ajibade and Siders, 2021, p. 102187). Ajibade et al. (2020) also outlines several specific distinctions between managed retreat and climigration, such as their causal mechanisms. Further, according to Ajibade et al. (2020) managed retreat is initiated directly from a climate hazard (i.e., sea level rise), whereas climigration is triggered by indirect climatic effects. For example, extreme heat could lead to drought which causes crop failure and food insecurity. People may thus be motivated to relocate to find areas that have more food resources. The two constructs also differ in their legal protections, rights and funding structures, and discursive effects (Ajibade et al., 2020; Hanna et al., 2019).

4.2 Personal mobility

Research in residential mobility has driven a significant proportion of place attachment research. Moving residences is typically voluntary and peaceful, driven by factors that pull people toward a new place, including benefits such as a better job or improved living conditions. Alternatively, people can be pushed from a place because their needs do not match what a current place offers (Dang and Weiss, 2021), their socioeconomic statues changes, or physical changes may make a place undesirable to live in (Kothari, 2020). In these situations, moving can feel positive, like a search for new opportunities or a liberation from constraints, or it can feel oppressive and out of one's control (Madanipour, 2020; Williams and Miller, 2024). For example, tenants' rights research identifies the perils of forced relocation of low to moderate income renters from no-fault evictions such as renovictions (eviction to allow for renovations) and demovictions (eviction to demolish aged housing stock), which are made in the name of housing stock and neighborhood renewal (Ramiller, 2022).

In the Global North personal mobility has become a normal part of people's lifestyles rather than a one-off experience due to an increase in pleasure travel, commuting for work, second home ownership, and new technologies allowing for virtual travel or telecommuting (Cresswell, 2006; Gustafson, 2014; Lewicka, 2020). There is a tension identified in the literature among mobility, sedentarism, and privilege. This tension is heavily dependent on social position. Currently those who are able to opt into a mobile lifestyle are often considered more privileged than those who may be restricted in their movements, or are forced to move (Cresswell, 2009; Gustafson, 2001). However, it was not long ago that sedentarism was considered a privilege in place attachment research, and those who were able to have a secure and stable place to call home possessed an advantage (Di Masso et al., 2019). These debates have contributed to more interest in relocation and social justice issues which is only expected to increase as climate change intensifies (Ajibade et al., 2022; O'Donnell, 2022; Seeteram et al., 2023).

4.3 Forced relocation and resettlement

Approximately 15 million people are forced to relocate each year as a result of development induced/forced displacement and resettlement (DIDR or DFDR) (Doberstein and Stager, 2013; Piggott-McKellar et al., 2020; Wilmsen and Webber, 2015). This includes those relocated due to urban expansion, gentrification or redevelopment; and large infrastructure development like dams, hydro lines, mines, airports, national parks, and more recently green infrastructure projects such as windfarms (De Sherbinin et al., 2011; Hay, 1998; Vanclay, 2017; Wilmsen and Webber, 2015). Several authors have outlined similarities between DIDIR/DFDR and managed retreat cases, including that they are a result of human actions, can have long lead times (as is the case with sea level rise), and often impact the least powerful (Wilmsen and Webber, 2015). However, a major difference between the two fields, is that DIDR/DFDR projects are typically economically motivated and driven from the top-down (Hsu et al., 2019; Piggott-McKellar et al., 2020).

Natural disasters also force many people to relocate each year and motivates a substantial amount of research on place attachment and mobility. There is clear overlap between the fields of disaster risk and disaster recovery (DRDR) and managed retreat, especially when the drivers are climate-induced storms, floods, fires, and drought. This can sometimes make it difficult to distinguish the fields from each other in the literature. For example, some articles discuss DRDR and climate change adaptation (managed retreat is an adaptation tool) together and treat them the as one and the same (Doberstein et al., 2020). Although there are many similarities between the literature of place attachment and DRDR, and place attachment and managed retreat, there are also points of distinction. For example, the DRDR literature also includes temporary displacements (Iuchi, 2014), people eventually returning to place (Chamlee-Wright and Storr, 2009; Imura and Shaw, 2009; Paul et al., 2024), or situations in which people are not required to move at all, such as after earthquakes and volcanoes (Hsu et al., 2019; Piggott-McKellar et al., 2020; Wilmsen and Webber, 2015).

Forced relocation from DIDR/DFDR or DRDR may be structurally different and hold different implications for people than those experienced under managed retreat but they still provide useful insights into the social dynamics of population displacement (De Sherbinin et al., 2011; Pinter, 2021). For example, it is generally acknowledged in the DRR and DIDR literature that in the past, relocations have often had poor outcomes. Beyond the economic costs, these include exacerbation of historical inequities (Ajibade et al., 2022); the social, psychological, and cultural impact experienced by people when breaking of ties with cultures and communities (Ajibade et al., 2022; Hanna et al., 2019; Hino et al., 2017); top-down approaches that fail to communicate with and involve communities in meaningful ways (Hsu et al., 2019; Tadgell et al., 2018; Wilmsen and Webber, 2015; Yi and Yang, 2014); lack of long-term perspective (Imura and Shaw, 2009); adverse effects of power dynamics and government bureaucracy (Wilmsen and Webber, 2015); unsuitability of new locations; and lack of consideration of impacts on host communities (Perry and Lindell, 1997; Vanclay, 2017; Wilmsen and Webber, 2015). In order to address some of these lessons learned, organizations like the United Nations have produced resettlement policies and performance standards that focus on the protection of human rights of relocatees in developing nations (OECD-DAC, 1992; UN OCHA, 2004; UNHCR, 2015). Other researchers have also provided lessons learned from past relocations (Tubridy et al., 2021; Wilmsen and Webber, 2015), establishing guidelines for future relocations, including for less developed nations (Tadgell et al., 2018) and informal settlements (Doberstein and Stager, 2013).

5 Lessons from the literature

Important lessons about place attachment can be drawn from the various fields that encompass human movements discussed above. Since each mobility field differs in its similarities with managed retreat, some mobility fields contributed more resources to this review than others. The wide range of articles found illustrate how managed retreat affects place attachment and how it is influenced by place attachment. The key lessons are outlined below.

5.1 People have complex and changing attachments to places

5.1.1 People can have attachments to multiple different places

The mobilities turn in particular, has challenged the dominant paradigm of place attachment as sedentary, centred around a primary residence (home), and strengthened by longevity in place (Di Masso et al., 2019; Lewicka, 2020). It has caused place and place attachment researchers to grapple with the once-accepted idea that mobility is a threat (Devine-Wright, 2020; Lewicka, 2020; Williams and Miller, 2020) and to consider whether, instead of eroding place attachments, mobility can actually increase the number and types of attachments people hold. Research on multiple place attachments has centered around attachments to places other than a primary residence, including summer or second homes, wilderness and outdoor recreation areas (Lewicka, 2011a), meeting areas and public places, and sacred structures (Manzo, 2003). This research confirms what Brown and Perkins (1992) proposed long ago, that people can experience multiple attachments with a plurality of place meanings (Gustafson, 2014; Manzo et al., 2023). Devine-Wright and Quinn (2020, p. 226) suggest that with mobility becoming a lifestyle, more than ever people will experience a "mosaic of places" over their lifetime.

Within place attachment research, the life course approach explores how people attach to multiple places as they move through various stages of their lives (Di Masso et al., 2019). The life course paradigm has been part of social psychology research since the 1960s (Elder, 1994). Several studies explore people's relationships to a multitude of places from childhood to retirement, capturing changes to place attachment over this span of time (Bailey et al., 2021; Di Masso et al., 2019; Giuliani and Feldman, 1993; Manzo, 2003). Bailey et al.'s (2016) research about a proposed power line addition in Bristol, England, builds on the life course approach. These researchers proposed that currently held residential place attachments are influenced by people's life course trajectories. They proposed five distinct life course trajectories based on mobility patterns associated with different types of attachment, and found those who had a life trajectory characterized by living in one location for a long time were more rooted in place. For these people, power lines were deemed acceptable since they were always part of the landscape. The other extreme described people with life course trajectories that were more mobile. These people often moved to the area in search of places similar to their previous locations. They placed value on landscape aesthetics and viewed power lines as negative, ultimately opposing the power line project. This finding is consistent with research on place-based opposition by new residents. Life course research such as this highlights that people navigating place changes in their lives are often looking for continuity in their attachments and identity (Di Masso et al., 2019).

5.1.2 People can have many different types of attachments to a place

Along with research about having attachment to multiple different places, there is research about the idea people can have multiple *types* of place attachments to a place (Adams-Hutcheson, 2015). The concept of place attachment as singular has changed as researchers have sought language to capture the more nuanced linkages people

have with places, and the sense of mobility within and across types of attachment (Bissell, 2020; Lewicka, 2011b; Devine-Wright, 2020b; Van Manen, 1990).

Gustafson (2001) explained that people could have static or dynamic place attachments. They considered traditional and sedentary place attachments in terms of *roots*, and the more progressive, mobility influenced perspective of attachments as *routes*. They also emphasized rather than being mutually exclusive, there was room for both static and dynamic place attachments to co-exist. For example, one may still enjoy the stability of having a strong, fixed connection to a primary residence, while mobility in the form of travel can provide an opportunity for connections to other places (Gustafson, 2014; Raymond et al., 2021). In a similar fashion, Di Masso et al. (2019) proposed a *fixity* and *flow* framework comprised of six different categories of place attachment that range in dynamism from fixed (representing a place attachment that is centered and anchored in one place), through various ratios of fixity-flow, to flow (which has an absence of anchors and could represent virtual or imaginative travel). Like the life course approach, this framework helps to show that people can have place attachments with different levels of mobility that can change as one navigates across the life course.

Hummon's (1992) typology was one of the first to capture greater complexity in place attachment bonds by considering their emotional valence (positive or negative), their intensity (strong or weak), and their agency (active or passive). Lewicka (2011b) further developed Hummon's five-fold typology by renaming the two types of positive rootedness as *traditional* and *active* attachments (Bailey et al., 2016; Devine-Wright, 2020; Hummon, 1992; Lewicka, 2020, 2011b). They also included Hummon's three negative types of weak/non attachments, including *alienation* (dislike of place and desire to leave), *place relativity* (ambivalence or conditionally accepting attachment), and *placelessness* (place indifference or absence of emotional association with place). Of the two rooted types of positive place attachment, traditional attachments are thought to evolve through passive interaction with place (Bailey et al., 2016; Devine-Wright, 2020) by way of long-term rootedness such as familial or cultural ties (Pucker et al., 2023). Active attachments, in contrast, are more consciously made, often when people deliberately seek out a place and relocate there (Lewicka, 2020; Pucker et al., 2023). Overall, this refined typology by Lewicka has become the prevalent form used in the literature (Pucker et al., 2023).

Low (1992) furthered the idea of being able to have different types of place attachment at the same time by stating any of their proposed six types of place attachments could occur simultaneously. The different types of place attachment they proposed include genealogical, narrative, loss and destruction, economic, celebratory cultural events, and cosmological. Hay (1998) elaborated Low's genealogical type to show these historical linkages have multiple layers, including personal, familial, ancestral, and cultural (Cross, 2015). Cross (2015) also proposes several place attachment types but refers to them more as *processes* that shape residents' attachments. They state these processes are dynamic, occurring simultaneously, but each with a unique relationship to time (Cross, 2015). For example, "historical processes tend to deepen and expand attachment over time, while the narrative process might either deepen or weaken attachments … commodifying process generally fades over time while the spiritual process is notably static over time" (Cross, 2015, p. 515). They also note that these different types, or processes, of attachment can extend for long periods even after a person leaves a place (Cross, 2015).

Researchers have engaged in research that correlates various types of place attachment with different variables such as personality type, education, age, and social relations (Lewicka, 2020). There have also been studies looking for links between an individual's predominant type of attachment and their response to a disruption (Lewicka, 2020). For example, people with more active attachments may be able to adjust more quickly to a disruption than those whose place attachments are based on long-held daily routines (traditional attachments) (Lewicka, 2020). Other studies have compared types of place attachments to environmental threat response (Sullivan and Young, 2020), coping styles related to climate change (Parreira and Mouro, 2023), responses to community energy projects (Devine-Wright, 2013c; Van Veelen and Haggett, 2017), and to flood preparedness behavior (Mishra et al., 2010). These types of studies help provide more insight into how people may respond to different disruptions based on the types of attachments they have.

5.1.3 People can have attachments to places they visit for short periods of time or visit virtually

Research in residential mobility has explored place attachments and short-term and non-migratory relocation due to work travel and tourism, and in virtual settings (Bailey et al., 2021; Bissell, 2020). Innovations in travel infrastructure have increased mobility for work as well as for tourism (Di Masso et al., 2019; Gustafson, 2001). Employment-related mobility includes daily commuting, travel for work such as meetings and conferences, or relocation for longer periods of time (i.e., seasonal employment and fly-in/fly-out work; Bissell, 2020). Research in tourism explores the idea of having attachments to distant places in which we may not spend much time, especially recreation sites (Devine-Wright, 2020; Di Masso et al., 2019).

Research in such fields has brought attention to the differences between those who feel they belong in a place (i.e., insiders, such as residents who work and live in a place), and those who do not belong (i.e., outsiders, such as tourists and visitors to a place) (Gustafson, 2001; Lewicka, 2011a; Relph, 1976). For example, Gurney et al. (2021) and Marshall et al. (2019) found that after a coral bleaching event at the Great Barrier Reef, both residents and tourists reported a form of climate grief (an expected or real sense of loss due to degradation to places and ecosystems; Allen, 2020; Marshall et al., 2019) and solastalgia ("the inability to derive solace from the present state of one's environment"; Philippenko et al., 2021, p. 21). They found residents (insiders) who had a more meaningful relationship with the reef had higher rates of solastalgia and climate grief than those who were more interested in the aesthetic value of the reef (outsiders). Adams-Hutcheson (2015) found, among people relocated after an earthquake in New Zealand, that feelings of being an insider or an outsider were not mutually exclusive. Further, they found that strong place attachments could interact with the insider-outsider dynamic such that those who relocated felt like outsiders compared to those who were allowed to stay in place. This may undermine the sense of belonging and ability to make new attachments among the relocated.

Advancements in communication technologies will also require new ways of exploring how connections between people and places are evolving as more people have a 'virtually' mobile lifestyle without having to physically relocate (Barcus and Brunn, 2010). Within place attachment research scholars have proposed that virtual mobility may

overcome geographical distance, allowing one to be attached to places visited by way of visual images, or virtually online (Di Masso et al., 2019; Gustafson, 2014). In essence, allowing us to be in two places at once (Di Masso et al., 2019). The idea of being transported elsewhere through technology could help recreate, maintain, or change place attachments to places left behind as well as places people have yet to visit (Di Masso et al., 2019).

An example of the potential of technology in this context is the concept 'place elasticity,' a form of attachment proposed by Barcus and Brunn (2010) that recognizes how we can stretch our place boundaries. Such stretching is often driven by advances in transportation and technology, allowing for increasingly virtual relationships and connections with places where we used to live. Place elasticity allows for long-term engagement and connections to occur despite not living in, or even visiting, a place. This allows people to take advantage of economic or social opportunities away from the places which they physically live. Di Masso et al. (2019) emphasizes that these types of virtual attachment do not replace conventional place attachments. The research in this field challenges the long-held belief that development of place attachments is a slow process that depends on length of time in a place. Arguing that meaningful place attachments can also be created more quickly, Devine-Wright (2020) suggests follow-on questions including whether more mobile people have more place attachments, and how tangible place must be to foster attachment.

5.2 Place attachments are dynamic

5.2.1 Place attachment is a dynamic process

Place attachment research has traditionally focused more on the existence, strength and shape of attachments rather than the dynamic processes of attaching, detaching, and reattaching to place over time (Cross, 2015; Devine-Wright and Quinn, 2020; Fried, 2000; Grocke et al., 2022; Gustafson, 2014; Scannell and Gifford, 2010). Massey (1991) and Brown and Perkins (1992) were early critics of place being seen as only singular and static, which was a popular stance of humanistic geographers at the time (Dickinson, 2019). As places increasingly began to be considered more complex and dynamic, place attachments evolved along parallel lines (Dandy et al., 2019; Giuliani and Feldman, 1993; Gustafson, 2014; Lewicka, 2020). Place attachments are now thought to be dynamic, continually being (re) constructed, adapted, reshaped, and ebbing and flowing over time (Kim, 2021; Williams and Miller, 2020).

The literature sometimes refers to the process of how people-place bonds form as *building place* (Million, 1992) or *place-making* (Kothari, 2020; Williams, 2014b). Phenomenologists, such as Seamon (2014), have long argued that dynamic processes occur simultaneously to make place (Cross, 2015). For example, Seamon proposes that place-making develops through the everyday habitual body movements (i.e., walking to work, picking kids up from school etc.), that make up what he refers to as *a body ballet* of compounding daily, weekly, and monthly routines (Cresswell, 2009; Cross, 2015; Lewicka, 2011a; Seamon, 2014; Williams and Miller, 2020). Grocke et al. (2022) reiterates the idea that dynamic processes contribute to the place attachment process through "the dynamism of decision-making that constantly evaluates changes to social-environmental settings and the reiteration of the bonding process" (p. 301). Here, it is important to note, that planners, architects, and landscape architects also use the term 'place-making' but in a different context; deliberately designing places to improve community well-being and livability (Marshall and Bishop, 2015). Such work is outside the scope of this review.

Conceptual frameworks have been proposed by several authors in attempts to characterize the place attachment process after a disruption to a place or during a relocation (Brown and Perkins, 1992; Devine-Wright and Quinn, 2020; Greene et al., 2011; Inalhan and Finch, 2004; Million, 1992; Prewitt Diaz and Dayal, 2008). Although the frameworks vary, they all have a loose structure of a period before the disruption happens where there may or may not be preparation for change, followed by transition and recovery stages. The process is seen as a continuum but it is not linear in its progression (Kothari, 2020; Whittle et al., 2014). Additionally, the stages do not have clear edges and they may overlap with each other (Whittle et al., 2014). Little research has been done to understand mechanisms within the process (Lewicka, 2020; Manzo and Devine-Wright, 2020b) but it is thought to take considerable work because one must successfully let go of existing attachments (detach), re-establish old attachments, or create new ones in a new location (Brown and Perkins, 1992; Devine-Wright and Quinn, 2020; Dickinson, 2019; Perez Murcia, 2020; Zheng et al., 2019).

A few researchers have explored what happens in the transition stage of the place attachment process, finding it a dynamic time that is disorienting to people (Cox and Perry, 2011; Madanipour, 2020; Prayag et al., 2021; Silver and Grek-Martin, 2015). People feel unmoored during this period because disruption causes the loss of physical and psychological markers and forces changes to people's routines, both of which in turn affect their sense of continuity and stability (Cox and Perry, 2011; Madanipour, 2020; Silver and Grek-Martin, 2015). Eventually people start to reorientate themselves and find their bearings by reconstructing their identity as they navigate through the psychological, social, and emotional responses to change they have experienced (Binder et al., 2019; Cox and Perry, 2011). Cox and Perry (2011) found place attachment to be important to reorientation because it helped to recreate community and self-identity through repeated cycles of disorientation and reorientation. Similarly, Harms (2015) referred to circuits of displacement and emplacement with each circuit having a role in the cumulative process of place making. These studies contribute to the understanding that place attachment bonds are in a process of continuous instability and renegotiation during a disruption (Madanipour, 2020).

The recovery stage of the place attachment process after a disruption is also not well understood, especially when relocation is required (Adams-Hutcheson, 2015; Dickinson, 2019; Rumbach et al., 2016; Whittle et al., 2014; Zheng et al., 2019). The term emplacement has been used to describe the processes of building or rebuilding connections after disruption or relocation (Kothari, 2020; Perez Murcia, 2020). Similar to place-making, this can be achieved by developing new habits and rituals that will result in new (re)attachments (Prayag et al., 2021) and by "renegotiating conflicts and reconciling losses and trauma" (Zheng et al., 2019, p. 7). Million (1992) also indicates the recovery period is a time when reflective reconciliation begins and displacement recedes to the background. They add that there may be moments that "jolt us back to our loss" (p. 199) which reminds us that the recovery process is recursive and not linear (Million, 1992). As for when this recovery process might be completed, Million (1992) muses that rebuilding place may be done after "the emergence of both the past and the future alongside the present during the course of daily involvements with daily things" (p. 207). Winstanley et al. (2015) indicates that despite

irreversible change having happened, recovery is achieved when one "no longer has to renegotiate how to carry out everyday life activities, while acknowledging degrees of adaptation and change in the physical environment, in social interaction and in individual psychologies and behaviours" (p. 128).

5.2.2 Place attachments change during place change/relocation

The research is quiet about the specifics of how and when detachments and reattachments occur but there are several studies illustrating that place attachments do change when there is a disruption to place or a relocation from place. Chow and Healey (2008) are frequently referred to as one of the first to do a longitudinal study showing changing place attachments. Their research captured the transitional process first-year university students experience when they move away from home to a new social and cultural environment. Specifically, they studied students over a five-month period and found that place meanings were constantly being evaluated and re-defined after relocation. They acknowledge this may be influenced by the students' age and stage of life, both of which present other complexities. Kim (2021) also found people's attachments to place changed during neighborhood change caused by increasing short term rentals and overcrowding from tourism. In particular, they found that residents experienced fluidity in their attachment to place as they "continuously construct, adapt and reshape their connections to place" (Kim, 2021, p. 129). Further, they showed that place attachments could amplify or attenuate during neighborhood change depending on a variety of factors including proximity to development or how changes impact residents' quality of life. Cheng and Chou (2015) also found that bonds grew or weakened depending on initial levels of attachment. Considering an environmental corollary to neighborhood change, Gurney et al. (2021, p. 27) found "emotional and intangible elements of sense of place" (including pride, place identity and place attachment) became heightened during reef decline, when more "instrumental elements of senses of place" (lifestyle and aesthetics) declined.

5.3 Place attachments play a role in decisions to relocate

5.3.1 Place attachments inhibit more than prompt decisions to relocate

Understanding environmental behavior is a primary focus in place attachment research, including the role of place attachment in the decision to relocate away from a risk (Feng et al., 2022; Solecki and Friedman, 2021). Multiple factors are involved in a person's decision to relocate including economic, social, environmental, political, and emotional considerations, which make each situation unique (Chan et al., 2022; Dandy et al., 2019; Kothari, 2020). Among these factors, place attachment has been found to play an important role in a person's decision to relocate (Bukvic and Barnett, 2022; Dandy et al., 2019; Mallette et al., 2021), either inhibiting or prompting a decision to leave (Bukvic et al., 2022; Dandy et al., 2019).

Although there are examples of place attachments prompting a decision to leave (Dandy et al., 2019; Depari and Lindell, 2023; Holley et al., 2022), overall, the majority of research shows strong place attachments are a barrier to relocation (Dandy et al., 2019; Masterson et al., 2017; Steimanis et al., 2021; Swapan and Sadeque, 2021). Several studies have found individual and community place attachments, among other factors, played a role in decisions *not* to migrate (Adams, 2016; Sengupta and Samanta, 2022; Upadhyay et al., 2024), or not to relocate when exposed to climate risks in particular (Dannenberg et al., 2019; Fattah Hulio et al., 2023; Holley et al., 2022; Phillips et al., 2022; Woodhall-Melnik and Weissman, 2023; Yee et al., 2022). This seems to contradict a common perception that disasters make people devalue place and relocate to safer areas (Oracion, 2021). Nevertheless, as Gurney et al. (2021) found around the Great Barrier Reef, if a place has been threatened or disrupted sometimes people become more aware and appreciative of their environment (McKinzie, 2019), strengthening their attachment to it (Binder et al., 2019; Cox and Perry, 2011; Devine-Wright and Howes, 2010; Lemée et al., 2019; Lewicka, 2020). This phenomenon is often referred to as latent place attachment and can affect relocation decisions, often adding to people's determination not to relocate (Binder et al., 2019).

Based on the assumption that strong place attachments are a barrier to relocation, Bukvic et al. (2022) and Rey-Valette et al. (2019) mapped the strength of place attachments to predict future willingness to relocate from coastal risks in the eastern US and the south of France, respectively. Bukvic et al. (2022) found rural residents tended to have higher place attachment and determined such residents would therefore be less willing to relocate, and Rey-Valette et al. (2019) found there was a correlation between willingness to relocate and distance from the sea, where those further from the sea were more willing to relocate. Both studies were meant to inform planning and policy decisions by helping to understand who might be more open or resistant to relocation. Bukvic et al. (2022) also developed regional maps displaying exposure to coastal flooding. When compared to maps showing place attachment strength, they could identify which people living in high-risk areas may be more likely to relocate. In this situation, communities with lower place attachment could be targeted first for relocation and act as a signal for others with higher attachment to place who may be more resistant.

5.3.2 Risk perception and place attachment can influence each other in decisions to relocate

The contribution of risk perception to understanding the relationship between place attachment and decision to relocate is complex (Bonaiuto et al., 2016; Lie et al., 2023). In some cases, strong place attachment affects risk perception by making people more aware of environmental risks, resulting in increased risk coping behavior. For example, Woodhall-Melnik and Weissman (2023) found that those who were aware and concerned about future risks openly discussed willingness to relocate. Similarly, Quinn et al. (2018) found people with low place attachment were less likely to perceive flood risk and therefore less likely to feel motivated to choose adaptation measures like moving.

In other cases, strong place attachment diminishes risk perception, leading to actions that contribute to immobility (Jamali and Nejat, 2016; Lie et al., 2023; Steimanis et al., 2021). For example, Costas et al. (2015) and De Dominicis et al. (2015) both studied coastal communities facing risk from sea level rise and flooding, and found that place attachment moderated risk perception by leading to the underestimation of the impact of risk. This in turn weakened communities' risk-coping intentions. Further, Pucker et al. (2023) found strong place attachment in Hawaiian residents living in vulnerable coastal areas made them feel secure enough to

stay and handle changes that might happen to their place. This is often referred to as risk perception normalization (Dang and Weiss, 2021) or optimism bias (Solecki and Friedman, 2021). In these situations, residents seem to accept the risk (i.e., living near the coast) in exchange for benefits including the sense of permanence and stability offered to them by place attachment (Costas et al., 2015). In some circumstances however, diminishing risk perception and coping intentions could restrict other life opportunities (Jamali and Nejat, 2016), or put people in danger if they are in high-risk situations and they do not relocate (Chan et al., 2022; Dannenberg et al., 2019; Lewicka, 2011a; Masterson et al., 2017; Phillips et al., 2012).

Lastly, a few researchers have focused on how specific *types* of place attachment can affect response to a risk (i.e., stay or move away from a risk) (Devine-Wright, 2013c; Mishra et al., 2010; Sullivan and Young, 2020; Van Veelen and Haggett, 2017). With regards to making the decision to move away from a risk, Quinn et al. (2018) found people with relative (ambivalent) place attachment types at the town scale were less likely to perceive flood risk, which in turn affected their choice not to move. Similarly, Parreira and Mouro (2023) found active (intentional) attachment types were associated with higher risk perception and adoption of coping strategies like moving due to sea level rise. Lie et al. (2023) characterized different dimensions of place attachments and found bonds made through generational ties, historical knowledge, and closeness to nature increased risk awareness of flooding but did not necessarily translate into risk perception. However, Lie et al. (2023) are not alone in finding that place dependency and family bonds influenced people to not relocate (Woodhall-Melnik and Weissman, 2023).

5.4 Place attachments play positive and negative roles during place change/ relocation

5.4.1 Disruption to place attachments due to place change/relocation can have negative consequences to health and well-being

Many factors can influence individual and community place attachments after a disruption to place or due to a relocation. These include the existing characteristics of individuals and communities (Jamali and Nejat, 2016; Rumbach et al., 2016) and the characteristics of the disruption itself (Barcus and Brunn, 2010; Di Masso et al., 2019; Solecki and Friedman, 2021).

Disruptions and relocations result in physical changes as well as changes to symbolic meanings and social aspects of place (Manzo et al., 2023). Further, in personal mobility studies, it has been known for some time that frequent relocation negatively affects physical health (Stokols et al., 1983), but there is increasing understanding that relocation can also severely affect psychological health and well-being (Carroll et al., 2009). One of the earliest studies about place attachment and mobility is Fried's (1966) study on the forced relocation of a Boston neighborhood due to urban renewal. The frequently cited study found residents experienced grief and mourning when relocated. They also found that community ties either provided stability, allowing people to be highly functional, or prevented them from embracing wider life opportunities that mobility may provide (Fried, 1966). Psycho-social responses to disruptions or to a relocation can include profound feelings of loss for both tangible (possessions, homes, infrastructure), and intangible elements (Alston et al., 2018; Kothari, 2020; Prewitt Diaz and Dayal, 2008). Intangible losses can include histories, identity, social cohesion, belonging and community, and place attachments (Alston et al., 2018; Kothari, 2020).

More specifically, a disruption to a place or a relocation can strain or rupture people-place bonds (Quinn et al., 2015). This requires individuals to change or rearrange their old daily routines and habits (Dickinson, 2019; Lewicka, 2011a), and their psychological processes of cognition and affect (Zheng et al., 2019). Changes such as these can cause fear, anxiety and stress (Cheng and Chou, 2015; Phillips et al., 2022; Woodhall-Melnik and Grogan, 2019), a sense of powerlessness (Phillips and Murphy, 2021), and can produce feelings of nostalgia, alienation, or a sense of placelessness (Fullilove, 1996; Zheng et al., 2019). These feelings can undermine the positive aspects of place attachment such as a sense of stability, connectivity, security, and well-being (Fresque-Baxter and Armitage, 2012; Fullilove, 2014; Jamali and Nejat, 2016; Phillips and Murphy, 2021; Woodhall-Melnik and Grogan, 2019; Zheng et al., 2019). Research shows that relocation in particular adds stress to the disaster experience (Adams-Hutcheson, 2015) because being physically separated from your group identity and your sense of security affects mental health more profoundly (Dannenberg et al., 2019; Jamali and Nejat, 2016; McMichael and Powell, 2021; Porter, 2015; Woodhall-Melnik and Grogan, 2019).

Several expressions have been introduced to the lexicon to convey the loss, grief and mourning caused by disruptions to place or relocation from place (Fried, 2000; Phillips and Murphy, 2021; Silver and Grek-Martin, 2015). These include *solstalgia* ("the inability to derive solace from the present state of one's environment"; Philippenko et al., 2021, p. 21) and *rootshock* (a "traumatic stress reaction to the loss of one's emotional ecosystem"; Fullilove, 2014, p. 149). Both concepts have been found to affect people's ability to cope and could be exacerbated by place attachment (Fried, 2000; Gurney et al., 2021; Marshall et al., 2019; Silver and Grek-Martin, 2015). The concept of *climate grief* has also been introduced (an expected or real sense of loss due to degradation to places and ecosystems) and is applicable to disruptions that are specifically climate-related (Allen, 2020; Marshall et al., 2019).

5.4.2 Place attachments have a dualistic role in recovery from place change/ relocation

After a disruption to place or a relocation, emphasis has traditionally been on a return to normal as fast as possible with the focus on physical and economic recovery over social-psychological concerns (Cox and Perry, 2011; Dickinson, 2019). However, rebuilding community, identity and belonging is also important (Perez Murcia, 2020), and increasingly the idea of fostering physical, mental and social wellbeing in parallel is increasingly considered important for recovery (Fresque-Baxter and Armitage, 2012; Prayag et al., 2021; Woodhall-Melnik and Weissman, 2023).

A challenge identified in the literature, however, is that place attachment may have dual roles in recovery, just like it does in decision to relocate (Table 2). On the one hand, place attachments can act as a barrier to, or hindrance to recovery, potentially making it harder to move forward in the recovery process (Binder et al., 2019). For example, change may feel so overwhelming that people want to protect their existing place attachments and identities in order to maintain some stability and security, even if those are only illusory (Fresque-Baxter and Armitage, 2012). This may inhibit people detaching from

TABLE 2 Positive and negative roles of place attachment (PA) in decisions to relocate and in recovery after a disruption/relocation.

	Decision to Relocate	Recovery after a disruption/relocation
	Prompts relocation	Aids recovery
Positive	• After a disruption places may be devalued, diminishing PA (Winstanley et al., 2015; Zheng et al., 2019), which encourages people to relocate away from risk (Oracion, 2021) • Strong PA can increase bonds with the wider community, increasing desire for communal action such as, moving together to keep the community intact (Depari and Lindell, 2023) • Strong PA can increase peoples' risk perception encouraging them to move from high-risk situations (Woodhall-Melnik and Weissman, 2023)	After a disruption PA can help: • (Re)develop social ties and social capital that play critical roles in recovery (Binder et al., 2019; Cox and Perry, 2011; Prayag et al., 2021) • Unite communities, leading to communal coping (Adams-Hutcheson, 2015; Silver and Grek-Martin, 2015; Woodhall-Melnik and Grogan, 2019) PA can help provide continuity and stability: • By acting as a bridge from an old place to a new place (Di Masso et al., 2019; Manzo et al., 2023; Williams and Miller, 2024) • Via loosening PA prior to a disruption to reduce shock (Brunacini, 2023; Manzo, 2003; Prayag et al., 2021; Quinn et al., 2015) • By helping people attach quicker to new communities (i.e. settlement identity and place congruent continuity) (Berroeta et al., 2021; Feldman, 1990; Lewicka, 2020; Manzo et al., 2021; Williams and Miller, 2024)
	Barrier to relocation	Inhibits recovery
Negative	• Strong PA is one of the best indicators for why people do not want to relocate despite risk (Jamali and Nejat, 2016) • Latent PA can strengthen PA after a disruption increasing desire not to relocate despite the risk (Binder et al., 2019; Cox and Perry, 2011; Devine-Wright and Howes, 2010; Lemée et al., 2019; Lewicka, 2020; McKinzie, 2019) • PA can decrease risk perception (optimism bias/risk perception normalization) causing people to remain in place despite putting themselves at risk (Chan et al., 2022; Dannenberg et al., 2019; Lewicka, 2011a; Masterson et al., 2017; Phillips et al., 2022), and potentially miss other life opportunities (Jamali and Nejat, 2016)	• Strong PA to 'old' places can enhance feelings of pain and loss after a disruption, or make people want to protect existing senses of identity and retain a feeling of stability (Fresque-Baxter and Armitage, 2012). Both may inhibit detaching from old places and reattaching to new places, undermining a sense of belonging to new places (Adams-Hutcheson, 2015)

existing places enough to move them forward in the recovery process. Adams-Hutcheson (2015) also found strong place attachments can undermine relocated individuals' sense of belonging and ability to make new attachments if they feel like outsiders compared to those who were allowed to stay in place. Lastly, Lewicka (2020) suggested that an individual's predominant type of attachment may also affect their response to the overall impact of a disruption. Specifically, they proposed people with more traditional place attachments that are based on long-held daily routines may take longer to adjust after a disruption than those with active attachment types.

On the other hand, place attachment has also been found to act as an aid to recovery and to promote healing after a disruption (Jamali and Nejat, 2016; Paul et al., 2024; Prayag et al., 2021; Winstanley et al., 2015; Woodhall-Melnik and Grogan, 2019). For example, latent place attachments that strengthen after a disruption or relocation may inhibit detachment of old bonds, but they may also help with recovery. In particular, research has found that individual and community place attachments play a large role in the development and maintenance of social capital through social ties (Cox and Perry, 2011; Prayag et al., 2021). Social capital has been identified as playing a critical role in disaster recovery and is an indicator of overall well-being (Binder et al., 2019; Jamali and Nejat, 2016; Prayag et al., 2021; Quinn et al., 2021, 2015). However, the buffering effects of social connections may not be possible in situations where residents are relocated permanently and scattered (Quinn et al., 2021). For individuals who stay in or return to place, however, disasters can also lead to communal coping where communities come together during a disruption. This helps provide purpose, identity and fosters reconnection (Adams-Hutcheson, 2015; Silver and Grek-Martin, 2015; Woodhall-Melnik and Grogan, 2019). Understanding how to renew place attachments after a disruption or relocation may be an important factor in recovery to a new normal.

5.4.3 Place attachments may be able to provide stability during place change/relocation

Place attachment can have a positive impact on recovery by providing stability and purposeful direction while people are undergoing change (Di Masso et al., 2019; Manzo et al., 2023; Williams and Miller, 2024) (Table 2). People generally seek security and stability in their lives (Feldman, 1990; Lewicka, 2020), but rapid or ongoing changes to place can lead to feelings of instability and can affect our ontological security. Ontological security is a state that exists when one has safety and stability, both individually and collectively, that allows for the development of personal and group identity (Giddens, 1991; Laing, 1964). Brown and Perkins (1992) and later Manzo et al. (2021) proposed that people are constantly balancing a mixture of stable/fixed and changing/fluid place attachments to maintain a sense of security as they navigate through their lives. When a disruption or change occurs that overwhelms people, they may be able to find a "thread of continuity or stability" via their place attachments (Manzo et al., 2021, p. 282).

Minimizing and restoring broken bonds quickly after a disruption will obviously help maintain or re-establish a sense of security and could be important components of recovery (Lewicka, 2020). However, Brown

and Perkins (1992) and Brunacini (2023) argue that the intentional loosening of existing attachments to place and related obligations (detachment), may also be a way to help navigate periods of instability. This implies that we can prepare people by increasing their anticipation of place detachment, and untangle their emotions about a current place while simultaneously imagining a new existence in a new place (Agyeman et al., 2009; Brown and Perkins, 1992; Brunacini, 2023; Giuliani and Feldman, 1993; Tschakert et al., 2017). By encouraging detachment to begin in the pre-disruption phase, perhaps recovery can start prior to relocation and the two processes of detachment and emplacement can occur simultaneously (Kothari, 2020; Tschakert et al., 2017). This could help an individuals' stability and resilience, and potentially prompt a recovery experience more like those who relocate voluntarily (Brunacini, 2023; Manzo, 2003; Prayag et al., 2021; Quinn et al., 2015). This may work best in situations where there is a long pre-disruption phase, such as for those facing a slowly changing place or anticipating relocating in the future (Agyeman et al., 2009; Brown and Perkins, 1992; Brunacini, 2023; Giuliani and Feldman, 1993; Tschakert et al., 2017).

Residential mobility research explains how relocated people often try to (re)establish or maintain a sense of self continuity by choosing similar types of settlements (i.e., suburban, urban, rural, etc.), a phenomenon called settlement identity (Devine-Wright and Quinn, 2020; Feldman, 1990; Gustafson, 2001; Scannell and Gifford, 2010). Choosing similar settlement types may cause less disruption to people's identity and personal sense of continuity, and it may help them grow roots in new places quicker (Feldman, 1990; Lewicka, 2020). Place congruent continuity is a similar concept that describes matching one's self-concept to place features (i.e., I am a country person, I am a city person) to help maintain a sense of continuity in one's life (Feldman, 1990; Lewicka, 2020). Lewicka (2020) describes two other ways people use places to serve as sources of continuity, including place referent continuity, which is triggered by conscious or unconscious memories of place, and perceived continuity, where place is perceived through its continuous history. These concepts can potentially inform future mobility decisions and place attachment formations (Bailey et al., 2021).

Lastly, a new conceptual tool has been proposed that may give insight in how to maintain ontological security through disruption/relocation (Williams and Miller, 2024). Building on the work of early champions for a more holistic and dynamic view of place (Brown and Perkins, 1992; Cresswell, 2009; Williams and Miller, 2020), several researchers suggest that places are uncentered, complex "multi-scaled relations of materials and flows" that normalize change over time and space (Williams and Miller, 2024, p. 298). Massey (1991) refers to these structures as constellations. Others suggest webs (Raymond et al., 2021), assemblages, or rhizomes (Williams and Miller, 2024). Their rationale is that these web-like structures can easily accommodate a more progressive view of place attachment, which considers individuals and communities to have multiple place attachments that: are plural in discourse and practice, vary in type and strength (Kim, 2021; Williams and Miller, 2020), represent a broad range of positive and negative emotions (Dandy et al., 2019; Manzo, 2003), are created by a variety of memories, emotions and experience (Manzo and Devine-Wright, 2020b), and are dynamic, ebbing and flowing over time (Kim, 2021; Williams and Miller, 2020). By considering places and attachments in this way, mobility and transitions can be normalized, allowing for (re) connection of people and communities to a multiplicity of places at various spatial and temporal scales (Berroeta et al., 2021; Manzo et al., 2021; Williams and Miller, 2024). This perspective may provide people a way to feel their ontological security is less impacted through disruption or relocation (Williams and Miller, 2024).

6 Conclusion

Renewed interest in managed retreat is driven by the urgency of climate change responses. Millions of people currently live in low-lying floodplains and high-risk coastal areas, and may need to relocate in the future due to climate-related flooding and sea-level rise. Managed retreat is a difficult climate adaptation option to undertake because it triggers a complex mix of economic, social-cultural and psychological factors. Place attachment is among these psycho-social factors that can contribute to understanding more about managed retreat. Specifically, how can place attachments change over the course of managed retreat, how can managed retreat affect place attachment and vice versa, and how can place attachment impede managed retreat or promote recovery? Research into these questions is currently limited and broadly distributed across fields and vocabularies (Bukvic et al., 2022), which could partially be a result as well as cause of the incomplete conceptualization of both constructs. Taking a broader view of managed retreat as climate-induced mobility has allowed us an opportunity for insight into place attachment research that may help managed retreat researchers and practitioners move the field forward. For example, research on the broader concepts of personal mobility and forced relocation have contributed to our understanding of place attachments by way of concepts like settlement identity, place elasticity and the life course approach. Other specific findings from our review that have improved understanding of place attachment and how it may inform human responses to retreat are summarized below.

Current research supports a more progressive view of place attachment that is complex, dynamic, and frames mobility not as a threat but as something more akin to an opportunity (Dandy et al., 2019; Giuliani and Feldman, 1993; Lewicka, 2020). Growing in acceptance is the idea that places can have multiple contested identities based on different perspectives, and individuals and communities have multiple types of attachments to a place that vary in type, valence, and strength, as well as over time (Kim, 2021; Williams and Miller, 2020). Further, they can have attachments to several different places, even those they have visited temporarily or virtually. More understanding is needed about the characteristics of different type of attachments, their relationships to each other, and how they influence and respond to change (Marshall et al., 2012; Masterson et al., 2017). This web-like view of place attachments raises questions about how the number and diversity of attachments influences our mobility patterns and our response during place change or relocation.

Although research on the dynamic nature of place attachments is sparse, there is greater receptivity to the possibility that they can change over time as they are continually (re)constructed, adapted, and reshaped (Kim, 2021; Williams and Miller, 2020). Disruptions to place, including relocation, reveal there is a non-linear, fluid process that place attachments may follow through pre-transition, transition, and recovery stages. Little is known about the temporal characteristics of each stage or how bonds detach and reattach. However, there is some understanding that the transition period is a tumultuous time when people move through cycles of disorientation and reorientation, which may help them move toward recovery by detaching, reorienting, and

renegotiating place attachments (Cox and Holmes, 2000; Harms, 2015; Silver and Grek-Martin, 2015). We concur with researchers who call for more research to understand processes about how bonds to place are formed, developed, and sustained over time, as well as what happens when they are disrupted (Bailey et al., 2016; Brunacini, 2023; Cheng and Chou, 2015; Cross, 2015; Manzo and Devine-Wright, 2020b; Lewicka, 2011a). There is specifically a gap about place attachment changes during relocation (Adams-Hutcheson, 2015).

Making the decision to relocate is complex and is influenced by many factors including place attachment. The literature also indicates that place attachments have a dualistic role, helping or hindering the decision to relocate, and during recovery after a place change or relocation. This dual nature of place attachment is complicated, and there is still a lot of work needed to disentangle the nuances of the nature of place attachment and how it motivates some people to relocate, while constraining others (Woodhall-Melnik and Weissman, 2023).

There is a growing understanding that disruption to place attachments can have negative consequences on people's physical *and* mental health and wellbeing. However, the stability and ontological security that place attachments provide, and which can have positive effects, are less understood. The promise that place attachment offers in reinforcing self-continuity should be better studied to understand its utility for promoting recovery and reinforcing self-continuity in persons who experience managed retreat (Brown and Perkins, 1992; Brunacini, 2023; Giuliani and Feldman, 1993; Lewicka, 2020; Masterson et al., 2017; Tschakert et al., 2017).

Full pre-and-post disruption longitudinal studies are presently rare but would be helpful to understand the dynamism of the psycho-social processes, including place attachments, that people undergo following disruption over a long period of time (Cox and Perry, 2011; Cross, 2015; Dang and Weiss, 2021; Devine-Wright and Quinn, 2020; Kothari, 2020; Lewicka, 2011a; Masterson et al., 2017; Zheng et al., 2019). As well, more qualitative studies are needed as they can offer a more nuanced understanding about decisions to relocate and the place attachment process, than can traditional quantitative studies that use surveys and self-report measures to determine the existence and strength of place attachments (Binder et al., 2015; Cheng and Chou, 2015; Devine-Wright and Quinn, 2020; Herandez et al., 2020; Lewicka, 2011a). For example, Simms et al.'s (2021) qualitative study of Isle de Jean Charles residents helped policy makers understand the deep connection residents had with their land and resulted in a change to a standard policy restricting access to properties left behind. By allowing continued access to their old land, residents have been able to maintain some emotional connection to the 'old' place, which played a role in their decision to accept a buyout while easing the relocation transition.

Findings from this review have improved our understanding of place attachments and how they may inform human responses to retreat which will be helpful at both the theoretical and practical levels (Agyeman et al., 2009; Devine-Wright and Quinn, 2020; Low and Altman, 1992; Quinn et al., 2015). Further, the findings highlight opportunities where future place attachment research can potentially play a role in easing the stress and trauma caused by the increase in managed retreat expected in the future.

Author contributions

RW-M: Conceptualization, Funding acquisition, Investigation, Methodology, Writing – original draft. JB: Conceptualization, Methodology, Writing – review & editing. KF: Conceptualization, Methodology, Writing – review & editing. JW-M: Methodology, Writing – review & editing. KS: Conceptualization, Funding acquisition, Methodology, Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Improving economic assessment and decision-making for managed retreat through CBA+: a targeted literature review

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There is growing recognition that managed retreat, also known as strategic relocation, could be an increasingly important adaptation measure in the face of climate change and rising natural hazard risk. However, managed retreat's potential benefits are limited by challenges in funding, negative participant experiences, public and political opposition, uncertainty in long-term climate change and natural hazard risk, and equity concerns, all of which increase the complexity of managed retreat decision-making. While there is some research on how economic assessment tools can be used to aid in managed retreat decision-making, there is a knowledge gap in how these practises contribute to both the causes and potential resolution of the challenges associated with managed retreat. To begin to fill this gap, this paper presents a targeted literature review on the nexus between managed retreat, cost–benefit analysis of climate change adaptation and natural hazard risk reduction, and alternative economic assessment and decision-making tools. We identify connections between economic assessment practises and the primary challenges associated with managed retreat and then present several avenues where changes or additions to standard economic assessment approaches such as cost–benefit analysis (which we collectively refer to as 'CBA+') could lead to better managed retreat outcomes. Finally, we present a framework and 10 key principles that summarise key aspects of CBA+ to help agencies involved in managed retreat improve outcomes through economic assessment and decision-making process design. The most important key principles are the context- and community-specific design of economic assessment and decision-making processes, and the need for ongoing and thorough community engagement and co-production.

KEYWORDS

managed retreat, cost–benefit analysis, strategic relocation, economic assessment, climate change adaptation, disaster risk reduction, decision-making

1 Introduction

Managed retreat – the purposeful, coordinated movement of people and assets out of harm's way (Siders, 2019a) – has received increasing attention among academics and practitioners in the fields of climate change adaptation (CCA) and disaster risk reduction (DRR) in recent years (Pinter, 2021; Boudreault et al., 2023). As flood intensities and losses rise (Dottori et al., 2018), and with climate change projections of increasing storm intensity (Seneviratne et al., 2023) and likely sea level rise of up to 1.1 m by 2,100 (Oppenheimer and Glavovic, 2022), there is growing recognition that managed retreat may play an important role in reducing natural hazard risk and adapting to climate change (Kick et al., 2011; Binder et al.,

2015; Siders, 2019a; Mach and Siders, 2021; Taylor Aiken and Mabon, 2024).

Managed retreat has many potential advantages, including avoiding costly repeated loss-rebuild cycles (Greer and Binder, 2017), fully eliminating hazard exposure (Siders and Keenan, 2020), avoiding the negative impacts of flood protection works (Abel et al., 2011; Hino et al., 2017; Mach and Siders, 2021), and providing amenity and protection benefits for the surrounding community through naturalisation of the affected lands (Dedekorkut-Howes et al., 2020; Dodman et al., 2022; O'Donnell, 2022). However, challenges have arisen related to how managed retreat projects are selected, designed, and implemented, and their resulting outcomes. These challenges will be discussed in more depth in Section 2, but include:

- poor participant experiences (e.g., long timelines, confusing bureaucracy, insufficient monetary and other supports) (Siders, 2019b; Nguyen, 2020; Dundon and Abkowitz, 2021; Ehrenfeucht and Nelson, 2023),
- equity concerns over the selection, process, and outcomes of managed retreat (Siders, 2019b; Kraan et al., 2021; Ajibade et al., 2022; Thistlethwaite et al., 2023),
- lack of proactive planning and implementation (Saunders-Hastings et al., 2020; Ajibade et al., 2022; Thistlethwaite et al., 2023) and,
- difficulty acquiring funding and maintaining programmes and institutional knowledge (Greer and Binder, 2017; Shi et al., 2022; Cottar and Wandel, 2024).

These challenges contribute to negative outcomes for many participants and communities (Greer and Binder, 2017; Mach and Siders, 2021) and a failure to fully capitalise on managed retreat's potential benefits (Braamskamp and Penning-Rowsell, 2018), leading to strong public and political opposition in many areas (Dundon and Abkowitz, 2021; Dodman et al., 2022).

One factor contributing to these challenges is the difficulty inherent in managed retreat decision-making. Deciding whether, where, and in what manner to relocate people and infrastructure requires considering a wide range of potential impacts, many of which are intangible and difficult to measure (Kind, 2014; Hudson and Botzen, 2019). Other challenges include trying to accommodate different visions for the community's future (Mach and Siders, 2021), and attempting to evaluate different forms of managed retreat in comparison to each other and against other forms of adaptation [e.g., Turner et al. (2007), Revell et al. (2021)]. It is also difficult to incorporate the many uncertainties related to the timing and magnitude of climatic and social change into decision-making (Lawrence et al., 2020).

Although various economic assessment (EA) tools have been used to help communities evaluate the many factors required in CCA and DRR decision-making in a systematic way, the most common tool has been cost–benefit analysis [CBA; Markanday et al. (2019)]. However, CBA has faced many criticisms related to how it is typically applied to CCA and DRR decision-making. Criticisms of CBA include: its requirement to monetize all impacts; difficulty accounting for the 'deep uncertainty' inherent in long-term climate change; ignoring issues of equity and differential distribution of costs and benefits; undervaluing future generations (Lempert, 2014; Markanday et al., 2019); and being incommensurable with Indigenous value systems (Choy, 2018). These criticisms, described in more detail in Section 3.1, can be particularly impactful when CBA is applied to managed retreat.

When compared to other adaptation measures, managed retreat has a broader range and often greater weight placed on intangible impacts (e.g., attachment to place, community cohesion) (Agyeman et al., 2009; Skidmore and Cohon, 2022), has more significant equity concerns (Siders, 2019b), and is strongly affected by climate change uncertainty (Abel et al., 2011; Dodman et al., 2022; Keeler et al., 2022). Moreover, the risk reduction achieved by managed retreat is permanent, with little or no ongoing costs, making results highly sensitive to the choice of time horizon and discount rate (Boardman et al., 2018).

Despite CBA's shortcomings when applied to managed retreat, and CCA more broadly, it is widely used and often plays a large role in decision-making (Alexander et al., 2016; Markanday et al., 2019). CBAs are also required when applying for funding and other supports in some jurisdictions [e.g., US Federal Emergency Management Agency's (FEMA) Hazard Mitigation Assistance Programme (FEMA, 2024)] and this has further entrenched CBA in those jurisdictions as a widespread and enduring decision-making tool for managed retreat. Therefore, how CBA is designed, implemented, and interpreted for managed retreat programmes may have substantial impacts on programme outcomes. Thus, improving CBA practises is a promising research avenue that may help to achieve better managed retreat outcomes.

To date, there has been minimal examination in the literature of how the use of EA tools like CBA influence the outcomes of managed retreat. This research gap includes both how EAs and decision-making processes could be contributing to poor managed retreat outcomes, and how improvements to these tools and processes could lead to better outcomes.

This paper aims to address this knowledge gap through a targeted literature review and analysis of three bodies of literature: (1) managed retreat, (2) CBA of DRR and CCA, and (3) alternative EA and decision-making tools [e.g., multi-criteria decision analysis (MCDA), robust decision making (RDM), real options analysis (ROA), and dynamic adaptive policy pathways (DAPP) (Haasnoot et al., 2013)]. Searches were conducted using the University of Waterloo's Omni catalogue system, which includes 445 databases (e.g., Web of Science, Scopus, Science Direct). Inclusive search terms were used to account for synonyms of managed retreat (e.g., 'strategic retreat,' 'planned relocation,' 'managed realignment,' 'buyout') and CBA (e.g., 'cost–benefit analysis,' 'benefit–cost analysis,' 'economic assessment'). In addition to individual searches for 'managed retreat' and its many variations, additional searches were conducted combining each of these variations with each of the supplementary economic assessment and decision-making types and their variations (i.e., CBA, MCDA, ROA, RDM, DAPP), as well as citation mining for relevant papers referenced in the primary findings. A total of 128 studies and reports are included in this review, with 14 of those studies presenting an EA of managed retreat. A systematic review was not conducted because of the impracticalities related to the large size of the three individual bodies of literature and the many forms that overlap between these bodies of literature could take. Instead, the targeted review presented here is meant to explore the main themes from each body of literature, identify how the underexplored overlap between these areas could offer insights to improve managed retreat outcomes, and demonstrate

the potential value of further research within the three bodies of literature.

The remainder of the paper is organised as follows. Section 2 presents a review of the challenges associated with managed retreat. Section 3 provides an overview of EA's use for managed retreat, beginning with particular challenges and special considerations when using CBA for managed retreat (Section 3.1), followed by a review of current literature on the EA of managed retreat, including alternative and complementary tools, like MCDA, RDM, ROA, and DAPP (Section 3.2). Section 4 provides a discussion of the linkages between EA and managed retreat outcomes, and identifies potential avenues where changes or additions to cost–benefit analysis (which we collectively refer to as 'CBA+') could lead to better managed retreat outcomes. Finally, we present a framework and 10 key principles related to CBA+ which will provide guidance for community- and context-specific decision-making processes that could improve managed retreat outcomes.

A note on terminology and context: The term 'managed retreat' is somewhat controversial and contested, with many alternatives and nuances in definition proposed across the literature (O'Donnell, 2022; Thistlethwaite et al., 2023). This paper uses 'managed retreat' as an umbrella term to broadly capture all programmes which permanently relocate people and infrastructure in a planned and strategic way in order to reduce natural hazard risk and/or adapt to climate change. This includes programmes that may otherwise be described as buyouts, relocation, resettlement, retreat the line, managed realignment, or other similar terms. This paper largely focuses on managed retreat in the context of Western nations where a central organising body is involved (e.g., municipal government) and does not explore climate migration or autonomous relocation. This review also focuses on managed retreat mainly in the context of flooding as that is the most common application in the literature, however we assume the same approaches and concerns could broadly apply to other natural hazards, such as geomorphic hazards (e.g., landslide, coastal erosion) or wildfire (McConnell and Koslov, 2024).

2 Challenges related to managed retreat

In order to evaluate how EA and decision-making practises may affect managed retreat outcomes, it is first necessary to understand the challenges facing managed retreat as a mainstream CCA and DRR strategy. This section provides a summary of the challenges related to managed retreat, however for more detailed discussions please see (Freudenberg et al., 2016; Siders, 2019a, 2019b; Saunders-Hastings et al., 2020), as well as the additional citations below.

2.1 Contested goals and objectives

A fundamental challenge for managed retreat decision-making is a lack of agreement on what it means for retreat to be successful (Hino et al., 2017; Ajibade et al., 2022). CCA is a classic 'wicked problem' (Siders and Pierce, 2021) where 'success' can be defined differently by different parties, or when examined at different scales (Ajibade et al., 2022). Although early managed retreat programmes typically focused on measures of success linked to technical, managerial, and compensation targets, this is now changing (Ajibade et al., 2022). Factors of success now commonly include broader objectives like achieving equitable outcomes, community empowerment, ecosystem restoration, or addressing inequity and injustice (Greer and Binder, 2017; Pinter, 2021; Ajibade et al., 2022; Bower et al., 2023; Ehrenfeucht and Nelson, 2023).

A lack of clarity and agreement on objectives and priorities exacerbates the already challenging decision-making landscape of managed retreat. For example, how various objectives are prioritised can lead to ignoring some values, prioritising some values over others (e.g., intangible community values versus monetized impacts of flood damage) or assessing those values in a different way (e.g., the use of pre-flood versus post-flood property valuations), which can affect the selection, manner of implementation, and participant outcomes of managed retreat.

2.2 Equity concerns

Equity and inequity concerns are central themes across the managed retreat literature [e.g., Hino et al. (2017), Siders (2019b), Kraan et al. (2021)]. Land use and housing issues, including location, market value, community characteristics, and natural hazard vulnerability, are strongly tied to economic and social factors, as well as histories of discrimination and forced relocation (Ajibade et al., 2022; Tubridy et al., 2022). Managed retreat directly interacts with these factors and histories through the selective purchase or non-purchase of homes, targeting certain neighbourhoods over others, decisions to pursue other adaptation measures instead of retreat, and in some cases, forced relocation through expropriation. The distribution and characteristics of where managed retreat is considered and implemented therefore has the potential to raise a variety of equity-related concerns.

There are many examples of equity issues identified in the managed retreat literature. Some examples include: the overrepresentation of lower income and minority communities in flood-prone areas, and thus potential for managed retreat, due to histories of racism and colonialism (Hino et al., 2017; Lieberknecht and Mueller, 2023); wealthier neighbourhoods being prioritised for structural protection (Lieberknecht and Mueller, 2023); and reduced 'voluntariness' of buyout programmes in lower income and more vulnerable neighbourhoods (Greer et al., 2022). As the name suggests, buyouts are typically aimed only at property owners, providing little or no support for renters, who are often lower income, and support is typically lacking for mobile home residents who may own their home but not their land, leading to distinct vulnerabilities (Marino, 2018; Dundon and Camp, 2021; Kraan et al., 2021).

When communities actively seek to be relocated, lower income, minority, and Indigenous communities (e.g., Isle de Jean Charles, Louisiana, and Shishmarif and Newtok, Alaska) also have more difficulty accessing government funding and support (Hino et al., 2017; Marino, 2018; Pinter, 2021). Since most buyout programmes focus on the household rather than community scale, Indigenous communities may find it difficult to access funding and support for managed retreat due to their lack of privately owned homes and land.

Taken together, it is not always clear if, or when, managed retreat is working as envisioned by removing the most vulnerable people and structures from hazard exposure, or, if already disadvantaged

segments of society are being unfairly targeted and coerced to participate and, in doing so, lose important community supports (Greer and Binder, 2017).

2.3 Poor experiences and implementation issues

Many studies have investigated the challenges of managed retreat from the perspective of both participants and the implementing agencies, identifying a range of common issues related to poor participant experience, some of which can have long-term, negative quality of life impacts. Some common challenges include:

- lengthy timelines, which can affect insurance claims and/or prevent participants from leaving high-risk areas or precarious housing arrangements (Nguyen, 2020; Dundon and Camp, 2021);
- insufficient compensation to relocate to areas with lower natural hazard and social vulnerabilities (McGhee et al., 2020),
- lack of transparency and poor communication (Siders, 2019b),
- feeling pressure to accept buyout offers in nominally 'voluntary' programmes (Greer et al., 2022);
- buyout eligibility based on fixed property damage thresholds that limit homeowner options (Siders, 2019b),
- post-retreat patchwork neighbourhood patterns, resulting in decreased or more costly infrastructure maintenance and negative community impacts (Kraan et al., 2021) and,
- negative income effects following relocation (Hoang and Noy, 2023).

Additional planning challenges have been identified that influence the likelihood of managed retreat being selected over other adaptation alternatives and whether objectives are met during implementation. Funding challenges are common due to high property costs and a lack of funding programmes that allow for property buyouts, particularly without an instigating disaster (Lawrence et al., 2020; Saunders-Hastings et al., 2020; Dodman et al., 2022). Local authorities also often lack the administrative capacity and financial resources to plan managed retreat programmes (Lawrence et al., 2020; Dodman et al., 2022). In post-disaster buyouts, the objective to carry out rapid managed retreat via short programme timelines often conflicts with the need for thorough community engagement and community visioning (Saunders-Hastings et al., 2020; Kraan et al., 2021). In many communities there is a lack of available land and/or housing, especially affordable housing with lower natural hazard and social vulnerability (Abel et al., 2011; Doberstein et al., 2020). And lastly, there are significant challenges related to planning and making decisions under uncertainty, often with different participant objectives and conceptions of success (Eriksen et al., 2015; Bloemen et al., 2019).

2.4 Public and political opposition to retreat

The idea of relocation due to natural hazard risk can be contentious, and managed retreat has become so controversial in some communities that it is difficult or impossible to discuss (Anderson, 2022). The concept of managed retreat raises difficult conversations around community and societal values, and what can or cannot be protected (O'Donnell, 2022). Managed retreat is often downplayed or dismissed due to misperceptions of risk (Driessen et al., 2016; Dundon and Abkowitz, 2021) or viewing managed retreat as a threat to real estate values (Landry et al., 2003; Dedekorkut-Howes et al., 2020; Hashida and Dundas, 2023). The fairness of retreat-related compensation is commonly questioned, which can be seen as either a wealth transfer to affluent homeowners who knowingly took on risk (Siders, 2019b; Tubridy et al., 2022), or as insufficient compensation for households in need (Braamskamp and Penning-Rowsell, 2018; Thistlethwaite et al., 2020; Ehrenfeucht and Nelson, 2023). Discussing managed retreat can also be a political risk as there can be strong pressure to maintain the status quo (Gibbs, 2016; Anderson, 2022; Keeler et al., 2022).

Many residents also have a strong sense of place attachment or place dependency, which may lead to opposition to retreat (Siders, 2019a; Mach and Siders, 2021), and this is often accentuated by fears of community erosion and patchwork retreat patterns (Braamskamp and Penning-Rowsell, 2018; Mach and Siders, 2021). Government-run, non-risk-based insurance and disaster financial assistance programmes can further incentivise living in high-risk areas by shielding residents from the financial consequences of natural disasters (Dundon and Abkowitz, 2021; Dodman et al., 2022), factors which may need to be accounted for in managed retreat planning and EAs.

The main risk posed by public and political opposition is that managed retreat will be left off the table when communities discuss CCA and DRR alternatives. Failing to consider the full suite of adaptation alternatives not only increases the chance of maladaptation and the associated increase in future negative impacts (Wise et al., 2014), but can also cause communities to miss out on the benefits of proactive planning for a potential future where managed retreat might be required, even if it is not the preferred approach at the present time (Lawrence et al., 2020).

2.5 Proactive versus reactive retreat

Although proactive managed retreat is rare (Lawrence et al., 2020; Hanna et al., 2021), there are many benefits of proactive rather than reactive retreat (Saunders-Hastings et al., 2020). Ajibade et al. (2022, p. 8) suggest that pre-emptive managed retreat is more likely to be broadly successful compared to reactive examples as it 'may allow for a variety of logistical, economic, socio-cultural, and intersectional justice concerns to be centred and addressed before a resettlement programme is implemented.' Similarly, Siders et al. (2019, p. 761) observed that 'a preferred alternative is for retreat to be integrated into the pursuit of broader societal goals… and its implementation tailored to context-specific goals.' Relying solely on reactive retreat therefore contributes to path-dependence and potential maladaptation (Kwadijk et al., 2010; Haasnoot et al., 2021; van Alphen et al., 2022). Reactive managed retreat also reduces the possibility of using 'retreat lands' for flood protection and other nature-based solutions like dune or wetland enhancement (Haasnoot et al., 2019; Dodman et al., 2022).

Reactive managed retreat also inherently brings a host of negative impacts related to the double trauma of first experiencing a disaster and then experiencing a reactive buyout. Common negative impacts include: psychological stress and trauma (Hudson et al., 2019);

emergency response and clean-up costs (Nelson and Camp, 2020); environmental contamination (Dedekorkut-Howes et al., 2020); loss or damage of items/resources that could have been relocated (Hudson et al., 2019), some of which cannot be replaced or repaired (Heikkila and Huang, 2014); injury and loss of life (Jonkman et al., 2008); major quality of life impacts, such as triggering homelessness (Kind, 2014); and economic losses from the inefficient nature of recovery spending (Heikkila and Huang, 2014). Many, if not all, of these impacts could be avoided through proactive approaches to managed retreat.

3 Economic assessment of managed retreat

The technical, long-lasting, and uncertain nature of CCA and DRR planning makes managed retreat decision-making a highly complex endeavour. Using established, holistic EA tools can help decision-makers better understand complex situations, facilitate the comparison of different alternatives and trade-offs (Middlesex University Flood Hazard Research Centre, 2014; Boardman et al., 2018), improve communication (De Brito and Evers, 2016; Boardman et al., 2018), and increase transparency (Robertson and Shaw, 1999, 2006). Although many EA tools are available to help make evidence-based, transparent, and efficient CCA and DRR decisions that meet societal objectives, the most common is CBA (Alexander et al., 2016; Markanday et al., 2019). The widespread use of CBA (with its significant criticisms) means that improvements in CBA practises could also confer substantial benefits on managed retreat outcomes. Although this section focuses on CBA, the general concepts and concerns discussed also apply to the practise of EA more broadly. Alternative forms of EA, and their comparative strengths and weaknesses, are discussed in more detail in Sections 3.2 and 4.4.

In its idealised form, CBA's aim is to identify the course of action that maximises total societal welfare by assessing all the costs and benefits of each alternative by converting the potential positive and negative impacts to a common, monetary measure (Kind et al., 2017; Boardman et al., 2018). In practise, CBAs are typically limited in scope to the costs and benefits that can be easily measured/quantified, or that are deemed to be most important to the decision.

The detailed methodology of CBA is beyond the scope of this paper, but broadly, the steps involved include:

1 Identifying alternatives that may fulfil the project's goals and objectives
2 Monetizing relevant costs and benefits for each alternative relative to a baseline scenario
3 Discounting future costs and benefits to their present value
4 Summing the discounted costs and benefits for all 'affected people' included in the analysis
5 Comparing the total costs and benefits to calculate the Net Present Value (NPV), Benefit–Cost Ratio (BCR), and/or Return on Investment of each alternative

In the absence of other considerations, the alternative with the highest NPV is seen as providing the greatest societal benefit and is selected; alternatively, every project where net present benefits outweigh net present costs (i.e., positive NPV or BCR > 1) would be recommended for implementation or further consideration (Boardman et al., 2018).

While this concept seems appealing as a way to simplify complex decision-making and demonstrate efficient use of public funds (Alexander et al., 2016), there are many nuances, challenges, and potential biases that limit CBA's utility, particularly in complex realms like managed retreat.

3.1 Challenges and special considerations for CBA of managed retreat

Section 3.1 summarises criticisms of how standard CBA practises have typically been implemented for CCA and DRR evaluation and identifies special considerations where these approaches may present particular challenges for managed retreat.

3.1.1 Value selection and monetization

A commonly cited limitation of CBA is the requirement to monetize all impacts (positive and negative) and the resulting prioritisation of market values (e.g., infrastructure) over non-market values (e.g., social capital, spiritual values) (Moore, 2012; Li et al., 2014; André et al., 2016; Markanday et al., 2019). Managed retreat CBAs commonly undervalue or omit many potentially important values, such as:

- ecosystem services (Moore, 2012; Li et al., 2014; Markanday et al., 2019; Dodman et al., 2022),
- health impacts (Heikkila and Huang, 2014; Markanday et al., 2019),
- psychological impacts of managed retreat or experiencing a disaster (Hudson and Botzen, 2019; Nelson and Camp, 2020),
- place attachment (Heikkila and Huang, 2014; Nguyen, 2020),
- Indigenous values (Choy, 2018),
- lost social connections and sense of community (Heikkila and Huang, 2014; Hanna et al., 2020),
- planning, public engagement, and other pre-retreat transaction costs (Tubridy et al., 2022),
- co-benefits from the post-retreat lands and reduced residual flood damage (Lawrence et al., 2019) and,
- post-retreat land rehabilitation, social supports, and impacts on the receiving community (Tubridy et al., 2022).

These are potentially serious limitations since including or excluding a given value can change the preferred alternative (Meyer et al., 2012), shift the NPV from negative to positive or vice versa (Brouwer and Van Ek, 2004), or lead to recommendations that do not represent the true costs and benefits of managed retreat (or its alternatives) or that do not represent the values of the affected community. However, measuring these non-market values in a way that is commensurate with easily monetized market values is difficult, requiring additional resources, and is subject to assumptions and uncertainty (Hudson and Botzen, 2019) so it is not always clear or agreed upon which values are appropriate to monetize (Markanday et al., 2019).

3.1.2 Indigenous values and substitutability

The issues of value selection and monetization are particularly challenging when applying CBA to Indigenous communities.

Indigenous communities likely have values that are at odds with CBA's utility theory and welfare economics roots of individual utility maximisation and aggregation (Kind et al., 2017; Boardman et al., 2018), such as Indigenous conceptions of community wellbeing and communal property rights and obligations (Venn and Quiggin, 2007; Choy, 2018).

Traditional CBA, and the Kaldor-Hicks compensation test on which it is based, requires substitutability between sources of utility (i.e., any loss can be exactly offset by any gain of the same value) (Boardman et al., 2018). The non-substitutability typical of many Indigenous values makes it difficult, or potentially impossible, to use CBA to evaluate some impacts on Indigenous peoples and land (Venn and Quiggin, 2007; Choy, 2018; Manero et al., 2022). Opinions differ on whether it is better to attempt to quantify Indigenous values to ensure they are not ignored, or whether these values must be considered outside of CBA due to worldview incompatibility (Venn and Quiggin, 2007; Choy, 2018). Questions of substitutability are also relevant to discussions of 'strong' vs. 'weak' sustainability and whether natural and human capital should be viewed as substitutable in CBAs (Ekins et al., 2003).

3.1.3 Deep uncertainty

Planning for CCA and DRR involves confronting interacting and compounding uncertainties, such as the effectiveness and cost of adaptation and risk reduction measures, future changes in both climate and social systems, and the measurement of non-market values (Hanna et al., 2020). Additional technical uncertainties arise from challenges in downscaling climate change projections, particularly for extreme events and small-scale watersheds (Hinkel et al., 2019; Haasnoot et al., 2021), and in damage modelling that translates flood depths into societal impacts (Merz et al., 2010; Woodward et al., 2014; Nelson and Camp, 2020).

Although CBAs account for uncertainties with known probabilities by using expected value calculations (i.e., the weighted average of the possible values an uncertain parameter could take, weighted by the probability of each outcome), this approach is challenging or impossible to use when faced with complex, compounding uncertainties (Hanna et al., 2020), and does not work at all for 'deep uncertainties' where probabilities cannot be assigned due to uncertainty about basic mechanisms and relationships (Hinkel and Bisaro, 2015; Buurman and Babovic, 2016). As future climate and cultural conditions depend on unknowable future societal choices, rates of technological progress, and poorly understood climate change feedbacks, CCA and DRR planning is fraught with 'deep uncertainties' (Buurman and Babovic, 2016; Bloemen et al., 2019; Haasnoot et al., 2019). CBAs may therefore provide inadequate information to understand the nature and consequences of uncertainty and whether any given adaptation measure will be robust to the range of potential futures (e.g., rates of climate change, changing societal risk tolerance). CBAs may even lead to decisions based on 'spurious certainty' and an overreliance on a single source of information (Biggs et al., 2009).

3.1.4 Discount rates and time horizons

The practise of discounting within CBA is used to make the value of future costs and benefits more comparable to those incurred today, considering both the opportunity cost of the chosen alternative and humanity's inherent immediacy preference. The discount rate determines the magnitude of the preference for the near over the far future; the 'present value' of future costs and benefits decreases with larger discount rates and as impacts move further into the future (Boardman et al., 2018). It is important to recognise that traditional discount rates based on expected investment returns can strongly bias CBA results against alternatives with high immediate costs but larger long-term benefits, such as managed retreat (Dennig, 2018; Markanday et al., 2019).

Many proposals have been made to address the challenge of assigning discount rates for CCA, such as low, declining, zero, or even negative discount rates (Turner et al., 2007; Li et al., 2014; Dennig, 2018; Markanday et al., 2019; Nelson and Camp, 2020). In contrast to these views, Dudley et al. (2019) argue that discounting theory is sound and adopting different discount rates for temporally remote events introduces bias. With no consensus, government-prescribed or typical discount rates are commonly used, often without consideration of the decision context, and sensitivity analyses are performed to examine how different discount rates would change the resulting rankings (Kind, 2014; Li et al., 2014; Dawson et al., 2018; Nelson and Camp, 2020).

Since the benefits of managed retreat typically continue far in the future, time horizon and discount rate choices can substantially impact CBA outcomes (Hino et al., 2017; Dennig, 2018; Dudley et al., 2019; Haasnoot et al., 2020) and can have large intergenerational equity implications (Markanday et al., 2019). The time horizon for EAs is often set as the lifespan of the proposed infrastructure investment (Boardman et al., 2018). However, since managed retreat is often compared to infrastructure-based alternatives, such as a protective floodwall, it is common to use time horizons based on those infrastructure lifespans, despite managed retreat's benefits accruing in perpetuity.

3.1.5 Scenario, boundary, and baseline selection

The design and selection of EA scenarios are important for all EAs since excluded scenarios are automatically precluded from analysis, and analyzing unfeasible or unrealistic scenarios does not aid in planning (Dawson et al., 2018; Li et al., 2014). Note that within this paper the term 'alternative' is used to describe the overarching adaptation measure being considered (e.g., managed retreat, seawall construction, beach nourishment), while 'scenario' includes both the adaptation alternative and all the additional specifications (e.g., timing, staging, and scale of implementation, comparing different compensation schemes) that differentiate each of the variations being assessed within an EA.

CBAs also require setting geographic and political boundaries and identifying who has status as an 'affected person' (Li et al., 2014; Boardman et al., 2018). These choices dictate the scale at which costs and benefits are assessed, and influence which effects are interpreted as transfers or redistributions within the system, and therefore as net-neutral (Boardman et al., 2018). For example, CBAs at the scale of a local government may view post-retreat property tax reductions as a cost (i.e., if relocated individuals move out of the community), while at a higher-scale this would be viewed as a net-zero change (i.e., tax payments by relocated households continue, but in another community). Similarly, some land uses may continue elsewhere following relocation or rezoning, which could be a low- or zero-cost effect at a higher scale but may appear as a loss at a local scale (Brouwer and Van Ek, 2004).

Finally, scenarios should be compared to an approximation of a future where none of the alternatives are implemented, known as the baseline, rather than assuming that conditions will remain unchanged (Boardman et al., 2018). In the case of a post-disaster CBA for managed retreat, the baseline would be a community in which flooded homeowners rebuild in place and then continue to suffer flood risks or periodic loss/rebuild cycles. Setting realistic baselines is a difficult process: uncertainties in future economic growth, technological innovation, cultural change, and the degree to which individuals take on autonomous adaptation independent of community initiatives add further uncertainty, particularly for the long time frames involved in managed retreat (Moore, 2012; Li et al., 2014; Watkiss et al., 2015).

3.1.6 Non-marginal impacts, equity, and risk aversion

Traditional CBA theory assumes that costs and benefits are marginal (i.e., they are incremental changes small enough not to disrupt larger systems), however, this assumption can be broken by the disruptive impacts of extreme events (Adler, 2016; Dudley et al., 2019). This is particularly important for low income and other vulnerable populations where disasters may have disproportionately large effects, such as inducing homelessness or triggering large out-migrations (Kind et al., 2020). One solution is the use of risk aversion and/or equity weights, which assign greater value to impacts that make up a large percentage of total wealth, or to all impacts experienced by lower-income households, respectively (Kind et al., 2017, 2020). However, the use of equity and risk aversion weights is uncommon because assigning weights can be seen as imposing an external value system, CBAs typically assume redistribution will occur elsewhere in society (e.g., via the tax system), and using weights requires expert judgement and additional information on the affected population and the distribution of impacts, which may not be available (Kind et al., 2017, 2020; Markanday et al., 2019; US Office of Management and Budget, 2023).

3.1.7 Subjectivity and comparisons

The sometimes subjective and inconsistent choice of discount rates, values, time horizons, and other CBA parameters makes it difficult to compare and extrapolate results from one study to another (Dedekorkut-Howes et al., 2020). While a standardised CBA process for CCA and DRR could help overcome these challenges, prescriptive CBA methods may prevent the necessary community- and context-specific aspects of good CBA design, and could entrench poor practises, such as excluding particular non-market values (André et al., 2016). CBA's subjectivity, enacted through many parameter and value choices, can also reinforce local or institutional biases, preventing new perspectives or more transformational changes from being considered or implemented (Siders and Keenan, 2020). For example, selecting a short time horizon and high discount rate, and focusing on real estate value and other market impacts, could be used to bias decision-making away from considering managed retreat.

3.1.8 Optimism bias and overreliance on cost–benefit analysis

Despite the issues discussed in Sections 3.1.1–3.1.7, there is a common overreliance on CBAs in decision-making processes (Hinkel and Bisaro, 2015). For example, a UK flood protection funding programme required an 8:1 BCR, which prevented some beneficial projects from proceeding and caused other projects to reduce protection levels to fit the arbitrary threshold (Alexander et al., 2016). Similarly, eligibility for national buyout funding in the United States is often based on a prescribed CBA focused on house value and level of damage, which preferentially targets lower income neighbourhoods for buyouts without considering broader contexts (Siders, 2019b). In an analysis of over 2000 CBAs for public investment projects, researchers found evidence that CBAs consistently underestimated costs and overestimated benefits, and placed unfounded confidence in the accuracy and 'unbiased' nature of these estimates, resulting in overestimating BCRs by an average of 50–200% depending on the investment type (Flyvbjerg and Bester, 2021).

3.2 Current literature on the economic assessment of managed retreat

3.2.1 Economic assessment tools and approach

Although the body of managed retreat literature has grown rapidly in recent years, the number of papers on the EA of managed retreat remains small (Boudreault et al., 2023). In total, we found just 14 papers that presented an EA of managed retreat as a CCA or DRR measure (Table 1). In all 14 cases the natural hazard being addressed was flooding, with 5 studies addressing riverine flooding and the other 9 studies addressing sea level rise and coastal flooding. The 14 studies had a global spread, including 4 in North America, 6 in Europe, 3 in Oceania, and 1 in Asia. However, within this small body of literature is a wide range of approaches and levels of detail, indicating that this is still an emerging field, and that researchers and practitioners are experimenting with novel approaches. Also of note is that all 14 studies presented EAs of hypothetical cases or as a demonstration of new techniques or practises that could be used in real-world cases. No studies were found which reported on EA practises that were used in real-world managed retreat programmes.

While nine studies utilised largely traditional CBA methodology to compare alternatives, the remaining five studies combined CBA with one or more complementary tools. To improve uncertainty analysis, three studies also used real options analysis (ROA) (Lawrence et al., 2019; Stroombergen and Lawrence, 2022), two used robust decision making (RDM) (Ramm et al., 2018; Boudreault et al., 2023), and three used dynamic adaptive policy pathways (DAPP) (Ramm et al., 2018; Lawrence et al., 2019; Stroombergen and Lawrence, 2022). Similarly, three studies also incorporated multi-criteria decision analysis (MCDA) to better capture intangible impacts (Lawrence et al., 2019; Skidmore and Cohon, 2022; Stroombergen and Lawrence, 2022). Please see Section 4.2 for further discussion of these complementary tools and their impact on managed retreat decision-making and outcomes.

3.2.2 Value selection, monetization, and estimation

Across the 14 studies, there was large variation in the values considered, as well as the selection of values that were monetized or not monetized. Construction and implementation costs (e.g., buyout costs, demolition, operation and maintenance of protection infrastructure), and the benefit of avoided flood losses (typically measured as a reduction in average annual damage) were the most common values considered, but this was not universal. For example,

TABLE 1 Summary of economic assessment approaches used across the 14 cost–benefit assessment studies reviewed.

Study references	Tools used in addition to CBA	Adaptation measures considered	Alternative forms of retreat considered	Case study location	Treatment of intangible impacts
André et al. (2016)	N/A	Protect Retreat Status Quo	- Division of Ownership ('Usufruct') - Buy and Lease Back	Hypothetical town, France	Monetized select impacts (e.g., loss of seagrass meadows, psychological effects)
Boudreault et al. (2023)	RDM	Retreat Status Quo	- Pre-Disaster Buyout - Post-Disaster Buyout - Division of Ownership ('Usufruct') - Neighbourhood-Level - Property-Level	Southwest Quebec, Canada	Two scenarios: Intangible flood losses insignificant or equal to property damage
Cardona et al. (2020)	N/A	Protect Accommodate Retreat	N/A	Furadouro Beach, Portugal	N/A
Creach et al. (2020)	N/A	Accommodate Retreat	N/A	La Gueriniere, France	Reduction in risk of death
Dottori et al. (2023)	N/A	Protect Accommodate Retreat	N/A	All of Europe	N/A
Finn et al. (2024)	N/A	Protect Retreat	N/A	Sumas Lake (*Xhotsa*), British Columbia, Canada	N/A
Lawrence et al. (2019)	ROA DAPP MCDA	Protect Retreat Status Quo	- Full Scale Retreat - Limited retreat following natural shoreline adjustment	Hawke's Bay, New Zealand	Qualitative factors included in MCDA (e.g., socio-economic and environmental impacts, Maori relationship with their ancestral lands)
Meyer et al. (2012)	N/A	Accommodate Retreat	N/A	Erlina and Grimma, Germany	Transaction costs (e.g., planning and design, communications) measured qualitatively separate from CBA
Ramm et al. (2018)	RDM DAPP	Protect Accommodate	N/A	Lakes Entrance, Australia	Qualitative 'Lived Values' assessment of 5 factors: Scenery, Natural Environment, Safety, Proximity to Water, Lifestyle
Revell et al. (2021)	N/A	Protect Retreat	- Buy and Lease Back	Imperial Beach, California, USA	Monetized select impacts (ecosystem services, change in recreational value)
Skidmore and Cohon (2022)	MCDA	Retreat Accommodate Status Quo	- 6 Different Receiving Locations	Kivalina, Alaska	Four categories of qualitative factors in MCDA: Risk to Humans, Environmental Protection, Convenience, Equity and Social Justice
Stroombergen and Lawrence (2022)	ROA DAPP	Protect Retreat	- Full Scale Retreat - Partial Retreat	Hutt River and Hawke's Bay, New Zealand	N/A

(Continued)

TABLE 1 (Continued)

Study references	Tools used in addition to CBA	Adaptation measures considered	Alternative forms of retreat considered	Case study location	Treatment of intangible impacts
Turner et al. (2007)	N/A	Protect Retreat Status Quo	- Scale of Retreat Varies Across 5 Scenarios - Scenarios differ in balance of Economic Growth and Habitat Creation	Humber Estuary, UK	Monetized select impacts (habitat creation, carbon sequestration)
Zeng et al. (2023)	N/A	Retreat	N/A	Jiangxi, China	N/A

The categorisation of adaptation measures is based on the PARA framework (Doberstein et al., 2019).

in Lawrence et al.'s (2019) MCDA of six scenarios made up of different combinations and sequences of large- and small-scale managed retreat, protection, and 'do nothing' alternatives over a 100-year period, all monetary costs were excluded in an attempt to increase focus on typically undervalued considerations such as socio-economic impacts and Indigenous relationships with the land. However, this led to an implicit assumption that the structural protection alternative was 100% effective, introducing a bias against the non-protection measures. Similarly, Cardona et al. (2020) did not assess the reductions in average annual damage associated with each adaptation alternative considered (protect, accommodate, retreat) and instead only monetized project costs. This made all adaptation measures appear equally effective in reducing hazard risk, which is unlikely to be the case. Finn et al. (2024), took another approach and only calculated the total assessed value of all properties within the historical boundaries of a flood-prone area (i.e., the base financial cost of retreating 100% of those properties) and compared that to the costs of four proposed alternatives focused on protection; this exercise demonstrated that managed retreat costs were within the range of the four protection alternatives and was therefore worth further consideration. Finally, when assessing various flood risk reduction alternatives (protection, managed retreat, and two forms of accommodation), rather than calculating expected reductions in flood damage, Creach et al. (2020) quantified the reduction in the number of homes that posed a high-risk of death during flood events, as measured using the Extreme Inherent Vulnerability index.

A variety of methods were also used to assess the direct costs and benefits of the managed retreat programmes themselves. Some examples of costs considered in addition to property purchase and demolition included: damage to home contents and additional living expenses during temporary displacement (Boudreault et al., 2023); transaction costs (e.g., communication, negotiation) (Meyer et al., 2012; Zeng et al., 2023); opportunity cost of lost agricultural land (Turner et al., 2007); and loan interest (Zeng et al., 2023). Examples of additional market costs and benefits assessed include the economic impacts of changes in recreation and tourism (André et al., 2016; Revell et al., 2021), carbon sequestration (Turner et al., 2007), lower maintenance costs due to wave attenuation (Turner et al., 2007), and predictions of increased post-relocation wages in rural China (Zeng et al., 2023).

The inclusion or exclusion of intangible, or otherwise difficult to monetize values (e.g., reductions in emergency response costs), also varied widely among studies. Most studies simply listed potential non-market impacts that were not quantitatively assessed, and for some studies this list was the only acknowledgement of intangible impacts (e.g., Cardona et al., 2020). Other studies monetized some intangible values, with the choice of which values to monetize likely due to perceived community interest or easy data availability. Some examples include the enjoyment of wider beaches (André et al., 2016; Revell et al., 2021), increased post-flood use of psychotropic drugs as a proxy for psychological distress (André et al., 2016), replacement costs of impacted ecosystems (Revell et al., 2021), and habitat creation (Turner et al., 2007). Boudreault et al. (2023) also assessed one scenario where intangible flood losses were assumed to be equal to property damage.

In addition to selecting which values to assess, the choice of monetization method can also significantly influence EA outcomes. Avoided flood losses are typically the largest benefit in managed retreat CBAs, and there were large variations across the studies in the approach and level of detail used for the two main aspects of damage estimation: flood modelling and converting flood depths to property damage (Meyer et al., 2012; Revell et al., 2021; Dottori et al., 2023; Zeng et al., 2023). Boudreault et al. (2023) explored the impact of the choice of flood loss estimation methods by using two different damage modelling approaches when generating RDM scenarios.

3.2.3 Scenario design and comparisons

While most studies shared a common goal of comparing managed retreat with alternative forms of adaptation, each study took a different approach to defining and assessing these alternatives. Several studies included a baseline scenario (André et al., 2016; Ramm et al., 2018; Creach et al., 2020; Skidmore and Cohon, 2022; Boudreault et al., 2023), while the remaining studies only compared scenarios that included adaptation measures. Geographic and scale considerations differed across the studies, ranging from hyper-local to continent-scale analyses; one study examined both property-level and neighbourhood-level scales (Boudreault et al., 2023), another study used a hypothetical analysis of a fictional town (André et al., 2016), others focused on regional-scale (Humber Estuary, UK; Turner et al., 2007) or continent-scale EAs (Europe; Dottori et al., 2023), and some studies included analysis of different potential receiving areas (Skidmore and Cohon, 2022) or pre-disaster vs. post-disaster managed retreat (Boudreault et al., 2023). Several studies compared different forms of managed retreat, such as buy and rent back programmes (André et al., 2016; Revell et al., 2021), or usufruct arrangements that separated bare ownership (typically held by a public authority) from use rights maintained by the residents until managed retreat is triggered (André et al., 2016; Boudreault et al., 2023). Although many

studies assessed each adaptation alternative independently, some studies assessed scenarios with different combinations (Turner et al., 2007) or sequencing of alternatives (Lawrence et al., 2019; Stroombergen and Lawrence, 2022).

There was no consistency in how studies identified the number, range, and types of alternatives being assessed alongside managed retreat. Approaches used included only assessing the managed retreat component of an established flood risk reduction plan (Zeng et al., 2023), comparing managed retreat to 'do nothing' approaches with continued post-disaster assistance (Boudreault et al., 2023), comparing one simple representative of each of adaptation category (e.g., protection, accommodation, and retreat) (Cardona et al., 2020), comparing managed retreat to various forms of coastal modification (e.g., beach nourishment, living dunes, groynes with sand nourishment) (Revell et al., 2021), scaling the use of each adaptation alternative to meet varying policy targets (Turner et al., 2007), and comparing managed retreat to different forms of accommodation (e.g., warning and evacuation programmes, second story shelters) (Creach et al., 2020).

As discussed in Section 3.1.5, the scope and boundaries of EA studies play large roles in determining the EA's perspective, and therefore how impacts are measured. An explicit statement of scope and boundary was absent from most of the studies, leaving the reader to infer them from study details (e.g., value selection, valuation methods). This lack of specificity can lead to inconsistencies, such as labelling decreased local tax revenue as a cost of managed retreat (implying a localised scope and narrow boundaries) while also assessing increased recreation for the wider region as a benefit (implying a regional/societal-scale scope) (André et al., 2016). Boudreault et al. (2023) was the only study to directly address the issue of different perspectives and scopes, presenting results from the perspectives of both a public authority and a homeowner (the primary distinction being whether government payments for rebuilding/relocation were treated as a benefit or a cost), and also evaluating managed retreat at both property- and neighbourhood-levels. Similarly, only Skidmore and Cohon (2022) attempted to address the specific perspective, and noted challenges, of managed retreat for an Indigenous community where viable relocation sites were limited. Finn et al. (2024) presented an extended discussion of Indigenous jurisdiction and law related to their case study in Sumas Lake, British Columbia, but did not incorporate any Indigenous values or perspective into the CBA itself.

3.2.4 Discount rate and time horizon

The choice of time horizon and discount rate was highly variable across the 14 EA studies. Of the 14 studies, the two most common time horizons used for the main analysis were 50–60 years (André et al., 2016; Cardona et al., 2020; Boudreault et al., 2023; Zeng et al., 2023) and 85–100 years (Turner et al., 2007; Meyer et al., 2012; Lawrence et al., 2019; Creach et al., 2020; Revell et al., 2021; Stroombergen and Lawrence, 2022). Discount rates for the main analysis also varied, from a low of 1% (Revell et al., 2021), to a middle range of 2.5–4% (Turner et al., 2007; André et al., 2016; Cardona et al., 2020; Creach et al., 2020; Stroombergen and Lawrence, 2022; Dottori et al., 2023), to higher rates more representative of anticipated market returns from 5 to 8% (Boudreault et al., 2023; Zeng et al., 2023). As mentioned in Section 3.1.4, a lower discount rate (e.g., 1%) will tend to favour projects with long-term benefits and will be supportive of addressing intergenerational equity concerns, while a higher discount rate (e.g., 8%) will favour projects with lower immediate costs and high immediate benefits, both of which will tend to place a lower value on significant future benefits and intergenerational equity.

For studies that combined CBA with MCDA (Lawrence et al., 2019; Skidmore and Cohon, 2022; Stroombergen and Lawrence, 2022), the timeframe considered by participants when evaluating qualitative impacts was not specified and may not have matched the timeframe of the financial assessment (e.g., participants may have considered multi-generational environmental and social impacts while the financial assessment had a shorter, fixed time horizon). This lack of timeline specificity makes interpreting the results more difficult and may have unintentionally distorted participant responses depending on their interpretation of the assessment's timeframe.

3.2.5 Uncertainty and sensitivity analysis

The treatment of uncertainty varied substantially across the 14 studies. Following best practises for dealing with uncertainty in EAs, all studies other than Cardona et al. (2020) performed some level of sensitivity analysis. This involves recalculating assessment results while varying values and parameters about which there is uncertainty in order to test the results' robustness to uncertainty in parameter values (Boardman et al., 2018). The most common factors used in the sensitivity analyses were discount rate (Turner et al., 2007; Meyer et al., 2012; Revell et al., 2021; Stroombergen and Lawrence, 2022; Boudreault et al., 2023), and the assessed value of one or more of the monetized impacts (Turner et al., 2007; Meyer et al., 2012; André et al., 2016; Revell et al., 2021; Boudreault et al., 2023; Dottori et al., 2023; Zeng et al., 2023; Finn et al., 2024). There was no consistency across studies as to which values were included or the range of uncertainty that was tested.

The RDM studies had the most thorough treatment of uncertainty, using Monte Carlo simulation to assess thousands of hypothetical scenarios, each using a different combination of parameters within a predetermined, expected range of values (Ramm et al., 2018; Boudreault et al., 2023). In addition, the two RDM studies and one of two ROA studies (Stroombergen and Lawrence, 2022) were the only studies to include different rates and severities of climate change in their scenario designs. The other ROA study (Lawrence et al., 2019) considered only a single rate of sea level rise, reducing ROA's advantages in planning for an uncertain future through the ability to postpone investment. Similarly, all three DAPP studies (Ramm et al., 2018; Lawrence et al., 2019; Stroombergen and Lawrence, 2022) used a set number of dates and fixed dates as opportunities to switch adaptation strategies, a choice which reduced flexibility about switching to a new adaptation strategy as and when climate conditions change.

4 Discussion

The targeted review of managed retreat and EA of CCA and DRR literature helped to identify several avenues where changes and additions to CBA and decision-making processes may help to facilitate improved managed retreat outcomes. These changes, which we collectively refer to as 'CBA+', are discussed in detail in the following section.

4.1 Context-specific economic assessment and decision-making processes

Arguably the greatest opportunity to improve managed retreat outcomes through changes to EA and related decision-making is to align these processes with the specific community and decision-making contexts. Except for Boudreault et al. (2023), managed retreat EAs in the literature were typically presented from one perspective (e.g., the local government) and with the goal of providing a single, holistic evaluation of the program's societal effects. However, given the many different participants in managed retreat programmes (e.g., community members, local government or other organising bodies, higher-level government funders, non-government organisations), each with their own values, objectives, and priorities, a single EA is unlikely to align with all parties, and may not perfectly align with any of them. This issue is further complicated by the heterogeneity that typically exists within communities, groups, and organisations. This heterogeneity means that different values, objectives, and priorities can exist not only between groups but also within them, and can affect the level of engagement and representation of different participants' viewpoints within the EA process (Costa and Kahn, 2003).

As suggested by Brouwer and Van Ek (2004), multiple separate or sub-assessments may be needed to fully understand the costs, benefits, and tradeoffs of the proposed alternatives. For example, a neighbourhood deciding whether to accept a buyout offer, a municipal government selecting amongst multiple adaptation alternatives, and a higher-level government weighing the costs of managed retreat against future recovery spending would each have a different perspective on the nature and scope of the decision at hand, and would benefit from an EA that included different values and parameters. This distinction could help identify how a managed retreat programme, or a specific form of managed retreat, may be beneficial for one party and detrimental to another. In those cases, the programme design could be altered to account for these differences, such as changing the scale or timing of managed retreat or providing additional compensation or supports for certain populations. However, the time, effort, and cost of assessment should also be commensurate with the importance of the decision in question and the resources available. Conducting additional assessments has costs, including opportunity costs, which should be considered against the value of information to be gained and the benefits of more rapid decision-making and action.

Stroombergen and Lawrence (2022) presented a case where an ROA indicated that delaying a large CCA investment was more economical, but the community opted for immediate implementation due to political preferences and the results of public consultation. The community was risk averse and feared that future councils may not follow through on the plan, so immediate implementation was seen as fairer to current homeowners. If the EA had incorporated these perspectives from the beginning, the process could have been used to better refine the alternatives under consideration, or perhaps resurrect a preferable alternative that was previously omitted from consideration because of the initial focus on economic efficiency rather than the community's stated priorities.

The above example also highlights the importance of predetermining a clear role for EA in the broader decision-making process (Shi et al., 2022). In some cases, a decision where non-economic community values are prioritised over a traditional CBA may signify a successfully functioning decision-making process, while in other cases it may demonstrate a failure to account for appropriate values in the CBA design, resulting in wasted time and resources. The distinction between these two cases would be whether decision-making and the consideration of different types of values followed a thoughtful, pre-determined process, or was a surprise result undermining previous work. Even where flexibility in the design and role of EAs in the decision-making process is limited by legal and regulatory structure [e.g., the CBA requirement and guidance in FEMA's Hazard Mitigation Assistance Programme (FEMA, 2024)], it is beneficial to maintain transparency and be thoughtful in the choices that are made.

The selection of values and decisions about how values are considered in the decision-making process could also have large impacts on EA and managed retreat outcomes. As discussed in Section 2, many of the challenges related to manage retreat involve impacts and values that traditional CBAs would not typically capture. Failure to account for the most important values related to managed retreat outcomes could lead to making decisions without the appropriate information, a false sense of confidence in a purportedly holistic EA, and/or selecting adaptation measures that have unintended negative consequences, particularly on the most vulnerable populations. In addition, technical nuances in value selection and measurement can have substantial effects on assessment outcomes, such as how property values are estimated in compensation and flood impact calculations (e.g., pre- vs. post-flood valuations, assessed value, replacement cost).

The research revealed that the measurement and representation of key financial costs may also affect the viability and ultimate implementation of managed retreat. For example, the design and costing of the proposed compensation scheme (e.g., pre- vs. post-disaster valuation, 'home for a home' assessments or top-ups, legal and moving expenses, pre- and post-relocation support programmes) can have a large effect on the total cost of the programme, and therefore whether it appears 'economically efficient' and thus eligible for funding. Where EAs are the basis for funding decisions, this may also effectively determine the level of compensation and supports received by the participating households, thereby affecting relocation options and quality of life outcomes.

Not all values must (or should) be included in an EA, but there should be an explicit recognition of the values that are *not* formally assessed within the decision-making process to ensure they are not ignored. For example, Boudreault et al. (2023) intentionally omitted the effects of land-use change following relocation despite acknowledging that changes in land use powerfully impact the cost-effectiveness of managed retreat. While this omission greatly limits the study's ability to assess the societal impacts of managed retreat against its alternatives, the explicit recognition of the omission is important for appropriately interpreting and using the study results in decision-making.

If equity impacts and considerations of Indigenous values and history are community priorities, and it is decided not to quantitatively assess these, better managed retreat outcomes related to these values are more likely to be achieved if their place in the decision-making process is made explicit from the outset. Indigenous values may be better represented through a systematic process or tool such as MCDA, or through qualitative reporting and consideration by the decision-making body, depending on the community needs and preference.

Context-specific considerations potentially affect many other aspects of EA design as well, including discount rates, time horizons, and boundary and baseline selection. A shorter time frame and/or higher discount rate may be appropriate in some contexts (e.g., primarily financial or short-term decision contexts), while longer time frames and/or lower discount rates may be appropriate in others (e.g., decisions focused on ecological restoration or long-term community planning and CCA). Similarly, EA boundaries should match the decision-making context, whether that be of individual homeowners, neighbourhoods, towns, or society as a whole.

4.2 Community engagement and co-production of managed retreat programmes

An almost ubiquitous theme in the managed retreat literature is the benefit of, and need for more, community engagement and co-production of managed retreat programmes (Dodman et al., 2022; O'Donnell, 2022; Bower et al., 2023; Dundon and Abkowitz, 2024), a theme that could also be applied to the design and execution of managed retreat EA and decision-making processes (Brouwer and Van Ek, 2004). EA design based on community engagement and co-production helps to align the assessment with the context-specific needs and perspectives of the community and decision-makers, ensures that the community's values are captured and prioritised appropriately, and builds buy-in for the final EA results and decision. Engaging the community early in the EA process can also be an important step in the design of creative and realistic scenarios (Hanna et al., 2021), which is discussed in more detail in Section 4.3. Community engagement processes should also recognise the heterogeneity of communities and the multiple voices that exist within organisations to diversify the voices heard and encourage discussion between parties (Golden and Bencherki, 2021).

The process of conducting EAs, particularly those that involve direct community engagement, is often as valuable as the assessment results, and therefore EA processes should be designed to maximise these benefits (Brouwer and Van Ek, 2004). Community engagement, and EA more broadly, also benefit from an iterative process, whereby new information and early assessment results feed back into the design and modification of the scenarios under consideration and the assessment design itself (Brouwer and Van Ek, 2004; Sayers et al., 2015). An iterative, participatory process may be particularly impactful for avoiding unforeseen equity impacts and providing different groups the opportunity to identify additional or misrepresented impacts, which could then influence both the project design and later iterations of the EA and final decision (Ehrenfeucht and Nelson, 2023).

Co-production and deep community engagement will be especially important for managed retreat projects led by or involving Indigenous groups. As discussed in Sections 3.1.2 and 4.1, traditional EA methods often do not align with Indigenous world views (Venn and Quiggin, 2007; Choy, 2018; Manero et al., 2022), and EA and decision-making processes that do not involve and empower Indigenous communities may be more likely to entrench, rather than resolve, histories of colonialism and forced relocation (Marino, 2018; Siders et al., 2021; Jessee, 2022).

4.3 Creative and realistic scenario design

As the number and complexity of scenarios under consideration is necessarily limited, creative and realistic scenarios should be chosen to provide the most usable information for decision-makers. This helps to avoid missing out on the benefits of novel solutions and wasting resources evaluating impractical proposals (Mach and Siders, 2021). For example, including alternative forms of managed retreat, such as usufruct arrangements and buy and rent back (Abel et al., 2011; André et al., 2016; Keeler et al., 2022; Boudreault et al., 2023), can help reduce community opposition, fund property purchases through rental income, encourage consideration of pre-emptive managed retreat, and provide timing flexibility in the face of uncertain rates of climate change. Failing to include and assess creative designs like these may result in selecting a less desirable, higher-cost alternative.

The use of DAPP to show how managed retreat can be used alongside and in sequence with other adaptation measures is another example of how scenario choice and design may broaden community discussions and considerations (Ramm et al., 2018; Lawrence et al., 2019; Stroombergen and Lawrence, 2022). The combination of DAPP and EA tools such as CBA also encourages long-term planning. This may help reduce the reliance on, and the negative impacts of, post-disaster retreat, either by increasing the desirability of pre-emptive retreat or by demonstrating the value of pre-planning even if a disaster is ultimately needed to trigger managed retreat.

However, the literature review revealed that there is still room for improvement in the inclusion of different scales and staging of managed retreat within EAs. Most managed retreat EAs were framed as a single decision of whether to relocate a pre-determined community or set of homes at a single time. Boudreault et al. (2023) compared property-level to neighbourhood-level managed retreat scenarios, and other studies utilised DAPP or alternative purchase arrangements to make some allowance for staging managed retreat, but there are opportunities to explore scenarios that better preserve community cohesion and reduce uncertainty and funding limitations.

4.4 Selecting and combining the appropriate tool(s)

Although there is extensive literature critiquing and identifying the limitations of CBA for CCA and DRR [e.g., Markanday et al. (2019)], the continued widespread use of CBA despite these critiques means that improving CBA methods might confer significant benefits to programme outcomes. One avenue for improvement is to combine CBA with other tools. Although the details of these complementary tools are beyond the scope of this paper, this section will outline how MCDA, ROA, RDM, and DAPP could compensate for CBA's weaknesses and contribute to better managed retreat outcomes.

One approach to overcome CBA's requirement to monetize impacts is to combine CBA with MCDA, as demonstrated by Lawrence et al. (2019) and Skidmore and Cohon (2022). MCDA's primary benefit is the ability to account for and compare quantitative and qualitative assessments of scenario impacts in the same analysis (Dittrich et al., 2016). MCDA is also highly flexible, with many variations that can accommodate different types of

values, measurement techniques, scoring and tradeoff philosophies, complexities, and level of community and expert involvement needed (Siders and Pierce, 2021; Cinelli et al., 2023). Combining CBA and MCDA allows for the tangible, financial effects of managed retreat to be estimated using a tool designed for that purpose (i.e., CBA), while using MCDA to capture and compare additional values that the community identifies as inappropriate for monetization. An MCDA co-designed with the community could identify impacts that would otherwise be ignored, rebalance the relative priority of impacts in line with the community's values, and build trust and buy-in to the process, all of which could lead to better managed retreat experiences and outcomes.

However, MCDA is not a panacea and is susceptible to bias and manipulation by influential parties if the process is not designed with equity and equitable participation in mind (Lawrence et al., 2019; Skidmore and Cohon, 2022). Additionally, MCDAs can be complex processes that require a lot of resources and community participation, and some forms of MCDA suffer from the same limitations as CBA (e.g., lack of substitutability of values, disagreement on value weightings/priorities) so it is important to design an appropriate approach and to understand its nuances when interpreting the results (Dittrich et al., 2016; Zhu et al., 2017).

ROA, RDM, and DAPP all provide additional tools to make better decisions under uncertainty and can easily be combined with CBA for managed retreat decision-making. ROA and RDM are technical EA approaches that adapt CBA to account for the potential benefit of delaying decisions or staging implementation to take advantage of new information as it becomes available [ROA; Kind et al. (2018)], or to test alternatives against a wide range of potential futures (typically thousands) to see how robust they are too unpredictable events, such as long-term climate change [RDM; Lempert, 2014; Dittrich et al., 2016). In contrast, DAPP is a planning tool that helps communities map out how CCA measures could be combined and sequenced in different ways over time, identify triggers for when changing approaches may be warranted, and develop an adaptive management plan to assist in monitoring conditions and implementing supporting actions (Haasnoot et al., 2013).

Despite the advantages these additional tools provide, they are not yet standardised and can require substantial cost, expertise, time, and data to execute well. Given that local authorities often lack these resources, there is a need to balance practicality with sufficient complexity and community engagement to capture the most important impacts of managed retreat. For example, Lawrence et al. (2020) and Stroombergen and Lawrence (2022) used a novel 'cut-off' probability approach to ROA to address a major drawback of traditional ROA, the need to assign probabilities to each potential future, which is generally considered impossible for the long-term effects of climate change (Hinkel and Bisaro, 2015; Kind et al., 2018). However, it is unlikely that local government staff would have the capacity to implement this type of newer approach. Dittrich et al. (2016) suggested that using simplified versions of ROA and RDM which take advantage of key benefits while sacrificing some rigour may be a good compromise. The need for simplified but appropriate EA methodologies also applies to CBA itself, since capturing the full impacts of managed retreat may become too complex to effectively analyze. This need for simplicity was demonstrated in the limited range of values and scenarios explored in all the CBA studies reviewed, highlighting the need for careful scenario and parameter selection and the importance of community involvement from the beginning of study design.

4.5 Balancing guidance, standardisation, and flexibility

In addition to the studies reviewed, managed retreat practitioners have access to a range of guidance documents on how to conduct EAs for CCA and DRR, not to mention the extensive literature on EA more broadly. Various government entities have produced detailed guidance on the EA of CCA and DRR programmes, including Canada (Muir et al., 2021), the United States (Federal Emergency Management Agency, 2024), and the United Kingdon (HM Treasury, 2021, 2022, 2024). Additional guidance in the form of a detailed review of available costing approaches for managed retreat impacts (Olufson, 2019) or more general guidance on managed retreat planning and implementation (Freudenberg et al., 2016; Saunders-Hastings et al., 2020; Thistlethwaite et al., 2023; Dundon and Abkowitz, 2024) is also beginning to emerge. However, there may be an opportunity to improve managed retreat outcomes through more effective EA and decision-making guidance. For example, it has been observed that managed retreat programmes often lack sufficient guidance and capacity (Ramm et al., 2018; Hanna et al., 2020; Curran-Groome et al., 2021), designing complex processes from scratch is costly and time consuming (André et al., 2016; Greer and Binder, 2017), and FEMA's CBA requirements have been criticised for having negative equity outcomes (Siders, 2019b).

One challenge in developing improved EA guidance will be to balance the provision of useful direction that raises standards, allows greater inter-study comparisons, and reduces barriers for lower-capacity communities, while maintaining the flexibility to design context-specific assessments that are likely to improve managed retreat outcomes. Establishing a standardised EA approach also risks entrenching poor practises (e.g., excluding particular values, introducing bias) (André et al., 2016), so any standard should be designed and implemented with care and with opportunities for wide ranging community engagement and iterative improvement. These challenges highlight the subjective nature of both EA design and managed retreat decision-making more broadly, which is also demonstrated by the many options and choices in EA design and use discussed in this paper. The ability to bias managed retreat decisions and outcomes, whether intentional or not, through subjective EA and decision-making choices emphasises the importance of well-considered, transparent processes that balance standardisation and flexibility.

4.6 Framework for managed retreat economic assessment and decision-making

To collect and synthesise the observations presented above, a framework was developed to provide a high-level process that

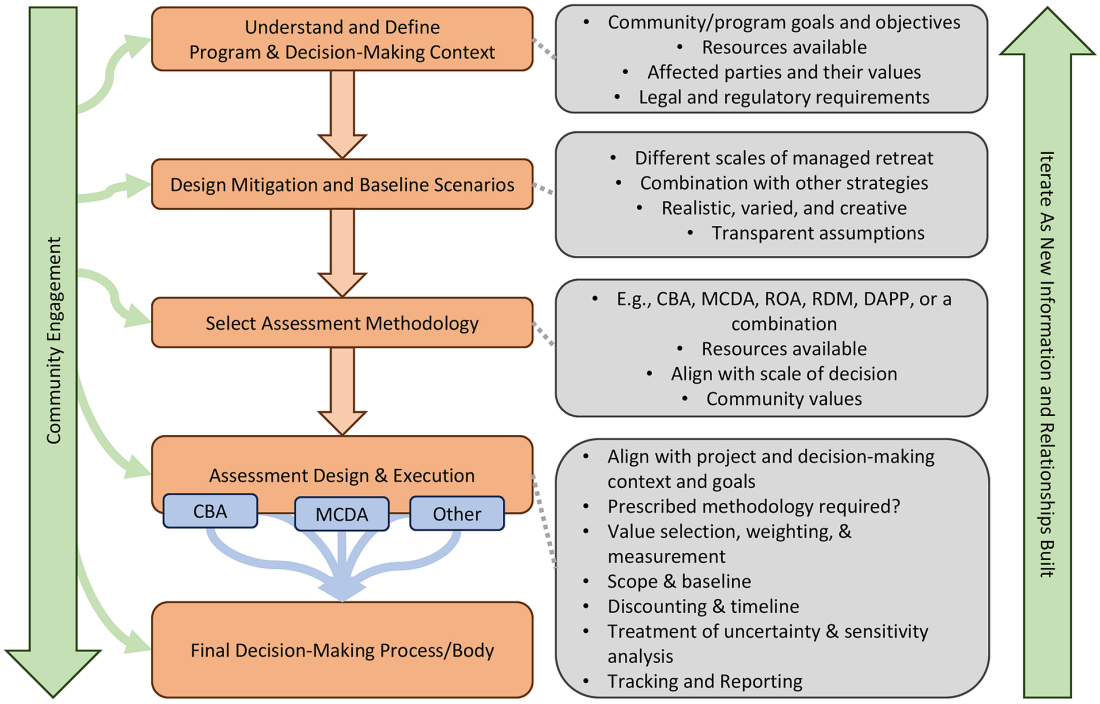


FIGURE 1
This framework provides organisations involved in managed retreat with a high-level process to follow for designing an improved economic assessment and decision-making process (CBA+), based on the key principles drawn from our review of the managed retreat and economic assessment literature, with the goal of improving managed retreat programme outcomes.

organisations involved in managed retreat can follow to design an EA and decision-making process using a CBA+ approach, with the goal of achieving more positive programme outcomes (Figure 1). This framework captures the key principles presented in this paper, which are summarised in the next section.

We believe that following this framework will help practitioners to resolve the five main managed retreat challenges discussed in Section 2. For example, conducting multiple context-specific EAs based on community engagement and co-production can help to recognise and address the heterogeneous nature of communities and provide a tool to work through contested goals, objectives, and values (Section 2.1). Equity concerns (Section 2.2) can be addressed through the use of equity weights, inclusive community co-production, and the design of creative managed retreat solutions that shift where programme benefits and costs accrue. Poor managed retreat experiences and implementation issues (Section 2.3) could be reduced by capturing a wider breadth of monetary and non-monetary impacts of retreat when comparing alternatives and by building in efforts to reduce negative outcomes (e.g., higher compensation levels, social supports). Similarly, public and political opposition to retreat (Section 2.4) may be reduced through enhanced community engagement/co-production, better-designed managed retreat programmes, and more transparent and relevant EAs that reflect community values and account for uncertainty using tools like MCDA, ROA, and RDM. Finally, the negative effects of reactive post-disaster retreat (Section 2.5) could be reduced by facilitating pre-disaster planning through EAs based on the CBA+ framework. The CBA+ concepts could help communities grapple with the benefits and costs of managed retreat in a productive, inclusive, and non-threatening way.

5 Conclusion

While there is a thoroughly developed body of literature detailing the benefits and challenges of managed retreat, and a growing literature on EA applications for retreat, there remains a gap between these two areas of research and an open question of how EA practises may be affecting managed retreat outcomes. This paper attempts to identify where in the design of managed retreat EAs there may be opportunities to increase the benefits and resolve some of the challenges associated with managed retreat, with the goal of encouraging discourse and collective efforts to fill this research gap.

The following are 10 key principles for managed retreat EA and decision-making to accompany the framework from Section 4.6. These principles, which we collectively refer to as CBA+, succinctly summarise the main conclusions of this study:

Community engagement and co-production: Community engagement and co-production should be incorporated as fully and at as many stages as possible in both developing and executing the EA and decision-making processes.

Contextual relevance: EA and decision-making processes for managed retreat should be specific to the context and nature of the decisions being made. Even within the same managed retreat project, an EA or decision-making process intended for one purpose or group may be inappropriate for another. Key areas for contextualization include: the level of effort, time, and resources required; the tools/

techniques that are chosen and in what combination; which values are considered, how they are measured, and how they are weighed/prioritised against each other; who is involved and what roles they play; the generation and selection of the scenarios being assessed; and, how the final adaptation decision is ultimately made.

Importance of process: The process of conducting an EA (e.g., community consultation, selection of methodology, values, and valuation approaches, conducting valuation studies, iterative methodology refinement) is often more valuable than the final outcome, and it is important to design the process to maximise these benefits.

Scenarios driven by community values: The development and comparison of scenarios under consideration should encourage creative and varied solutions that are driven by the full spectrum and heterogeneity of community values and input, and that achieve other societal goals where possible.

Expose and address uncertainty: Major sources of uncertainty should be identified and systematically addressed in all EAs.

Conduct sensitivity analyses: Sensitivity analyses should be conducted for all parameters and metrics where the EA outcome could be substantially affected by reasonable variations. The range of values tested within a sensitivity analysis will depend on the risk tolerance of the decision-maker and should typically be within a realistic range of variation.

Consider multiple tools, approaches, and inputs: A CBA will provide useful information in most decision-making contexts but should not be the only input to a decision. Instead, CBAs, and other similar EAs, should be used alongside other tools and techniques, such as MCDA and DAPP, in a broader and inclusive decision-making process.

Understand limitations: It is important to understand and consider the choices, assumptions, uncertainties, and limitations involved in all EAs when interpreting and comparing results, and when deciding whether the assessment is relevant to the decision at hand.

Proactively consider retreat: Where possible, planners and decision-makers should attempt to complete as much communication, community engagement, planning, and EA as possible prior to experiencing a disaster, regardless of whether pre-emptive retreat is desired or realistic.

Build learning and adaptive management into the process: Decision-making processes surrounding managed retreat are likely to be iterative and require repeating steps or stages as new information becomes available and new relationships are built. Build learning, adaptive management, tracking, and reporting into the process to ensure that these opportunities are not lost, that programme evaluation is possible, and that lessons are captured and implemented for future projects.

While we believe following these 10 key principles would help to achieve better managed retreat outcomes, there are still knowledge gaps on how EAs are being used in managed retreat decision-making and how they are affecting programme outcomes. To begin filling these gaps we suggest several avenues for future research, including: (1) interviews with managed retreat practitioners and policy makers to better understand the role of EAs in managed retreat decision-making, and to identify what needs are not currently being met; (2) analyses of the connection between particular EA and decision-making processes and the resulting managed retreat outcomes to identify both best- and potentially problematic practises; (3) using the results of (1) and (2) to design and test alternative EA and decision-making processes, such as the framework presented in Section 4.6, with managed retreat practitioners and policy makers to further iterate and refine the practises and guidance. Additionally, there is little to no research that analyzes EA processes in previously implemented managed retreat programmes, which makes it difficult to assess whether the practises described in the literature accurately reflect what is being done in practise. Research collecting and describing real-world EA processes for managed retreat is another research avenue that would be beneficial to the field.

Author contributions

BC: Conceptualization, Investigation, Writing – original draft. BD: Conceptualization, Funding acquisition, Supervision, Writing – review & editing. VL: Conceptualization, Funding acquisition, Project administration, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Innovations in buyouts: lessons from lived and learned experience

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Across the United States, tens of thousands of people have sold their homes to the government to address risk from flooding or another natural hazard. After the sale, the structure is typically demolished and the land preserved as open space. This process, referred to as a home buyout, is the nation's primary mechanism for relocation assistance in the aftermath of a disaster or in the face of recurring hazards, and the number of homes that have been purchased and demolished in the past is dwarfed by the number that is anticipated in the future. Community members, researchers, practitioners, and advocates have long observed challenges with government-funded home buyout programs in the United States. Often, home buyouts do not meet communities' needs and can even create new problems. At the same time, demand for relocation support is growing in many areas, while current funding, programming, and expertise is insufficient to address the scale of the challenge. We need better buyouts that work for residents and local governments alike. To build a better buyout, we need to draw from the lived and learned experiences of both community members and practitioners. Between December 2021 and October 2022, the Natural Resources Defense Council (NRDC), in partnership with the Federal Emergency Management Agency (FEMA), CH Consulting, The Nature Conservancy (TNC), and the Climigration Network, convened conversations with buyout practitioners and buyout participants/residents of communities affected by buyouts. The participants spanned 14 states, from coastal to inland locations across the contiguous United States. This policy and practice review summarizes the recommendations generated through these workshop series, as well as the methods used to design and facilitate the sessions and subsequent work done to implement the recommendations and develop a community of practice for better buyouts.

KEYWORDS

managed retreat, home buyouts, climate adaptation, flood mitigation, community resilience

1 Introduction

Millions will be uprooted due to the effects of climate change in the coming decades, with as many as 13 million displaced due to sea level rise alone in the United States (Hauer et al., 2016). However, in many cases, only the most privileged will be able to move without financial and other assistance. Home buyouts are the country's primary tool for supported relocation out of harm's way, but community members, researchers, practitioners, and advocates have long observed barriers and inequities in these programs that make them challenging for both governments and communities (e.g., Mach et al., 2019; Siders, 2019). Federal assistance is often inaccessible to communities and programs themselves are flawed, often reproducing or exacerbating the effects of structural racism, colonialism, forced relocation, and inequitable

investment in disaster response and hazard mitigation (Reeves, 2011; Drakes et al., 2020; Emrich et al., 2022; Waters et al., 2024).

While federal, state, and local agencies have conducted home buyouts across the United States for decades, iterative policy improvement and innovation has historically been limited (Greer and Binder, 2017). The Innovations in Buyouts workshop series was convened to help close that innovation gap by leveraging the perspectives of individuals with lived experience and professional experience with home buyouts (Climigration Network, 2024). While it may not be possible to create a home buyout program that leaves everyone involved better off than before—the fact that relocation may be necessary in a given situation points to historic and ongoing policy failures that have placed people in harm's way—buyouts will remain an important tool for risk reduction in the face of a changing climate. The workshop discussions summarized below and the accompanying policy recommendations aim to address issues with buyouts as they are conducted today, as well as to provide a foundation for more holistic approaches to climate-related mobility.

1.1 The challenges of home buyouts

In the context of hazard mitigation, a buyout refers to a particular type of property acquisition: one in which a government entity purchases private property, demolishes the structures, and preserves the land for public benefit (Horn, 2024). This can be an attractive option from a fiscal or emergency management perspective, because the goal is to permanently remove risk to life and property at the site. As a result, buyouts provide a method to stop the repeated rebuilding cycle that underpins the National Flood Insurance Program (NFIP) and other disaster-related programs (Moore, 2017).

In the United States, buyouts are typically funded with federal grants and administered by state or local agencies; some funding sources, such as Federal Emergency Management Agency (FEMA) Hazard Mitigation Assistance grants, require that acquired land be maintained as open space to prevent future damage at that location and, ideally, to benefit the surrounding community via restored natural functions, recreation opportunities, etc. While larger, community-scale relocations have taken place using a buyout model (e.g., Tobin, 1992; Knobloch, 2005), most FEMA-funded buyout projects cover the acquisition of five or fewer properties at a time (Weber and Moore, 2019).

Ideally, buyout plans would be community-driven and developed before (rather than in response to) a disaster; buyout offers would be sufficient for participants to acquire comparable housing in a safer location; and the entity holding the land would maintain it in a way that improves community resilience. In practice, this is very challenging to achieve. Many issues with buyout program implementation are documented in the literature, including perceived or real coercion to participate (de Vries and Fraser, 2012; Binder and Greer, 2016; de Vries, 2017); lack of transparency (Binder and Greer, 2016; Siders, 2019); the long timeframes associated with federal grant programs and a mismatch in timing between recovery and hazard mitigation needs (Weber and Moore, 2019; Binder et al., 2020); no assurance that participants will have the ability or desire to relocate to places with lower risk (Loughran and Elliott, 2019; McGhee et al., 2020; Shi et al., 2022); and post-buyout land use that often provides little community benefit (Zavar and Hagelman, 2016). Overall, there is conflicting evidence for the long-term effects of buyouts in terms of community resilience, wealth, and wellbeing (Binder et al., 2019), and even the notion of "success" in a buyout context is challenging to define (Manda et al., 2023).

As buyouts are located at the intersection of housing and disasters, they interact with the underlying inequities in both systems, rooted in racial and socioeconomic dispossession and segregation that has concentrated risk in communities of color and low-wealth communities. While whiter, wealthier jurisdictions are more likely to receive buyout grants and have the capacity to execute them, researchers have found that buyouts are more likely to take place in less wealthy neighborhoods and communities of color within those jurisdictions (Tate et al., 2016; Loughran et al., 2019; Mach et al., 2019; Elliott et al., 2020). Buying out devalued homes in redlined or disinvested neighborhoods can be attractive from a cost–benefit perspective. This, however, places low-income communities and, disproportionately, communities of color in a position where they are more likely to face the emotionally and logistically challenging buyout process, while being less likely to have control over the process's conditions, requirements, and scope. Indeed, long-term outcomes from North Carolina locations where buyouts took place after Hurricanes Fran and Floyd suggest that buyouts contribute to market conditions that further segregate residential areas (Durfee, 2018).

Despite this, the realities of climate change mean that more households will want or need to move in the coming decades. Already, particularly after large flood disasters, local buyout programs may have more interest than available funding. For example, since Hurricane Harvey in 2017, Texas' Harris County Flood Control District has received a total of over 4,000 buyout applications—two and a half times more than the District has approved as of late 2024 (Harris County Flood Control District, 2024). Growing need and demand for relocation support will likely require building upon the flawed tool of buyouts not just to improve the outcomes of individual buyout projects but perhaps also to form the foundation of larger-scale managed retreat.

1.2 Centering community members as experts

The underlying framework for the Innovations in Buyouts workshop series was inspired by the founding principles of the Climigration Network, an organization bringing together people with lived and learned expertise to advance transformative, community-led approaches to climate displacement and relocation in the United States. The Network's experience is that the most innovative, important, and practical questions and approaches emerge when community members are centered as experts. Community and Indigenous leaders:

- Provide essential services in disasters and are passionate about helping residents make informed decisions about their future.
- Have an unparalleled understanding of the history, culture, and lived experiences within their communities, enabling them to advocate for policies and actions that meet the needs of residents.
- Have first-hand knowledge and experience of how climate change risks manifest at the community level.

- Have connections and established trust with residents who may otherwise be hard to reach.

The Network also asserts that missing representation of community voices in programs leads to gaps in goals and services. The Network builds teams of people with subject matter expertise and people from communities facing displacement or relocation to address challenges together.

Lead with Listening: A Guidebook for Community Conversations on Climate Migration (Climigration Network, 2021)—a resource developed by Network members, a creative team led by Scott Shigeoka and Mychal Estrada, and 40 co-creators with lived experience of climate risk and displacement—offers the following:

> *Some communities may be just starting to experience the impacts of climate change, and thinking about moving may be new. However, we heard that for others, climate change and climate migration is not a "future" problem—it is happening to them now. More than 40,000 households have received home buyouts from the Federal Emergency Management Agency since 1989, primarily in the form of post-disaster assistance. Communities such as Isle de Jean Charles in Louisiana, and Newtok in Alaska, have already faced the difficult decision to relocate and have struggled through the problems of inadequate relocation assistance.*
>
> *Community members are the experts on their lived experience—they are likely to have already witnessed or experienced the impacts forecasted by climate models and policy briefs. They may have been grappling with the emotional consequences of this challenge for a long time. It is imperative to first listen—and lead with questions, not answers—to learn from their knowledge and hear their needs before making recommendations. Overlooking their experience will likely lead to them feeling dismissed and ignored and will miss opportunities to leverage their valuable partnership.*
>
> *It's important to encourage people to listen to and share lived experiences. Creating space for this vulnerability, when done in a trauma-informed way, repositions people who have lived experience as experts in the conversation.*

Conversations about buyouts and relocation need to extend far beyond discussions of risk and real estate to include culture, relationships, and identity. Culture and social cohesion is essential to many communities' well-being, resilience and adaptive capacity, and cultural continuity, especially for Indigenous communities, communities of color, and other communities that have struggled through injustices to claim a place as their own (Climigration Network, 2021; Urban Ocean Lab and Office of the New York City Comptroller, 2022; Tamasiga et al., 2024). Buyout programs may present a threat to the connections to people and place that many communities rely on to sustain themselves.

Practitioners should prepare to hold space for conversations within the community that acknowledge that a buyout may not just represent loss of a home, but loss and grief of social networks, livelihoods, generational connections to land, and more (e.g., Jerolleman et al., 2024). And conversations are just the beginning—practitioners need to deeply and genuinely engage with community members in planning and designing programs that meet their needs.

2 Process

This paper captures the ideas generated from two sets ("tracks") of workshops:

1. Track 1: Six sessions held over 7 months with 30 buyout practitioners (defined as individuals with experience managing or administering buyout projects as part of their employment, including current and former federal, state, and local employees and individuals from academic and private organizations). This track was convened by NRDC in coordination with staff from FEMA. The process was designed and facilitated by CH Consulting, LLC, who also led the creation of a white paper/workshop synthesis document (Innovations in Buyouts Workshop Team, 2022).
2. Track 2: Three sessions held over 4 months with buyout recipients/community members (defined as individuals with personal experience of a buyout and/or who have served in a community organizing capacity in an area offered buyouts). This track was hosted jointly by NRDC, CH Consulting, TNC, and the Climigration Network and participants were offered compensation for their participation. A separate white paper/workshop synthesis summarizes the outputs of these conversations (Innovations in Buyouts Workshop Team, 2023).

Recognizing the complex relationship between community members and program staff, we deliberately hosted separate spaces for each track to foster a safe atmosphere for sharing information. The Track 1 conversations were held first, so that Track 2 participants could review and critique their recommendations. Each group was made aware of the others' activities and the ultimate goal of the sessions, namely, to:

- Articulate a set of concrete ideas for innovative actions to make buyouts faster, easier, and fairer across the country.
- Identify areas of alignment between the recommendations of buyout practitioners and recipients.

The geographic distribution of workshop participants is shown in Figure 1. Practitioners and recipients represented a diverse array of program types and geographies, including differences in jurisdiction size, community demographics, program scale/number of properties acquired, hazards intended to be addressed, funding source(s), and program voluntariness.

The Track 1 practitioners spent the first session reviewing existing critiques of buyout programs and the federal agencies and funding sources that support them, as documented in a variety of reports, scholarly articles, conference presentations, and other publications. In subsequent sessions, they shared the innovations they had tried in their own programs and discussed the results. The Track 2 conversations began with story sharing and efforts to build relationships and trust. Workshops with community members were carefully designed to acknowledge trauma and participants were able to pause or leave the discussions at any time, for any reason. Live English/Spanish interpretation and translated materials were provided so everyone could participate in their preferred language, and participants were offered compensation for their time and expertise.



FIGURE 1
Locations represented by practitioner and community workshop participants.

This policy and practice review represents a synthesis of the observations, ideas, and recommendations provided by workshop participants. Some are new ideas: approaches that have only been imagined or are in the process of being developed. Most, however, are innovative approaches implemented or attempted in one place that could be adapted in other places. This paper is not intended to be a consensus document; individual workshop participants should not be considered to endorse any specific suggestion.

3 Recommendations from lived and learned experience

The following framework identifies five key shifts that buyout programs should strive to make and that partners and stakeholders, including the federal government, philanthropic organizations, and private sector, should seek to enable and reinforce. The five shifts are:

1 From building for the past to planning for the future.
2 From reactive projects to proactive programs.
3 From valuing property to valuing people.
4 From insufficient to innovative funding.
5 From silos to partnerships.

Workshop participants emphasized that institutional buyout program support should exist across levels of government, and particularly at the state or sub-state scale, to enable these shifts. Applying lessons and avoiding reinvention of the wheel requires a certain level of sustainable, ongoing institutional capacity. This capacity must exist at an appropriate scale, whether that is at the municipality or county level (e.g., for larger or higher-capacity jurisdictions) or the state or watershed level (e.g., for areas with smaller or lower-capacity communities).

In the following section, each shift is described using examples from workshop discussions, followed by opportunities for policy change as identified by workshop participants. Because most buyout funding has federal sources, the policy recommendations focus on federal actions (for Congress and/or administrative agencies). However, state, local, or regional entities may also be able to implement versions of these actions. A compiled table of policy changes for each shift appears in Section 4.

3.1 Shift 1: from building for the past to planning for the future

Buyouts should be situated within a context of forward-looking planning. In short: buyouts should never be a surprise. Incorporating the possibility of buyouts into formal planning allows for a connection to the community's values and priorities, and it enables the other shifts to occur.

3.1.1 Description and examples

Formal planning processes, such as for hazard mitigation or economic development plans, provide an opportunity to consider buyouts in the larger context of a community. Incorporating the potential for buyouts into formal plans lays the groundwork for securing resources and building necessary relationships inside and outside government. It positions leaders both to act proactively in non-emergency situations and to be nimbler in the post-disaster environment. It also situates buyouts as one part of a holistic approach to meeting the community's needs in the face of flooding or other risk.

Practitioners and buyout recipients agreed that good planning requires real partnership, not just "outreach," early and often with the groups and individuals who have a direct stake in the outcomes. Beyond formal public participation requirements, thoughtful community partnership at this step provides a powerful opportunity to introduce buyouts as a tool to the broader public, gage potential interest from residents, and work with interested residents to design the program. Buyout recipients shared details about how their community's lack of participation in planning affected them and their perception of subsequent buyout programs. One reported that she and her neighbors received notices about mandatory buyouts in their neighborhood in the middle of the pandemic, when "the stress was

double." The neighbors soon came to learn that their low-income, primarily Spanish-speaking neighborhood was being bought out, while an adjacent golf course was being preserved: "They were destroying our homes to benefit another community with better resources." While the local government's intent was to offer residents a way out of a dangerous situation, the lack of transparent planning and coordination with the residents generated suspicion, defensiveness, and fear. The residents wanted more respect through a process that reinforced their voices, rights, and decision-making power. As one participant said, "The community that is going to move [should be] the one that matters most in the program."

At the same time, governments should not rely on the free labor of community members to advise them throughout the planning process. One buyout recipient who saw the need for a solution to flooding in her community reported becoming the local expert through her own efforts, then spending countless hours educating local officials so they could advocate for the community with state and federal agencies. Ideally, such community experts should receive compensation, either directly or via community-based organizations or other non-government partners; practitioners should also identify additional opportunities for training and knowledge building, for example through professional associations or informal knowledge-sharing with other practitioners.

Planning also offers a chance to identify capacity gaps and opportunities for addressing them. Practitioners emphasized the need for capacity building support from state and federal agencies. In the words of one participant, "Right now, buyouts have been done *ad hoc*. Someone gets the job, [for example] the floodplain manager gets the job, and then they assemble a team and all those other city staffers that are pulled into the project, they have full-time jobs too, and this is not an easy task […] But, if there's federal support, that's great. Having a back bench to go to or a set of experts or an entity in the county or the state who have done this a lot […] having a panel of experts at the state level would be really important for us to have."

Finally, realistic, forward-looking planning should also help avoid the need for future buyouts. The primary recommendation of workshop participants who had been through a buyout was to prevent the need for (additional) buyouts by building homes in safe locations. Several participants expressed sentiments like "my house should never have been built in this area in the first place" or "someone should have told us about the risk." As one participant noted, "[You] would think that this type of development would not keep occurring, but it does." Buyout recipients also wanted evidence that their local officials were taking risk seriously and not creating future problems; to continue placing people in harm's way would mean nothing had been learned from the buyout recipients' struggles.

3.1.2 Opportunities for policy change

The Disaster Mitigation Act of 2000 requires approved hazard mitigation plans as a prerequisite for receiving certain FEMA grants. However, local hazard mitigation plans are often very general and not well coordinated with land-use planning, zoning, or community visioning for the use of open space (Lyles et al., 2014). As described by practitioner participants, these plans tend to focus on identifying locations at risk and typically do not take the next step to identify projects, funding needs, and residents' priorities to reduce risk. Communities should take advantage of state and local hazard mitigation planning cycles to build political and financial support where residents have expressed interest in buyouts. Loss avoidance studies could also be persuasive to local decision makers.

Planning and land use are largely local responsibilities, but state and federal agencies can provide funding and other support. Specific recommendations from workshop participants included:

- Making federal funding for hazard mitigation, economic development, and similar efforts contingent upon adherence to strong floodplain management standards and avoidance of risky siting and construction, e.g., via implementation of the Federal Flood Risk Management Standard.
- Supporting (and enforcing) project development as an important component of hazard mitigation planning.
- Providing resources for state and local capacity building with accessible, up-front funding and technical assistance. Opportunities for increasing capacity building support include programs such as FEMA's Emergency Management Performance Grants and the "Building Resilient Infrastructure and Communities (BRIC) Direct Technical Assistance" (i.e., defining the BRIC acronym and capitalizing Direct Technical Assistance) program.
- Improving intra- and interagency coordination, e.g., between programs and agencies with hazard mitigation and disaster recovery roles, as well as communication between levels of government.
- Maintaining centralized, user-friendly repositories for locally relevant data to be used in planning, and creating additional data products to fill existing gaps (e.g., advisory layers for FEMA flood risk maps that depict current and projected flood elevations along with the lateral extent of high-risk areas).

3.2 Shift 2: from reactive projects to proactive programs

From the perspective of a government agency, buying a household out of their home is a complicated and sensitive process. It requires expertise and the time to develop that expertise. From the resident's perspective, it's a life-altering decision and the implications are best considered during a time of relative calm and security—not in the wake of a devastating crisis. Completing as much as possible before a flood or other disaster strikes (including building trust and communication channels, as well as administrative work) allows for quicker action when homeowners are ready to move.

3.2.1 Description and examples

In the immediate aftermath of a disaster, people may be ready to move, and a quick buyout offer might be welcome. Unfortunately, even solicitations of interest may take weeks or months and, by the time funding actually arrives, potential participants may have invested in costly repairs, sold the property on the private market, or even foreclosed or walked away. Homeowners cannot be expected to pass up opportunities to sell if a buyout is not swift or guaranteed. They also cannot be expected to live in damaged homes (or pay for alternative housing) for long, nor is the cost benefit calculation for making "interim" repairs easy to do in the face of long-term uncertainty.

The largest sources of federal funding for buyouts, such as FEMA Hazard Mitigation Grant Program (HMGP) and Department of Housing and Urban Development (HUD) Community Development

Block Grant-Disaster Recovery (CDBG-DR) funds, are only made available after a declared disaster, often months or even years after the event itself. However, there are ways that programs can work around this timing challenge by preparing as much as possible in advance. In communities that experience regular storms, and where residents may already be interested in a future buyout, there is no need to wait for the disaster to occur in order to get ready for the funding.

Practitioners can complete basic documentation on the homes and sellers, conduct initial reviews of eligibility and costs and benefits, and in some cases begin or even complete environmental and historic preservation or similar reviews. It takes time to assess the applicability of pre-calculated benefits or to identify title issues or remediation needs, for example. Shifting these time-consuming activities to the "pre-disaster" timeframe could enable many more people to be in a position to accept a buyout when it is formally offered.

Having more time also allows program staff to manage their own workloads and build expertise. As one practitioner said, "We as a city need to have more capacity so that, if there is an event that occurs and we have a homeowner pondering or agreeing to a buyout [we can act]. There's a series of efforts that are needed […] So many different things. How long is the process going to take? What does the homeowner have to do? What kind of other responsibilities are they accepting when they go through the buyout process? Where can they move to that is reasonably affordable given the buyout amount? What does that look like for their kids in their schools and their community and their churches and all those things that go along with that?"

Doing the administrative work gradually has capacity- and trust-building benefits, too. When buyout program managers have time to build relationships with potential buyout recipients, and explain options without the pressure and chaos of a post-disaster environment, there may be more trust and buy-in for the buyouts. Workshop participants that had received a buyout reported wildly varying experiences finding out about the program in their area. Some knew about it for years because their local government had been sending out information on a regular basis. Some learned about it from officials as part of a post-disaster emergency response effort. Some only learned about the buyout opportunity because a friend mentioned it, or because they happened to read about it in the news or on social media. All participants felt that people who are eligible or might become eligible for a buyout should be regularly communicated with, ideally long before a disaster happens.

Importantly, this information should be provided equitably across neighborhoods and in all relevant local languages. According to one buyout recipient, "This part is where we had a lot of problems. Because we are Hispanic and Latino […] Trying to gather information, especially the way they would treat us, lack of communication. There was no one that spoke our language, Spanish, so there was a lot of conflicts, and it was very frustrating. We did not speak English, so I could not understand anything about that mail that was coming in." Programs should not only ensure compliance with applicable language access requirements (e.g., under Title VI of the Civil Rights Act of 1964) but proactively identify approaches to ensure all residents can fully participate.

3.2.2 Policy change to reduce barriers

FEMA's own guidance documents have encouraged prospective grantees to "frontload" work on buyouts (Federal Emergency Management Agency, 2015) but that is challenging to do in practice. Shifting administrative work to a pre-disaster (and, often, pre-funding) timeframe requires capacity, resources, and certainty. Federal agencies can help with this in several ways, and specific recommendations from workshop participants include:

- Providing up-front (pre-disaster) funding for preparatory work and making such work explicitly eligible under opportunities such as Advance Assistance for FEMA's Hazard Mitigation Assistance grants.
- Authorizing a certain amount of funding to flow to a jurisdiction upon completion of their hazard mitigation plan to take immediate action on the preparatory activities described therein.
- Allowing buyout-related work begun before a federal grant is awarded to be eligible for reimbursement[1].
- Simplifying funding application processes across agencies, such as by implementing a federal government-wide uniform application process for hazard mitigation and related grants.
- Streamlining federally required benefit–cost analysis (BCA) processes, for example via:
  - Allowing "durable" area-wide BCA pre-approval, where average BCA values would cover a specified area over a particular timeframe.
  - Allowing for proxy evaluations, like severe repetitive loss status or the use of flood depth-damage curves, in BCA calculations.
  - Expand pre-calculated benefits to cover more activities, costs, and scenarios.

3.3 Shift 3: from valuing property to valuing people

Buyouts have well-documented social justice implications, especially (but not solely) with respect to racial equity (Elliott et al., 2020). From the perspective of government hazard mitigation or disaster recovery funding programs, grants for buyouts are a public benefit and awarding funds to a so-called disadvantaged community is a move toward equity. However, a buyout offer is unlikely to be experienced as a benefit by someone who does not want to move and sees buyouts as a tool for forced displacement. Siders (2019) conveys this tension as follows:

> *The USA has a long history of social inequality that has manifested in low-income and minority populations living in vulnerable areas. When buyouts disrupt communities, they may exacerbate this inequality. But not acting—leaving low-income and minority populations in areas known to be hazardous or using federal funding to rebuild in those areas—also perpetuates inequality.*

1 In January 2023, after the conclusion of the workshops, Congress passed the Hazard Eligibility and Local Projects Act, H.R.1917. This legislation allows certain eligible acquisition and demolition activities to be eligible for Hazard Mitigation Assistance funding even if they began before a grant award; historically, this was not allowed.

Accordingly, buyout programs should be tailored to—and designed in partnership with—the needs and goals of the actual people facing the hazards, with actions rooted in the human context of the community and members' ties to place and nature, rather than just the community's physical or financial risk.

3.3.1 Description and examples

Flood risk is disproportionately borne by low-wealth communities, and climate change is expected to further concentrate flood risk in Black communities and other communities of color (Wing et al., 2022). This is not a coincidence. Past and current laws and policies, along with disinvestment in housing and infrastructure, have forced households with historically low levels of political power into more vulnerable areas. When conditions are dire enough for buyouts to be proposed, they are likely just one more burden on top of the cumulative effects of long-term structural inequities.

Flood-prone communities are not a monolith and residents all have different risk tolerances, preferences, and circumstances. Even within the same community, some may want to leave and some may want to stay. However, buyout practitioners and recipients describe inequities in both situations, where communities or households that *want* buyouts have trouble accessing the resources to do so, and those that *do not want* buyouts feel that they have no other options. Buyout recipients reported a strong desire for programs to both feel fair and result in fair outcomes, but they agreed that exactly what this looks like will differ from place to place.

To achieve this, buyout program staff should be educated on how current and past laws, policies, land use decisions, previous buyout programs, and other local factors have contributed to distributions of risk, vulnerability, and investment. Staff should understand how the prioritization of lower-wealth communities and/or communities of color for buyouts can be experienced by residents as yet another target on their backs—a sacrifice zone populated by those who have already sacrificed the most. If residents perceive that the buyout program staff are ignorant or unfeeling about these forces beyond the residents' control, they may justifiably lack trust in the program, making it harder for those who might benefit from a buyout to even consider or explore it.

Even more important is designing the policies and procedures of the programs with equity as a goal and a measure of success. Understandably, compensation was a key focus of workshop participants, who emphasized that a household should be made better off by a buyout, regardless of their particular circumstances. Specific aspects of the discussion focused on the following:

- Home valuation: Buyout funding sources typically limit the actual purchase price of the home to fair market value (FMV), but reasonable people can disagree on what is fair, or which "market" is relevant. Even when the FMV is not disputed, the base price of the home is often not enough to make residents whole because of the additional expenses associated with moving and becoming reestablished in a new location, and the fact that comparable housing in a low-risk neighborhood is often extremely difficult to find at all, let alone for the same price as a (possibly severely devalued) home in a vulnerable location. Workshop participants recommended finding ways to supplement the purchase price of the home to make it possible for households to participate and move forward with their lives.
- Relocation incentives: Often those in the highest risk zones are the lowest wealth, or otherwise least able to relocate without additional resources. As it is in the best interest of the public to create open space in the highest risk areas, programs should consider "relocation incentives" or other supplemental funding that can be offered to people who volunteer for the buyouts in those areas. For example, some programs offer incentives to participants who relocate within the municipality or region as part of a strategy to disrupt the community as little as possible while still helping people move out of harm's way. However, this must be done carefully to avoid coercion to participate.
- Tenant support: Buyouts can be particularly hard on people who rent their homes, as funding programs are designed for property owners rather than tenants. When the owner takes a buyout, it essentially forces an eviction on the tenants. A program with equity as its goal will be able to justify compensation and other assistance to renters. For example, local buyout programs could provide assistance with finding and securing housing through housing counselors or similar services.

Beyond the property transaction itself, workshop participants stressed the need for personalized communication and guidance. The key difference between buyout recipients who reported an overall positive experience and those who did not was the guidance and support they received from at least one person they trusted. As one buyout recipient said, "[It is] so difficult to go through because you have already been through so much… [you need] a direct line to someone you can discuss things with on a regular basis." This should be the one and only time a household goes through this, so buyout recipients should have someone knowledgeable guiding them along the way.

Specific examples include:

- Competent, compassionate case management: The face of the buyout program is the case manager. Case managers should have the knowledge, cultural competence, time, and fortitude to patiently, compassionately, and skillfully walk with residents through their buyout process. Case managers can make sure that every household, regardless of their language, education, wealth, race, or any other potentially limiting factor, is able to access the information they need and the benefits the program offers that would be most helpful to them.
- Locally rooted staff: Where possible, buyout programs should employ members of the community, particularly in any aspects of the work that require outreach (e.g., case management and communications). This can build trust in the program, while also generating meaningful, visible jobs. One participant said that, after her community was decimated by Superstorm Sandy, dozens of members of the community sprang into action to help, even if they were affected themselves. She said "teachers, nurses, construction guys, healthcare workers, bankers, etc." were all willing to give their time and expertise to the challenges at hand. She lamented, however, that there wasn't a system in place to harness their energy and expertise in an organized fashion because, over time, it wasn't sustainable for everything to be done by volunteers. Buyout programs would be wise to prepare to fill positions with local people, because, as one participant observed, "they will stay if […] they are empowered to help."

- Culturally competent communication: Programs should be transparent while protecting confidential information. Programs in communities that have historic reasons to be skeptical of government programs, particularly government programs that involve relocation, can build trust by making sure that the information everyone needs is as clear, transparent, and accessible as possible. At the same time, through the case managers, individual households need to be able to ask questions that are sensitive to them in a private setting.
- Wrap-around services: Moving is stressful for most people, regardless of circumstance. In a buyout, the stresses are magnified by the bewildering process, often in a post-disaster context. Buyout recipients agreed across the board that buyout programs should offer services that help mitigate those stresses. Some examples include:

    - Emergency and transitional housing support services, such as providing places for people to safely shelter during emergencies and short-term housing for people who cannot stay in their homes until a buyout is finalized.
    - Financial services, such as mortgage negotiations and forgiveness, down payment assistance, low interest loans, financial counseling or planning, and moving assistance, including cash support or contracts.
    - Social services, such as school enrollment support for households with children, estate planning resources and other supports for elder residents, disability assistance, and employment and job training or placement assistance.
    - Mental health services for trauma and stress and physical health services for long-term impacts from flood or fire exposure. Recipients noted that one of their chief needs throughout and after the buyout was mental health support.
    - Legal services to support households as they review the legal implications of participating in a buyout program, immigration services for households with undocumented family members, and real estate legal services such as titling assistance.

3.3.2 Policy change to reduce barriers

Many policy barriers to more equitable buyouts exist in the funding process itself, especially when it comes to smaller, rural, disinvested, or otherwise lower-capacity communities. Funding for "wrap-around services" like movers or mental health support, or for additional payments to supplement an offer, may not be eligible under federal grants and thus out of reach for lower-resourced jurisdictions. In addition, federal grants typically waive Uniform Relocation Assistance and Real Property Acquisition Act (URA) benefits for homeowners participating in voluntary buyouts, because they are not considered to be displaced. Federal agencies providing funding should ensure that their programs fund and support localities starting with a community vision that reflects residents' top priorities.

More broadly, FEMA should act on recommendations from the Department of Homeland Security Office of Inspector General (2022), the U.S. Government Accountability Office (2022b) and from community members, advocates, and other experts who submitted feedback via recent comment periods (Federal Emergency Management Agency, DHS, 2021, 2022) to advance equity and address historical/current harms that its programs have caused.

Specific recommendations from workshop participants include:

- Allowing funding programs to compensate participants based on local housing needs rather than the market value of the homes they are acquiring. For example, FEMA Hazard Mitigation Assistance funding allows for a "shortfall" cost of up to $31,000 if housing in a safer location is more expensive than the buyout payment (Federal Emergency Management Agency, 2024). However, this amount is often insufficient and should be updated to reflect the reality of current housing markets.
- Making homeowners participating in voluntary buyouts eligible for URA relocation benefits in cases where fair market value will not meet rehousing needs.
- Simplifying benefit–cost analysis requirements and making reduced/zero cost shares for underserved communities more widely available.
- Allowing funding programs to fund and staff "wrap-around services" for participants and explore innovative approaches to supporting and incentivizing equitable practices among local programs.
- Supporting the development of methods for evaluating the equity of buyout programs, especially for more complex cases like tenant-occupied housing and mobile/manufactured homes.

3.4 Shift 4: from insufficient to innovative funding

FEMA and HUD grant programs are the primary sources of buyout funding in the country, but they are not the only options (Peterson et al., 2020). There are other federal agencies that fund acquisitions for the purpose of meeting their missions, such as land management, habitat restoration, or building and maintaining key public infrastructure (Horn, 2024). Often, federal funding must be supplemented by a non-federal match, typically made up of state or local dollars but sometimes borne by participants in the form of decreased offer amounts. Blending government funding sources can lead to increased complexity; in some cases, buyout programs avoid federal funding entirely to gain more control and flexibility. However, few jurisdictions can support a fully self-funded program. Better buyouts require better funding and, in many cases, this will require creative, streamlined combinations of multiple sources.

3.4.1 Description and examples

To meet demand and fill in the gaps left behind by federal funding sources, workshop participants suggested looking beyond the public sector. Creative, experimental thinking to reduce the economic burden of flood risk is already happening in the insurance sector, including experiments with catastrophe bonds and parametric insurance (e.g., Kousky et al., 2021). Philanthropy is another relatively untapped source for buyout funding, even though many charitable organizations and large donors have made addressing climate change their number one priority in recent years. Another area for innovation might be public-private partnerships, for example, with local businesses whose workforce draws significantly from communities in high-risk areas. Business leaders could become advocates and funders for buyouts and the construction or reconstruction of replacement housing in areas outside of floodplains near key places of employment. Additional possibilities noted by workshop participants include sales taxes, stormwater utility fees, and a tax on diesel. Some are considering

using resilience bonds or green bonds as a way to finance work without harming municipal credit ratings.

However, securing support for local funding of any kind requires persuading elected officials and other decision-makers that the buyout program plays a significant role in achieving key community goals. As noted in Section 3.1, planning for buyouts is critical for building the case that they deserve to be funded with local revenue, bonds, loans, or other sources. Local officials are often concerned with loss of tax base when converting structures to open space. A well-designed buyout program must account for this tension and seek to balance losses with well-articulated public benefits that are supported by evidence and data over time. This challenge is being met with various experiments, including an increasing number of methodologies to quantify and compare the costs of providing public amenities and services to vulnerable areas versus the income they generate over time in order to justify the right timing for buyouts. Financial mechanisms, such as a schedule of payments in lieu of taxes, could also provide an "off-ramp" of supplemental revenue and ease the transition.

Regardless of funding sources, workshop participants emphasized that buyout programs should cover all relevant expenses and be distributed according to community priorities and goals. Buyout recipients reported that, while the amount of money they received for their house and relocation expenses was adequate, it did not make them whole, and in some cases they were worse off after the buyout due to increased living expenses and the mental health and other impacts they and their neighbors experienced. The group offered several thoughts on how to adequately compensate buyout recipients:

- The traditional model of paying "pre-storm" fair market value is not appropriate in areas with rapidly increasing housing costs, especially in programs with long wait times. If a jurisdiction's priority is to prevent rebuilding in risky areas, they must be able and willing to make offers appropriate for the local housing market.
- Funding should be guaranteed before community members are required to complete paperwork, provide documentation, or complete other administrative steps.
- Relocation incentives and other supplemental payments can encourage greater participation by making buyouts a more viable option for more community members. However, they must be used carefully to avoid coercion and social pressures.
- Shorter timeframes (e.g., on the scale of a typical real estate transaction) make standard fair-market offers more feasible for sellers.
- Buyout recipients should be able to take appliances, fixtures, and other transportable items that are in good condition without risking offer amounts. Any salvage and recycling plans should be clearly communicated, so that buyout recipients understand how materials might be re-used and who might benefit.
- Funding for wrap-around services, particularly mental health support, should be a standard component of buyout programs. Whenever possible, programs should avoid reimbursement-based payments for moving services and similar benefits, because buyout recipients may not be able to front the cost.

3.4.2 Policy change to reduce barriers

Refer to Section 3.3 for discussion of funding-related recommendations for more equitable outcomes. Workshop participants recommended the following additional policy changes to make funding sources more flexible and easier to use:

- Simplifying processes/requirements for using multiple funding sources. Agencies need to align funding opportunities temporally as well as administratively (e.g., state and federal timelines can be misaligned, causing local programs to fail).
- Allowing use of NFIP funding streams, for example increasing the amount of Increased Cost of Compliance (ICC) coverage and making it explicitly applicable to/available for buyouts (for more information on ICC coverage, see Association of State Floodplain Managers, 2016; Wharton Center for Risk Management and Decision Processes, 2017). Another approach could be authorizing buyout funding via the NFIP claims process, so that eligible buyout recipients could be pre-approved and guaranteed a certain minimum offer as part of their insurance policy (Weber and Moore, 2019).
- Broadening the eligible activities supported by traditional buyout funding sources (see Section 3.3).
- Increasing federal support (financial and otherwise) for local and state capacity building. This could include creating capacity building set-asides within federal grant programs, providing expanded non-financial capacity building assistance via programs like FEMA's BRIC Direct Technical Assistance initiative, and incorporating capacity-focused metrics like the Rural Capacity Index (Headwaters Economics, 2024) into funding prioritization and evaluation processes.
- Supporting implementation of innovative local funding mechanisms, like resilience-based zoning ordinances.
- Increasing funding for resilient affordable housing development and residential retrofits.

3.5 Shift 5: from silos to partnerships

Buyouts are part of a larger ecosystem of hazard- and disaster-related programs, which is heavily fragmented and siloed (U.S. Government Accountability Office, 2022a). For buyouts to serve as the basis for a more holistic vision, it is critical for programs to work across silos—both within and across levels of government, and by forging genuine partnerships between governments, communities, and other actors. In the words of a workshop participant, "Partnerships can be very complicated and a headache, but they are really important and a part of good government."

A comprehensive buyout program could contribute to multiple local priorities, such as stormwater management, housing justice, climate resilience, economic development and workforce support, biodiversity, and/or recreation. These multiple benefits are more likely to be realized when the people committed to these various community and environmental benefits are brought into collaboration with each other to explore how buyouts could contribute to their respective missions.

3.5.1 Description and examples

Collaborative efforts within and across jurisdictions are not easy. Buyout programs can start small by leaning on existing collaborative

efforts, such as standing inter-departmental committees or working groups, to build awareness and test interest in further conversations about how buyouts might enable other priorities. If a regional approach is more appropriate, existing collaborations like regional planning agencies or watershed associations may be good places to start. Beyond government entities, building relationships with local community-based organizations (CBOs) can be critical. Often, CBOs are in the best position to represent community values and liaise between the government-sponsored buyout program and the residents who are, or may become, interested. Buyout managers may also wish to seek professional assistance from collaboration experts to develop and facilitate a strategy that is appropriate for their context and goals.

Each community is unique, so the range of actors that could be brought into the buyout conversation differs from program to program. Workshop participants offered suggestions for non-traditional collaborators and knowledge-sharing partners including the following: community land trusts, housing advocates, local history experts, landscape architects, faith communities, and academic institutions. They also named the need for collaborative evaluation and standard-setting: for example, developing best practices and quality standards so there is less variation in the information, resources, and level of care people receive in different areas.

As buyout practitioners work to build partnerships, they should be ready to face head-on the many potential tensions between buyouts and other community priorities. An example of this currently faced by many communities is housing scarcity: there is not enough housing or not enough affordable housing to begin with, so the idea of removing homes and driving residents into an already overwhelmed housing market is a difficult policy to pursue. This tension may be mitigated by a holistic approach to buyouts that includes building or rebuilding replacement housing and subsidizing it appropriately, but there are few examples of successes to draw on. It is a challenge that begs for creativity and experimentation and requires buyouts to work in concert with other solutions to community needs.

Finally, collaboration is critical for long-term land management. Ideally, buyouts begin with the end in mind—with a plan to use the land that is vacated to protect others by creating a buffer, to create natural spaces for habitat and other restorative functions, or to provide any number of public amenities. Tensions around buyouts can be mitigated substantially when they benefit both those who leave and those who stay. Strategic partnerships make this real, with community-based interest groups like advocacy organizations, non-profits, businesses, and academic or cultural institutions. Open-space experts are particularly important, such as landscape architects, garden centers, or others who can envision the spaces with engagement in the community, identify and connect with additional sources of funding to design and build them, and maintain them over the long run.

3.5.2 Policy change to reduce barriers

Many of the aforementioned policy recommendations also support partnership development, e.g., by helping governments and communities to build capacity. Additional recommendations include:

- Expanding the eligibility of nonprofits, such as land trusts and social justice organizations, to directly access federal hazard mitigation funding.
- Leveraging conservation tools (e.g., public lands designations) to support long-term land restoration, conservation, and maintenance.
- Supporting and/or facilitating cross-jurisdictional knowledge sharing, including from other countries.
- Funding cross-sector training and technical assistance.

4 Conclusion

By sharing their lived and learned expertise across a wide range of geographies and buyout experiences, Innovations in Buyouts workshop participants envisioned a more holistic buyout process that provides a better experience to both residents and implementing agencies. Instead of thinking of buyouts as discrete hazard mitigation projects, workshop participants emphasized that we need a structure that allows a community to plan ahead, complete as much work as it can before a disaster hits, and be ready to plug in sources of funding when and where they meet the community's specific needs. This institutional capacity might sit at the local government, county, watershed, or state level, but it must be informed by both local community members and the experiences of other programs from across the country. In particular, our community participants recommended tangible ways to incorporate lived experience into government programs.

Workshop participants noted the value of providing a concise reference for policymakers who are in a position to address issues with home buyouts. In that vein, Table 1 presents a compilation of the policy changes that could help enable those shifts, as listed in the preceding sections. Workshop participants also emphasized that people involved with buyouts need to continue to learn from one another and imagine new ideas together. As of late 2024, the Innovations in Buyouts workshop team is beginning to reconvene participants for additional conversations and encourages readers to explore ways to leverage both lived and learned experience in their own work. Beyond buyout practitioners and participants, other actors including funders, technical assistance providers, insurers, researchers, and policymakers all have a role to play.

Importantly, implementation of the recommendations presented here will require genuine partnership between governments and communities. Above all, state and local agencies are encouraged to build relationships with people facing current and future hazards and to build pathways for generative, non-extractive, two-way communication. Honest conversations held from a place of mutual trust can help practitioners and community members weigh options, costs, and tradeoffs and build the political and social will to pilot innovative approaches.

For communities where adapting in place is not a possible or desired outcome, residents and the public agencies that serve them should have a dignified, fair, and efficient system supporting relocation. Buyouts are a tool that can be employed to this end—but, like any tool, they are not in and of themselves a solution, and in many ways they are ill suited to current environmental and social contexts. In an ideal world, perhaps home buyouts could be avoided

TABLE 1 Compilation of opportunities for policy change, as recommended by workshop participants.

Shift	Recommendations
From building for the past to planning for the future	• Making federal funding for hazard mitigation, economic development, and similar efforts contingent upon adherence to strong floodplain management standards and avoidance of risky siting and construction, e.g., via implementation of the Federal Flood Risk Management Standard. • Supporting (and enforcing) project development as an important component of hazard mitigation planning. • Providing resources for state and local capacity building with accessible, up-front funding and technical assistance. Opportunities for increasing capacity building support include programs such as FEMA's Emergency Management Performance Grants and the BRIC Direct Technical Assistance program. • Improving intra- and interagency coordination, e.g., between programs and agencies with hazard mitigation and disaster recovery roles, as well as communication between levels of government. • Maintaining centralized, user-friendly repositories for locally relevant data to be used in planning, and creating additional data products to fill existing gaps (e.g., advisory layers for FEMA flood risk maps that depict current and projected flood elevations along with the lateral extent of high-risk areas).
From reactive projects to proactive programs	• Providing up-front (pre-disaster) funding for preparatory work and making such work explicitly eligible under opportunities such as Advance Assistance for FEMA's Hazard Mitigation Assistance grants. • Authorizing a certain amount of funding to flow to a jurisdiction upon completion of their hazard mitigation plan to take immediate action on the preparatory activities described therein. • Allowing buyout-related work begun before a federal grant is awarded to be eligible for reimbursement. • Simplifying funding application processes across agencies, such as by implementing a federal government-wide uniform application process for hazard mitigation and related grants. • Streamlining federally required BCA processes, for example via: o Allowing "durable" area-wide BCA pre-approval, where average BCA values would cover a specified area over a particular timeframe. o Allowing for proxy evaluations, like severe repetitive loss status or the use of flood depth-damage curves, in BCA calculations. o Expand pre-calculated benefits to cover more activities, costs, and scenarios.
From valuing property to valuing people	• Allowing funding programs to compensate participants based on local housing needs rather than the market value of the homes they are acquiring. For example, FEMA Hazard Mitigation Assistance funding allows for a "shortfall" cost of up to $31,000 if housing in a safer location is more expensive than the buyout payment. However, this amount is often insufficient and should be updated to reflect current housing markets. • Making homeowners participating in voluntary buyouts eligible for URA relocation benefits in cases where fair market value will not meet rehousing needs. • Simplifying benefit–cost analysis requirements and making reduced/zero cost shares for underserved communities more widely available. • Allowing funding programs to fund and staff "wrap-around services" for participants and explore innovative approaches to supporting and incentivizing equitable practices among local programs. • Supporting the development of methods for evaluating the equity of buyout programs, especially for more complex cases like tenant-occupied housing and mobile/manufactured homes.
From insufficient to innovative funding	• Simplifying processes/requirements for using multiple funding sources. Agencies need to align funding opportunities temporally as well as administratively (e.g., state and federal timelines can be misaligned, causing local programs to fail). • Allowing use of NFIP funding streams, for example increasing the amount of ICC coverage and making it explicitly applicable to/available for buyouts. Another approach could be authorizing buyout funding via the NFIP claims process, so that eligible buyout recipients could be pre-approved and guaranteed a certain minimum offer as part of their insurance policy. • Broadening the eligible activities supported by traditional buyout funding sources. • Increasing federal support (financial and otherwise) for local and state capacity building. This could include creating capacity building set-asides within federal grant programs, providing expanded non-financial capacity building assistance via programs like FEMA's BRIC Direct Technical Assistance initiative, and incorporating capacity-focused metrics like the Rural Capacity Index into funding prioritization and evaluation processes. • Supporting implementation of innovative local funding mechanisms, like resilience-based zoning ordinances. • Increasing funding for resilient affordable housing development and residential retrofits.
From silos to partnerships	• Expanding the eligibility of nonprofits, such as land trusts and social justice organizations, to directly access federal hazard mitigation funding. • Leveraging conservation tools (e.g., public lands designations) to support long-term land restoration, conservation, and maintenance. • Supporting and/or facilitating cross-jurisdictional knowledge sharing, including from other countries. • Funding cross-sector training and technical assistance.

altogether. However, with institutional capacity at the appropriate scale, and with the combined insights of lived and learned experience, buyouts can serve as a foundation for a better approach to climate-driven relocation.

Author contributions

AW: Conceptualization, Project administration, Writing – original draft, Writing – review & editing. KM: Conceptualization, Project administration, Writing – original draft, Writing – review & editing. MO: Conceptualization, Project administration, Writing – original draft, Writing – review & editing. SH: Conceptualization, Project administration, Writing – original draft, Writing – review & editing. CH: Conceptualization, Project administration, Writing – original draft, Writing – review & editing.

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CH was employed by CH Consulting, LLC.

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Generative AI statement

The authors declare that no Gen AI was used in the creation of this manuscript.

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Ecomyopia on the Chesapeake: social and cultural barriers to climate-induced managed retreat

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Ecomyopia is the tendency to ignore important environmental information that challenges structures of power and place-based identities. Predictions of relative sea-level rise on the Eastern Shore of Maryland include catastrophic land loss over the next 50 years but have not promoted serious discussion about managed retreat. We review literature emerging from Mary Douglas' theory of the cultural construction of environmental risk and psychological theories of cognitive dissonance and social identity to examine why many residents of the Chesapeake Bay resist relocation in the face of rising sea level. We use this theoretical synthesis to analyze 63 in-depth interviews conducted on the Eastern Shore of the Chesapeake Bay to examine how social institutions and widely shared narratives of heritage and identity frame discussion of sea-level rise. Technological solutions to shoreline erosion dominate the discourse as a means of avoiding cognitive dissonance caused by relocation's existential threat to place-based identity. As predicted by the Cultural Theory of Risk, group identities shape risk perceptions associated with rising sea level and climate change. Discourse in our case study illustrates how confirmation bias is a social process and why those who challenge the status quo are marginalized as environmental information is transformed into preferred solutions. We generalize from this case study to explain how ecomyopia can preclude managed retreat as a rational strategy in regions threatened by anthropogenic climate change and rising sea levels.

KEYWORDS

managed retreat, cultural theory of risk, cognitive dissonance, social identity, climate change, tidal flooding, ecomyopia

Introduction

Smith Island, home of the watermen for centuries, is a cultural icon and tourist destination in the middle of the Chesapeake Bay on the east coast of the United States (Figure 1). Maryland's official state dessert, the Smith Island Cake originated here. With a permanent population of around 200, it is accessible only by boat. The first European occupation began in 1686, and many current residents trace their ancestry back to colonial times (Rehak, 2024, p. ix). Like most of the Chesapeake Bay area, the island is experiencing more frequent flooding due to a combination of rising sea level and tectonic subsidence (Spanger-Siegfried et al., 2017). Although hurricane Isabel in 1993 caused more damage, a few homes and businesses on Smith Island were damaged by Superstorm Sandy in 2012. To avoid the risk of potential future storm damage, some residents petitioned the state for federal buyouts of their homes (Shostak, 2022). But most residents vehemently opposed the buyouts and county officials would not approve them. Instead, residents mobilized to form a non-profit advocacy group called "Smith Island United" and successfully petitioned for structural improvements to control erosion, which they see as the real threat to the community's survival (Kobell, 2014).



FIGURE 1
Interviews conducted in Talbot, Dorchester, and Somerset Counties on Maryland's Eastern Shore revealed how group identity and cognitive dissonance shape perceptions of risk associated with rapidly rising relative sea level. Interview locations and major geographical features are identified.

The response of Smith Islanders to the buyout proposal is not unique. As we will demonstrate, it exemplifies attitudes and beliefs found on Hoopers Island, Tilghman Island, and many other communities on Maryland's Eastern Shore (Kobell, 2020). When we read about the rejection of the Smith Island buyouts, we immediately thought about the broader implications for managed retreat. With no land elevation >5 feet above sea level and most structures situated at sea level, which is projected to rise rapidly, Smith Island would appear to be an exemplary candidate for managed retreat. Instead, the events on Smith Island exemplify "agnostic adaptation" (Kuh, 2015): adapting to some effects of climate change without attending to the core problem or even admitting climate change exists. Although agnostic adaptation encourages pro-active behavior to address environmental risk, it may detract from efforts to solve the long-term problem, which can eventually overwhelm short-term efforts (Koslov, 2020). In this article, we use research we conducted on Maryland's Eastern Shore to integrate the Cultural Theory of Risk with psychological theories of cognitive dissonance and social identity to explain the rejection of managed retreat. We situate these findings within the broader issue of ecomyopia: the tendency for societies to ignore, dismiss or deny environmental information with potentially catastrophic implications (Casagrande et al., 2017).

Relative sea level rise on the Eastern Shore of Maryland

The Eastern Shore of Maryland is bordered by the Atlantic Ocean to the east, and the Chesapeake Bay on the west (Figure 1). Hundreds of miles of shoreline and numerous rivers and wetlands dominate the terrain. Nearly a third of the population of Maryland resides on the Eastern Shore, but population density is low, with small towns scattered across the landscape. The history and the future of these towns is intimately tied to the ocean and the estuary, which are experiencing rapid environmental change due to rising sea level (Rehak, 2024). Casagrande first traveled to Smith Island in September 2016 to find out more about the failed buyout proposal and sample the famous cake. Upon disembarking from the ferry, he was surprised to find the streets knee-deep in water, blocking access to his accommodations. There was no storm. It was an abnormally high tide. It turns out that such "sunny day flooding" has become increasingly common and many locals consider it to be normal.

Maryland's Eastern Shore region is highly vulnerable to tidal flooding (Figure 2) and storm surge due to low elevation, land subsidence, erosion, and rising sea level resulting from glacial melt and warming ocean waters (Scott, n. d.). The IPCC (2023) indicates that relative sea level rise along the East Coast of the United States is



FIGURE 2
Abnormally high tides that cause "nuisance flooding" in the Chesapeake are becoming higher and more frequent because of rising absolute sea level combined with tectonic subsidence. Commercial fishing infrastructure like this Chesapeake waterman's shanty built to accommodate tidal flooding are an example of an adaptation that will eventually be overwhelmed.

accelerating due to anthropogenic climate change. Relative sea level is a result of changes in both absolute sea level and land elevation. Relative sea level (RSL) in the Chesapeake area is rising 50% faster than places like New York City because of tectonic subsidence that began with glacial retreat at the end of the Pleistocene (Piecuch et al., 2018). RSL has risen more than a foot over the past 100 years (Boon et al., 2010), and Boesch (2015) suggests that the accelerated effect of climate change could result in RSL rise of 5.7 feet by 2100.

The largest impacts of increased flooding on the Eastern Shore of Maryland will be seen in Somerset, Dorchester, Talbot, and Queen Anne's counties. In this region approximately 41,000 homes worth nearly $20 billion USD are situated <5 feet above mean high-tide lines (Boesch, 2015). Nearly 60% of Dorchester County lies in the 100-year floodplain (Cole and Shore, 2008). Tidal nuisance flooding, or "sunny day flooding," exceeding 1.5 feet above mean high water, has risen rapidly in these counties, and could become a daily occurrence along the waterfront by 2050 (Sweet et al., 2014). Spanger-Siegfried et al. (2014) indicated that the waterfront in the city of Cambridge, in Dorchester County, will go from 30 flood events per year today to 242 flood events per year by 2050. According to Cole and Shore (2008), outside of Louisiana, Texas, Florida and North Carolina, the lower Eastern Shore between Dorchester County, Maryland, and Accomack County, Virginia have the largest population in the United States that is facing this extensive level of flood risk.

Shoreline erosion exacerbates the problem in the region. According to the Maryland Shore Erosion Task Force (2000), more than 260 acres of tidal shoreline are lost each year in Maryland. This is approximately 4.7 million cubic yards of shoreline eroding annually on the Chesapeake Bay (Chesapeake Bay Program Nutrient Subcommittee Sediment Workgroup's Tidal Sediment Task Force, 2005). The average rate of erosion in the region is a foot per year, but in some locations, it can be as much as 10 feet per year. This translates into 45,000 acres of shoreline lost over the past century. Erosion will accelerate with rising sea level (Maryland Shore Erosion Task Force, 2000).

The Eastern Shore is also vulnerable to flooding from increasing frequency and intensity of hurricanes and storms associated with human-induced climate change. Modeling by Emanuel (2005) indicates that, over the past 40 years, North Atlantic hurricanes have increased in accumulated annual duration by roughly 60% and that annual average storm wind speeds have increased by 50% over the same period. Low lying land, disappearing wetlands, unprotected shorelines, and eroding barrier islands along the Eastern Shore all allow for storm surge to be more destructive. In severe storms, people describe cars being flooded, houses falling into the bay, and even floating caskets that have emerged in the floods. Under existing conditions, the smallest increase in sea level can exacerbate storm flooding, and even weak storms will have magnified effects on people and property. The Eastern Shore Land Conservancy (2015) estimates that by the year 2050 a Category 1 hurricane with just a five-foot storm surge could flood more than 10,000 homes in the region.

Flooding currently impacts homes, commercial real estate, farms, forests, wetlands, and infrastructure, causing billions of dollars in damage and increasingly forcing people to relocate. Annapolis and Baltimore have experienced a 900% increase in flooding in their historic downtown areas. Estimates are that, without structural solutions, these cities will experience more than 300 flood events per year by 2,100. Annapolis, the state capital, is spending $82 million to control tidal flooding in its historic waterfront (Stephenson, 2024). Ocean City, a tourism powerhouse in Maryland, spends upwards of $10 million dollars every 4 years on beach renewal to keep its structures intact (Koslof, 2022).

Residents of the Eastern Shore are well-attuned to environmental changes (Rehak, 2024). They point out the encroachment of "ghost

forests"—stands of dead trees killed by salt-water intrusion (Kirwan and Gedan, 2019)—and the loss of large tracts of land to erosion in places like Hooper's Island, which is losing 24 acres a year (Kobell, 2020). Septic systems are failing as the water table rises. Residents lament the loss of cultural heritage as cemeteries erode and collapse into water. In locations that are dealing with increased frequency of tidal "sunny day flooding," people adapt by donning high-water waders, building berms around their yards, driving inexpensive used "saltwater cars" during high tides (Figure 3), and elevating homes and garages (Figure 4). Demographic and economic changes combined with inundation and erosion have contributed to abandonment of several Chesapeake Islands over the last 100 years (Arenstam Gibbons and Nicholls, 2006; Kenney and Brainard, 2014). In a process we will refer to as "retreat by attrition," older family homes in rural areas have been left to decay into the encroaching marsh (Figure 5) as younger generations move away for economic opportunity.

Although there is variation in beliefs based on age, occupation, religion, and political orientation, many long-term residents on the Eastern Shore avoid discussing climate change even as they lose their land to its forces (Kobell, 2020). Instead, they explain changes as immutable natural cycles and point to the forces of erosion which can be partially managed through structural solutions. The State of Maryland is proactive in providing support for climate adaptation, but local governments focus mostly on infrastructure improvements to control erosion and manage "nuisance" flooding. No comprehensive policies exist to address the problem of long-term rising sea level. Meanwhile, realtors talk about the "last mortgage cycle" in parts of the region due to banks being unwilling to underwrite mortgages with high flood risk. Blackwater National Wildlife Refuge (Figure 1) is purchasing land and homes to create coastal wetland migration corridors. The Maryland Department of Transportation is questioning investments in roads and bridges serving areas soon to be uninhabitable. Emergency personnel face increasing difficulties responding to areas frequently flooded by high tides.

Managed retreat as a policy option

The population exposed to sea level rise in North America could increase by 71% to 580,000 between 2020 and 2040 (IPCC, 2023, p. 100). By 2100, Hauer et al. (2016) predict a potential 13.1 million Americans could be migrating because of rising sea level. The population that will be impacted on Maryland's Eastern Shore is small, but the culture is iconic of the heritage of the Chesapeake and their water-based livelihoods make them highly vulnerable. What are potential solutions to the problem of rising sea level? Most American policy makers and the public prefer structural solutions like dams, seawalls, bulkheads, levees, dikes, flood containment reservoirs, drainage canals, raised roads, raised utilities, or beach nourishment (Bukvic and Owen, 2017; Mileti, 1999, p. 144). Each of these have negative impacts. For example, levees and dikes encourage development in areas naturally prone to flooding (Di Baldassarre et al., 2018), which can have lethal consequences, as in the case of levee failures in New Orleans during Hurricane Katrina (Pilkey et al., 2016, p. 41–49). Although a seawall might preclude surface water from entering a protected area, hydrostatic pressure of the



FIGURE 3
Many residents of Smith Island use older inexpensive "saltwater cars" during nuisance tidal flooding because of corrosion from the salt. Such adaptations help residents "normalize" events that others would find difficult. The red and white building is the only school on the island and is attended by eight students ranging from preschool through 7th grade. The potential loss of such cultural institutions due to declining population threatens community-based identity.



FIGURE 4
This Eastern Shore home has been elevated with a new and higher foundation to avoid water damage to living areas. Preferences for such structural solutions help to avoid the cognitive dissonance associated with more demanding solutions like relocation or managed retreat. Agnostic adaptation (attempts to mitigate increasing flood risk while avoiding topics like climate change or rising sea level) can alleviate risk in the short term while increasing it over the long term.



FIGURE 5
Retreat by attrition: multigenerational homes abandoned by younger residents who see little economic incentive to adapt properties to rising sea level dot the landscape. Here we see tidal salt marsh species like *Phragmites australis* and *Spartina* spp. taking over an abandoned property.

ocean forces water underground through sand or porous rock, which must be pumped out at great expense and risk of pump failure, which also occurred in New Orleans. A seawall also blocks inland rainwater from escaping a protected area during a high rain event like a hurricane, which causes flooding. Public funding for structural projects is contingent on benefit–cost analyses (Sylves, 2012). The value of real estate in Manhattan justifies high costs of protective infrastructure. This would not be true for sparsely populated places like Smith Island.

Individual property owners can make improvements to their homes and businesses like elevating a structure (Figure 4) or installing tide-control berms around a property (Cole and Shore, 2008). While

an elevated structure may protect personal items, utility delivery and access to the structure for emergency response are precluded during flooding. The National Flood Insurance Program (NFIP) requires participating communities to adapt and enforce such mitigations through building ordinances. In exchange, members of the community can purchase flood insurance from the federal government at a discount (Horn and Webel, 2023). Although the goal is to promote resilient development, the unintended consequence is that NFIP has encouraged more development in flood-prone areas (Peralta and Scott, 2024). Increased flooding resulting from climate change, beginning with Hurricane Katrina and Superstorm Sandy, has caused insurance claims to exceed revenue from premiums leaving the NFIP over $20 billion debt (Horn and Webel, 2023).

We assume most of the people in our study area do not want to relocate. But the landscape is dotted with homes abandoned to encroaching wetlands (Cole and Shore, 2008). Perhaps retreat caused by flooding and erosion could be more efficient, effective, and equitable if relocations are planned and supported with resources (Siders et al., 2021). "Managed retreat" refers to strategic assistance for the relocation of people and infrastructure away from areas vulnerable to hazards such as rising sea level and flooding (Hino et al., 2017). In the US, retreat has occurred mostly in the form of voluntary buyouts funded by Federal Emergency Management Agency (FEMA) or Housing and Urban Development (HUD) programs in which the government purchases property at fair-market value, removes structures, and the vacant land is turned over to the local government with the restriction that it can never be built on again (Siders, 2019). Some local governments have used the land to create parks for recreation while others have restored wetlands for flood control (Zavar and Hagelman Iii, 2016). The ethical justification for encouraging and assisting relocation from high-risk areas is to reduce injury and loss of life. Managed retreat could also relieve the pressure that increasing disasters resulting from climate change are placing on emergency responders (Arnell, 2022), in some cases overwhelming emergency management agencies.

A systematic approach to managed retreat would mitigate the emerging insurance crisis. Banerjee et al. (2024) estimate that over the last 30 years natural catastrophe insured losses have grown annually by 3% more than the global economy (p. 2). NFIP is heavily burdened by "repetitive loss" properties (Hayat and Moore, 2015) that can be prioritized for relocation with managed retreat (Frimpong et al., 2019). Escalating claims from climate-related hazards like hurricane winds are undermining private insurance profitability and firms are withdrawing coverage from entire states (First Street Foundation, 2023). Louisiana and Florida have created publicly backed insurers of last resort to ensure mortgages on homes and businesses can be obtained in flood-prone areas. As the impacts of climate change accelerate, artificially extending the availability of low-cost insurance is unsustainable and will likely replicate the human tragedy of New Orleans.

Managed retreat would also allow governments to strategically plan for disinvestment in infrastructure. State agencies like the Maryland Department of Transportation face decisions whether to continue maintaining or building roads and bridges serving areas likely to be uninhabitable within the typical 30-year planning cycle. Accepting managed retreat also presents the potential to transform the perception that humans can indefinitely subjugate nature because it requires a degree of humility and recognition of the value of natural ecological processes (Siders et al., 2021; Koslov, 2016).

We are not promoting managed retreat as a panacea. Some coastal cities will easily meet benefit–cost assessments and have geo-physical characteristics amenable to structural solutions. The loss of tax base when residents relocate to other jurisdictions threatens the financial stability of coastal municipalities, although comprehensive planned relocations within the same jurisdiction can help maintain the tax base (BenDor et al., 2020; Knobloch, 2005). Loss of tax base is more likely with *de facto* retreat by attrition.

Managed retreat has social justice implications. While the public generally supports voluntary buyouts, involuntary relocation using eminent domain raises concerns that governments may not act in an equitable manner (Mach et al., 2019; Siders, 2019). FEMA buyouts require benefit–cost justifications that can disqualify sparsely populated areas with low home values or promote "disproportionate protection of wealthy homeowners and relocation of low-income homeowners" (Siders, 2019, p. 250), depending on political and economic context.

Marino (2018) and Koslov (2016) document cases in which groups of homeowners desire relocation but governments attempt to deny them. In other cases, the majority in a community and their leaders may oppose relocations, which, as in the case of Smith Island, denies the opportunity to the few who want them. If the fair market value of a home is low or over-mortgaged, lower-income and elderly homeowners may not be able to afford a new home and cannot accept a buyout. Ideally, as in the case of Valmeyer, Illinois, plans are made collaboratively and inclusively to encourage equitable outcomes and protect the tax base (Knobloch, 2005). Siders et al. (2021) suggest that equitably just processes of managed retreat may offer potential to correct broad social inequities. While residents may feel that managed retreat amounts to appropriation of land and erasure of cultural heritage, it can provide a haven from the impacts of climate change and allow communities to reinvent themselves in a new location.

Statistical analyses of survey data to identify variables that influence perceptions and attitudes about relocation or buyouts provide a starting point for explaining socio-political outcomes of cases like ours. Although demographic and socio-economic characteristics are important variables, they alone have proven insufficient for predicting perceptions of relocation (Bubeck et al., 2018). Concern about flood risk has been correlated with support for buyouts (e.g., Hotard and Ross, 2023; Seebauer and Winkler, 2020). Studies have found that people who have experienced floods recently (Frimpong et al., 2019) or frequently (Bukvic et al., 2018; Robinson et al., 2018) are more likely to support or accept buyouts. Our research area experienced significant flooding from storms in 2003, 2007, and 2012 and many residents contend with chronic tidal flooding more than once per month. To our knowledge, only one property has ever been bought out in our study area and opposition to buyouts remains entrenched (Kobell, 2020). Although Chesapeake residents fear erosion, they express little concern about rising sea level, which appears to bias them toward agnostic adaptation and structural solutions.

Homeowner trust in buyout program administrators tends to increase the likelihood of participation (De Vries and Fraser, 2012; Kick et al., 2011). How was trust gained to allow buyouts in Staten Island (Koslov, 2016) but not on Smith Island? The theoretical framework we present below situates trust within the concept of group identity. Although attachment to place and community influence attitudes about buyouts, research has not clearly identified under

which conditions this translates into accepting or rejecting buyouts (De Vries and Fraser, 2012; Koslov, 2016; Phillips et al., 2012; Robinson et al., 2018).

If all the variables described above were similar between two communities, we still would not be able to predict which would embrace or reject buyout proposals. We propose a theoretical framework of how individual cognition and social dynamics interact to create ecomyopia and lead to rejection or alteration of environmental information that might encourage managed retreat.

Theoretical basis for Ecomyopia as an impediment to managed retreat

Here, we develop a theoretical framework for explaining perceptions of managed retreat on Maryland's Eastern Shore, including the potential for evading or denying the topic of rising sea level. Cultural Theory of Risk (CTR), first proposed by Douglas and Wildavsky (1982), has been applied widely in risk perception research (Siegrist and Árvai, 2020). We integrate CTR with psychological theories of cognitive dissonance and social identity to explain why many residents around the Chesapeake Bay strongly resist relocation in the face of rising sea level.

The essence of CTR is that any individual's perceptions of threats conform to their identity and worldview, both of which emerge from the social groups they feel they belong to and groups they are opposed to (Johnson and Swedlow, 2024). For Douglas and Wildavsky (1982), group membership conforms to two social dimensions: willingness to accept social controls (grid) and levels of group commitment (group). These social dimensions determine which types of threats or risks will be of concern to individuals who fall within one of four categories created by the two dimensions. They argued that environmentalists favor egalitarianism and tend to be more concerned with social equity and justice, mistrust large corporations and government bureaucracies, and therefore fear the impacts of technologies like nuclear energy. Conservative capitalists are more individualistic, eschew institutional control, value meritocracy, and focus on risks emerging from social upheaval that might threaten the free market.

Four subsequent decades of research demonstrated that clusters of characteristics and values associated with social groups correlate with concern about specific types of risks, including new technologies, environmental contamination, natural disasters, or climate change (cf. Buss and Craik, 1983; Chassang et al., 2024; Kahan, 2012; Johnson et al., 2020; Johnson and Swedlow, 2021; Wildavsky and Dake, 1990). Maibach et al. (2009) demonstrated how concern, dismissal, or denial regarding global warming is strongly correlated with social group characteristics and values like those proposed by Douglas and Wildavsky. Thompson (2003) admonished that differences in CTR values should be identified and brought to the forefront of conversations about climate change to facilitate progress through democratic compromise. His suggestion has influenced approaches to international treaty negotiation, IPCC recommendations, and participatory national policy processes (Verweij et al., 2022). In this study, we are using CTR to understand why perspectives on flood risk and solutions differ between residents and policymakers on a local scale.

An alternative explanation for perceptions of types of risk emerged independently in psychometric research with more of a focus on characteristics of the risks than characteristics of people (Siegrist and Árvai, 2020). This research indicated that two dimensions–uncertainty (how much is known about the threat) and dread (how afraid someone is about a threat)–greatly influence risk perceptions. Other researchers have found additional factors, including how widespread impacts could be, trust in experts, and ability to control the threat (Chassang et al., 2024). Quantitative survey researchers synthesized CTR and psychometric approaches to further clarify correlations between social groups and specific threats (Chassang et al., 2024; Kahan, 2012; Johnson and Swedlow, 2024). For example, why would some people feel more dread about a risk like climate change than others? But like Chassang et al. (2024), we are interested not just in what people perceive as threatening or why, but how such perceptions function.

Here, we build on the success of previous theoretical syntheses by utilizing cognitive dissonance theory to explain how social characteristics influence which characteristics of risks are attended to. We posit that in-group commitment and attachment to place can both impact risk perception. It is through socially mediated management of cognitive dissonance that people develop perceptions and behaviors related to dread, uncertainty, trust in experts, extent of potential impact, or ability to control a threat (Chassang et al., 2024). Why might sense of place cause a person to feel more dread and stronger group identity and how might positions on continuous survey scales lead to specific behaviors?

Leon Festinger proposed the theory of cognitive dissonance in which he argued that a person experiences psychological discomfort if two cognitions or behaviors are equally important but logically contradictory (Festinger, 1957). As a result of this discomfort, the subject changes a belief or behavior or seeks new information to enhance the consonant cognitions or diminish the importance of the dissonant cognition. This theory became a dominant paradigm in psychological research and led to hundreds of experiments in which subjects were forced to deal with their cognitive dissonance under controlled conditions so that researchers could observe changes in the values, opinions, or behaviors of research subjects (Harmon-Jones and Mills, 2019). The bulk of this research focused on individuals in experimental settings, but some social psychologists have followed Festinger's original focus on group dynamics (Cooper, 2007).

In their participant observation of cult members who believed the world would be destroyed, Festinger et al. (1956) found that cult members who were alone when the prophecy was disconfirmed changed their beliefs about the prophecy. Those who were together became even more committed to their beliefs and started to proselytize more aggressively. The cult members could not ignore that the world was not destroyed any more than our Chesapeake research subjects can ignore the impacts of rising sea level. In both cases, reactions to cognitive dissonance are a process of both individual cognition and social interaction.

Narratives of rising sea level and disappearing land have the potential to induce fear of loss of property, community, and identity among the residents and business owners around the Chesapeake. When experimental participants are confronted with a fear-evoking cognition that requires a difficult solution like a behavior change, they are more likely to engage in denial than those presented with a solution that appears more reasonable to achieve (Aronson, 2008). This conforms to research showing that people are more likely to engage in disaster mitigation behaviors if they believe they have the

capacity to successfully complete them; either alone (Babcicky and Seebauer, 2019) or as a group (Bubeck et al., 2018). In this way, individual cognition produces perceptions of risk control as measured in surveys (Chassang et al., 2024). Abandoning one's home and relocating is a difficult, socially contentious, and likely unreasonable option for many people (Hotard and Ross, 2023; Shostak, 2022). We would expect that the tendency of our Chesapeake research subjects to engage in denial of rising sea level and/or engage in structural solutions, even ones unlikely to succeed in the long run, will be heavily influenced by social interaction. Social processes influence how individual cognition leads to levels of dread or perceptions of risk control as measured in survey research (Chassang et al., 2024).

Festinger (1957) and subsequent researchers have emphasized that the more commitment one has to a belief, value, or behavior, the higher the potential is for cognitive dissonance (Harmon-Jones et al., 2015). Multigenerational attachment to place (referred to colloquially in our study area as "been-heres") in our Chesapeake population represents a high identity commitment that would be challenged by rising sea level and land loss. For more recent transplants (referred to colloquially as "come-heres"), difficult life-changing decisions like investing in a retirement home on the Chesapeake shoreline would also represent a high commitment. In all cases, people faced with the prospect of leaving a home and community are likely to resist relocation, even in the face of potentially catastrophic loss.

How people react to cognitive dissonance is heavily influenced by the groups they consider themselves to belong to or aspire to belong to. According to Social Identity Theory (Tajfel et al., 1979), much of one's personal identity is constructed out of their group membership; both how we see ourselves conforming to our group's values and ideals and how these are used to differentiate in-groups from contrasting groups in which "…a social category acquires its meaning by contrast with other categories" (Hogg, 2001, p. 56). Our perceptions of what represents a risk (Douglas and Wildavsky, 1982), including climate change, terrorism, or social deviance, are based on the values and ideals we use to categorize social groups, including how we believe contrasting groups are constructing risk differently.

Cognitive dissonance has also been shown to cause confirmation bias (Festinger, 1957 referred to this as "selective exposure"). To avoid dissonance-arousing situations, people prefer to be exposed to information supporting rather than conflicting with their current beliefs (Fischer and Greitemeyer, 2010). Kahan (2012) and Newman et al. (2018) found that the worldviews developed within the Cultural Theory of Risk influence the way people choose information and information sources when thinking about climate change. This could bias perceptions of how certain experts are about risk severity (Chassang et al., 2024). We would expect our Chesapeake research subjects experiencing rising sea level to select information that would avoid cognitive dissonance as they seek to explain their observations. Furthermore, much of the information they are selectively exposed to would likely be repeated in conversation. Confirmation bias is strongly associated with group commitment and identity (Kahan, 2012). Very strong commitments to group identity challenged by very serious threats like rising sea level could likely exacerbate confirmation bias and denial and result in proselytization like that documented by Festinger et al. (1956).

How might we explain impediments to managed retreat in our case study? Many inhabitants of the Chesapeake's Eastern Shore must find themselves in a state of chronic cognitive dissonance. Multi-generational residents, or been-heres, feel their commitment to place-based heritage is threatened, whether they accept rising sea-level and climate change or perceive others who believe in climate change as a threat. Retired and part-time come-heres must experience cognitive dissonance that normally follows the commitment of an important life-decision like buying a house and later realizing it is at high risk for flood damage (Festinger, 1957). Neither would escape chronic cognitive dissonance caused by observing increased tidal flooding, encroaching ghost forests, coastal erosion, or media attention to rising sea level. The slow onset of the problem would allow for social norms of cognitive and physical adaptation to develop. This process would be punctuated by moments of crises, like Superstorm Sandy and the Smith Island buyout proposal, that cause acute disconfirmation of normality. We would expect these events to generate perceptions of threat to within-group cohesion (e.g., some Smith Island residents wanted to be bought out) and threats from external contrasting groups (e.g., big government bureaucracies and environmental alarmists who "want us to leave"). We are interested in documenting how individual cognitive processes interact with social dynamics to produce reactions like the formation of Smith Island United and their aggressive pursuit of structural solutions.

Methods

The research study area included Talbot, Dorchester, and Somerset Counties on the Eastern Shore of Maryland (Figure 1), all of which are experiencing higher tides and are at increasing risk of flood damage over the next 50–100 years. Between May 2017 and July 2019, we conducted 63 semi-structured interviews. Forty-eight interviews were with homeowners, retirees, Chesapeake watermen, educators, realtors, tourism operators, restaurant owners, and others. Chesapeake watermen are independent commercial fishermen of oysters and blue crabs who tend to be religious and are respected regionally for their work ethic (Paolisso, 2002). Interviewees were recruited by contacting government offices, businesses, and people mentioned in news stories, through personal references (snowball sampling) and recruiting people during chance encounters while doing field work. Interviews were conducted in-person in residences or workplaces. We also conducted 15 policy interviews with county planners, floodplain and wildlife refuge managers, local emergency managers and dispatchers, elected officials, and the director of a conservation organization. Interviews lasted between 45 and 120 min and totaled 48 h and 28 min. All interviews were audio recorded and transcribed verbatim. Each interview was given a unique identifier by which the identities of interviewees could not be known. Transcriptions were then imported into MAXQDA for thematic analysis (Vaismoradi et al., 2013).

Semi-structured interviews followed an interview guide with a set of prepared questions. We began by asking what "the Chesapeake means to you" to solicit narratives of sense of place. Subsequent questions about tidal and storm surge flooding and the future of the community were intended to invoke cognitive dissonance. Interview questions also probed for identity, community and sense of place, flooding experience and perception of flood risk, individual and community adaptations to flooding, and observations and perceptions of the impact of climate change on flooding. We also encouraged interviewees to speak freely about topics related to flooding, and interviewers probed interesting or unexpected answers to solicit more in-depth perspectives.

An "explanatory research question" clarifies an identified phenomenon to explain why it occurs and produce hypotheses (Barroga and Matanguihan, 2022). We ask: how do individual cognition and social dynamics interact to preclude managed retreat as a response to rising sea level on the Eastern Shore of the Chesapeake? We assume that cognitive dissonance results from the conflict between physical evidence or information about rising sea level due to climate change and place-based identity and decisions to move into coastal areas. We derived seven hypotheses (Table 1) from the theoretical synthesis, which we tested using thematic analysis (Vaismoradi et al., 2013) in MAXQDA. We developed 29 codes for themes relating to phenomena predicted by the Cultural Theory of Risk, Group Identity Theory, and Cognitive Dissonance Theory. We then coded all 63 semi-structured interviews to identify, quantify, and present examples of how the hypotheses were supported or rejected. The tests of hypotheses were binary: statements providing evidence for the items in Table 1 exist in the discursive data or they do not. But we also provide quantitative support and explanations for our interpretations in our results.

Using MAXQDA, we systematically coded transcribed interviews for themes related to our deductive hypotheses (Vaismoradi et al., 2013), such as climate change, sea-level rise, erosion, identity, history, decision making, community and personal adaptations to flooding, and attitudes about relocation. MaxQDA allows users to query codes to identify relationships such as how often codes co-occur in coded text. We determined the frequency in which themes overlapped, revealing associations between concepts that emerged in narratives. All quotations below were excerpted from interview transcriptions. They are identified by a number and location where they were conducted or identified as an interview with policymakers.

Results

Our goal was to test hypotheses resulting from theoretical synthesis of the Cultural Theory of Risk (CTR), Cognitive Dissonance Theory, and Social Identity Theory to deductively explain how our study population thinks about risks of rising sea level and how that influences adaptive decisions including potential relocation. Of the 80 people we interviewed, 49 were male and 31 were female, 47% were life-long, mostly multi-generational, residents (been-heres) and 53% had moved into the area more recently (come-heres). Eight interviewees were self-described watermen.

All interviewees expressed apprehension about the future of the region, whether it was loss of cultural heritage and economic decline or loss of land because of rising sea level and erosion. About half the interviewees (47%) expressed belief in rising sea level, 29% denied it, and 23% were unclear. All policy interviewees expressed concern about rising relative sea level and its impacts but expressed reservations about discussing it outside of their professional networks. Fifty-six percent of the interviewees who expressed belief in rising sea level were come-heres and 44% were been-heres. The been-heres who expressed belief tended to be college educated and work in government or education. The largest difference was that those who clearly denied sea level was rising were twice as likely to be been-heres (67%) than come-heres (33%). Of the eight watermen, one expressed belief in rising sea level, two denied it, and five were uncommitted.

All but one of the emergency managers or policy experts were favorable about managed retreat, and every policy interviewee expressed concern about impacts on community and heritage. They noted that rising sea level hinders emergency response, threatens property values and property tax revenue, and will soon require infrastructure disinvestment decisions. None of the county or municipal personnel were implementing buyout programs or had near-term plans to do so. Among non-policy interviewees, 48% expressed negative attitudes about managed retreat and buyouts, 30% expressed positive attitudes and 22% were ambivalent. This indicates a gap between policy makers who see a need to begin planning for retreat and a public mostly ambivalent or somewhat hostile to the idea. As one policy interviewee put it:

> *Retreat is a four-letter word for a lot of the communities that you go into. You're going to learn that they really do not want to give up their heritage or their family's land or whatever…* (Policy 6).

TABLE 1 Hypotheses generated by the explanatory research question: how do individual cognition and social dynamics interact to preclude managed retreat as a response to rising sea level on the Eastern Shore of the Chesapeake? The theory from which each hypothesis derives is identified to indicate overlap within our theoretical synthesis. The test of each hypothesis is that interviewees will produce statements that serve as examples of each hypothesis or not.

Hypotheses	Theoretical perspective		
	Cultural theory of risk	Social identity	Cognitive dissonance
1. Commitment to group identity when evaluating threats	X	X	
2. Selective attention to risks because of commitment to decisions, sense of place, or cultural heritage	X	X	X
3. Psychological discomfort resulting from contradictory cognitions		X	X
4. Denial or evasion of relative sea-level rise			X
5. Social processes defining the feasibility of solutions	X	X	X
6. Denigrating or ignoring information that contradicts beliefs (confirmation bias)			X
7. Reactive behaviors like agnostic adaptation to tidal flooding, political engagement, or proselytizing	X	X	X

Belief in rising sea level appears to influence attitudes about managed retreat and buyouts. Of the interviewees who expressed favorable attitudes about managed retreat and buyouts, 82% expressed belief in rising sea level and 18% were uncommitted. No one who denied that sea level is rising had favorable attitudes about relocation. Conversely, of those with negative attitudes about managed retreat and buyouts, 47% denied sea level was rising, 23% believed sea level was rising, and 30% were uncommitted. As might be expected, come-heres were twice as likely as been-heres to have favorable attitudes toward buyouts and managed retreat.

Hypothesis 1: commitment to group identity when evaluating threats

In our analysis of interviews with the public, we coded 611 segments of text with the theme of group identity. The most common overlapping theme (42% of segments) was expressing a sense of community. For example:

> *It's the small-town feel. Every story you hear about a small town, everyone knows everyone, everyone's children play together, all of that is true…Everyone was a waterman. If you did not help on your dad's boat, maybe one of the neighbors needed help on their boat, and everyone helped out…* (Cambridge 1).

> *…if someone's in trouble, everyone is there and I mean everyone. If you cannot pay your electric bill, the church is gonna pay it or someone is gonna anonymously pay it.* (Smith Island 4).

Another important overlapping theme (27% of segments) was using local environmental knowledge to mark group identity and boundaries:

> *Some of those watermen are not dumb. They're not educated but they are intelligent…And there's generations of data, what you call data, what we call just history* (Crisfield 5).

> *People here know how to survive because they do know how to live off of Mother Nature. They know how to fish, they know how to forage, they know how to get through a storm, they know what to do when they do not have energy.* (Smith Island 16).

> *…you think all of these with damn PhDs, and they think they know what they are talking about and they are dead, damn wrong… I have a different perspective, because I live on an isolated island. It gives me insight and I can understand it a lot more than they can.* (Smith Island 3).

Somewhat less common, we found the theme of group identity overlapped with cultural heritage and tradition (11% of segments):

> *… our town is built on maritime heritage. And a smaller part, on agriculture heritage, that's who we are…We continue to harvest the bounty of the bay, even when there was no harvest to be harvested anymore…Those are the citizens that make up the heritage of the last two to three hundred years of this region.* (Crisfield 2).

The most pronounced example of a threat to cultural integrity posed by an outside group is how Smith Islanders viewed the buyout proposal as externally motivated and disrespectful of group identity:

> *They tried getting us off here after Sandy. They tried buying everybody out and there's quite a few people here that said they would not leave here unless they were in a coffin. So, there was no way they were letting them.* (Smith Island 14).

> *I think the government thought it was a good idea in a lot of ways 'cause they… would've helped some people, but the community felt like it would harm the neighborhood, so to speak, it will destroy our culture and they are very proud of their culture here and want to maintain it.* (Smith Island 10).

> *Quite a few people had talked about if they left the buyout on the table and Maryland tried pushing people off of the island, that we would try and push for Virginia to pick us up as part of their state.* (Smith Island 14).

As predicted by CTR and Social Identity Theory, these statements validate Hypothesis 1. Interviewees expressed commitment to group identity when evaluating threats. In response to our interview questions about flooding and government buyouts, residents explicitly excluded outsiders and government agents from a shared in-group sense of community that is based on social capital, cultural heritage, and ecological knowledge.

Hypothesis 2: selective attention to risks because of commitment to decisions, sense of place, or cultural heritage

Out of 611 interview segments relating to group identity, 106 (17%) involved discussion of risk or threats. Risk of losing heritage or community, including the dying lifestyle of the watermen, was mentioned in 26% of policy interviews, but 40% of interviews with the public. Policy interviewees focused more on the risk of losing heritage in a professional sense of protected assets:

> *I think there needs to be a political will to help the community be resilient, not to just say, you need to move—looking at the heritage of the people, you cannot get that back. You cannot just move them 20 miles and say their heritage is the same. It's the history of the state, because we are a water-dependent state in so many areas.* (Policy 4).

Although residents do see themselves as emblematic of a cultural ideal…

> *I think the other thing about the island is that it's such, it's very interesting to me that the state identity of Maryland is so consumed by what we are on Smith Island. You know, blue crabs, the Chesapeake Bay, the Smith Island cake. All that is so important and we are the heart of that.* (Smith Island 4).

…they were more concerned with how social change might affect their personal identities and blur social group boundaries:

> *There's still a lot of good people down there, but there's also been an influx of retirees down there in areas. I do not even know who these people are.* (St. Michaels 1).

> *I hate to see these islands turn into a bunch of high-rises. Once upon a time this marina would be chock full with nothing but workboats. You hardly ever saw a party boat, you never saw a sailboat, but that kind of gives you an idea of how many watermen there is left. It's a dying breed…It used to be that everybody was related to everybody around here. It's not that way anymore.* (Hoopers Island 1).

> *We got the millennials and the 'yuppies' on the upper island… they'll be here soon I'm sure…I hate to say it but they are out in the middle of the road with their bicycles and their double baby strollers and they are jogging… and got their goddamn kayaks all over the place.* (Hoopers Island 4).

But some were willing to accept social change to avoid losing all sense of place:

> *…my faith shows me that while the work on the water is kind of ebbing away and…it's so difficult to make a living on the water, that it's being replaced by tourism, you know, and I believe, I believe God has sent that to us to sustain us and cause us to be able to stay here.* (Smith Island 5).

Loss of population was a frequent topic among the public; in particular, whether cultural institutions like churches, schools, fire departments, and stores are sustainable.

> *When I was growing up, everybody knew everybody. Um, the highlight was the church. That's where we congregated. Almost everybody on the island would go to church and I notice now that both churches are only a handful of people in them.* (Hoopers Island 2).

> *…we have three churches and we do not have many people but we can manage to keep three churches going just on this small community and, uh, so we take one day at a time and that's all we can do.* (Smith Island 8).

> *Well a family of five moved here and we only lost four people that year!* (Smith Island 7).

These perceptions are nested within a group-based Eastern Shore worldview that local heritage and culture are not valued by outsiders, which creates the risk of disinvestment:

> *Who's going to buy houses on Smith Island to fix it up if the government says we are not supporting Smith Island anymore.* (Crisfield 5).

> *So, after Hurricane Sandy they were ready to do a buyout of the island, which would have bought out houses of anyone who wanted to sell out. But they only allotted two million dollars for it. It'd have also made us ineligible for any assistance whatsoever, meaning that from that point forward they would have given up on the island.* (Smith Island 4).

This perception reflects a very real benefit–cost policy worldview:

> *…we were told by the state nobody wanted to put money into anything that was going to be below a certain sea level or was in a flood hazard.* (Policy 9).

Residents clearly indicate that erosion, not sea-level rise, is the primary threat to their resources, lifestyle and heritage. Policymakers, on the other hand, view erosion as a major problem that is conceptualized within a broader context of rising sea level. Residents assert that erosion is an immediate threat to their community and should be prioritized to allow for structural solutions:

> *I've been living on this island…all my whole life. And as far as I can see, I do not see where the sea level has risen that much. We get eroded away…and we have got to get something done for that.* (Smith Island 15).

> *Well our thoughts, based here on the island, is that our problem is more related to erosion than climate change…for me climate change exists but it's less serious. It's not an immediate concern here on the island. Our immediate concern is erosion…erosion will do us in long before climate change.* (Smith Island 4).

> *Flooding? Right here, right now we do get flooded out. But we need to build some bulkheads…especially around this part of the island… because we are getting washed away.* (Smith Island 15).

> *…if they'd have put bulkheads or stones around Holland Island, it'd still be there today.* (Smith Island 14).

Interviewees mentioned concerns about other types of risks from flooding, but these tended not to co-occur with statements about group identity. Risks that flooding poses to infrastructure, tax base, and emergency response were mentioned only in policy interviews.

In our discussion of group identity above, we provide examples of high-commitment of multi-generational been-heres to a sense of community, cultural heritage, and group identity. Come-heres also expressed commitment to their decisions to relocate into the area. One woman married a been-here waterman and they decided to live on Smith Island. When asked if she would consider relocation, her response was personal, but also alludes to her group commitment:

> *No. Oh, no, never…Because this is your home, and it's my husband's…he has his boat and we have our home, you know, and history, the culture, we would not want to give up on it. No, no. Most people, most everybody would not.* (Smith Island 13).

These statements validate Hypothesis 2. As predicted by CTR and Social Identity Theory, commitment to sense of place and cultural heritage influenced which risks people would pay attention to. Residents were less concerned about sea-level rise and more concerned with the effects that out-migration or government disinvestment would have on the community. Interviewees focused on the failure of the government to address erosion, which shifts blame to the out-group. Cognitive Dissonance Theory predicts that

information contradicting important decisions like who to marry or where to live can create cognitive dissonance and therefore influence perceptions of risks.

Hypothesis 3: psychological discomfort resulting from contradictory cognitions

We identified 10 examples of people clearly talking about psychological discomfort that we attribute to cognitive dissonance. For example:

> *It's kind of like it comes up, like especially in high tide it will get worse or whatever but it's not like, we do not come together and sit around a table and discuss the future, we are just kinda living for tomorrow more than worry because if you worry, you can worry yourself to death.* (Ragged Point 1).

> *Because I know what's coming…I'll be dead and planted but…I really have a big concern for my grandchildren. I know what they are going to inherit.* (Crisfield 1).

> *Okay, erosion is the big issue here. I wish that all the monies that was put towards the studies for the global warming…sea level rise? Well it scares the crap out of people so I guess that's what the TV's want, you know…It's erosion here.* (Hoopers Island 3).

As expressed by a floodplain manager who is a been-here:

> *If you mention the word sea level rise, it really explodes in their mind…people depend on the water a hundred percent for their income…so they are right to deny it, because once they stop denying it, then they put doubt into their lives and once they put doubt into their livelihood, what else do you have?* (Policy 5).

As predicted by Cognitive Dissonance Theory, these statements validate Hypothesis 3. Cognitive dissonance emerges in these interviews due to contradictory cognitions that cause psychological discomfort. This discomfort forms the basis for responses to threats described in the following hypotheses.

Hypothesis 4: denial or evasion of relative sea-level rise

We found 40 examples of people denying sea level is rising that we believe result from cognitive dissonance induced by our questions:

> *This right here is a marina…where my grandfather used to keep his boat tied up. When I was a little, little boy…I remember climbing on and off the boat, and I do not see any difference of what it was like 50-some years ago.* (Hoopers Island 1).

> *Me relocate? I ain't going nowhere. Not because of flooding. That's not going to make me move, flooding…I'll be 75 in October and I've been living out here all my whole life. And as far as I can see, I do not see where the sea level has risen that much.* (Smith Island 15).

> *…I do not think that man can destroy what God has created. We need to watch what we do, we need to throw trash where it needs to go, and we need to do all the things, you know, that common sense tells you to do, and things that the Bible says is right to do pertaining to our environment and other things, but I do not think we can destroy the world or whatever, I just do not believe it.* (Smith Island 11).

> *…you hear all this stuff about we are sinking, we are sinking. We're not sinking. We're eroding away, but we are not sinking.* (Smith Island 15).

> *You know, I remember when I was a kid. That sea level has not come up. It's not no difference. It's erosion.* (Hoopers Island 3).

Cognitive Dissonance Theory predicts that people are more likely to engage in denial if a cognition they have high commitment to is threatened. The statements above validate Hypothesis 4. Interviewees situated their denial of sea level rise within high commitment to sense of place, group identity, religious belief, or life histories.

Hypothesis 5: social processes defining the feasibility of solutions

Relocation, including buyouts, is an unreasonable option for many interviewees:

> *No. I would not do it…Unless, you know, the tides come in relentlessly into the homes and, you know, you just cannot keep doing that over and over. That would be the only way.* (Smith Island 5).

Structural adaptation to erosion is by far the preferred solution. We coded 129 segments of text in which interviewees were talking about erosion. These were heavily concentrated in interviews with residents of Smith, Hoopers, and Deal Islands. In Hoopers Island Interview 3, 19% of the interviewee's verbiage was dedicated to erosion. Our data suggest that high commitment to group identity leads people to focus on erosion, rather than sea-level rise, to avoid cognitive dissonance. Homeowners perceive structural strategies to be more feasible, like raising a house to avoid water damage or installing bulkheads or rip rap to control erosion:

> *There's my house. I got a six-foot high foundation. I'm not gonna get flooded again. I've even got the garage floor above flood level.* (Hoopers Island 1).

> *…a lot of them, after that hurricane, they started, they lifted their houses and put a couple more layers of cinder block to raise it up.* (Royal Oak 1).

> *The old man used to come and get the tires…and would lay tires up and down the shoreline to stop the erosion.* (Hoopers Island 1).

Large-scale erosion control is expensive, so homeowners and business owners have channeled their concern into lobbying for government projects:

> *…we have the Smith Island United…We have a lobbyist…she lobbied to…help us get funding for the jetties and stuff that they built and the project they are doing down here now to shore up the shoreline over there to keep from eroding.* (Smith Island 1).

These types of statements validate Hypothesis 5. Per Social Identity Theory, interviewees construct identity as members of a group. As predicted by the Cultural Theory of Risk, group identity determines what types of risk an individual will be concerned about. Cognitive dissonance encourages interviewees to attend to risks that have solutions over which they can exercise more control. A major contribution of our theoretical synthesis is the implication that belonging to a group will enhance a sense of control. In this case, by interacting with other group members, interviewees leveraged group identity to lobby outside the group for structural solutions to erosion instead of managed retreat.

Hypothesis 6: denigrating or ignoring information that contradicts beliefs

Confirmation bias is interpreting or focusing on information that is consonant with deep convictions while ignoring contradictory information. This often results from cognitive dissonance. Residents and business owners provided numerous explanations of why their observations were evidence of erosion and not rising sea level:

> *If sea-level rise is the problem, why did the west side of Highland's Island go so much faster and the marsh is still on the east side.* (Crisfield 5).

Various explanations for why ghost forests (Figure 6) do not result from saltwater intrusion provide a good example:

> *Now there's a big old pine and it's dead, but there's one right beside it - perfectly healthy…it do not make sense. There's a thing called pine beetles and a lot of times if you go and look you'll see little teeny-tiny holes in the trees and there's sawdust at the bottom of them and that's from these pine beetles…* (Hoopers Island 1).

Regional biologists assert that pine beetle infestation is a problem that is exacerbated by saltwater weakening the trees. They point to the ground vegetation below the trees converting to salt-tolerant aquatic species as evidence for rising sea level. Both parties are paying attention to details consonant with their worldviews.

We also documented a type of confirmation bias that borders on proselytization. Policymakers, elected officials, and residents who believe in rising sea level are self-censoring either from fear of retribution or because they fear that invoking sea level rise will interfere with the ability to carry out their directives. This effectively eliminates dissonant information for all members of the community:

> *…it took me forever to understand that you do not talk about climate change down here. You talk about erosion and flooding, and that's okay. But do not talk about climate change.* (Deal Island 1).

> *Oh, absolutely a hot potato. You talk with someone at the counter and you can get yelled at. 'It's never, ever flooded on my property. The sea level rise does not matter.'* (Policy 5).



FIGURE 6
"Ghost forests" in which trees are dying off can be observed along coastal areas of the Chesapeake. Worldviews associated with different social identities determine whether people believe trees are dying because of saltwater intrusion into upland forest as a result of rising sea level or there are other causes like pine bark beetles.

> *"…we cannot think about this; it's the third rail in politics on the Eastern Shore to talk about sea-level rise, climate change, anything that has to do with changes to the environment."* (Policy 2).

> *If sea-level rise is a third rail, managed retreat is like a fifth rail. It's an asteroid.* (Policy 2).

These types of statements validate Hypothesis 6 that interviewees are engaging in confirmation bias because of cognitive dissonance. Self-censorship highlights how confirmation bias is a socially normative process.

Hypothesis 7: reactive behaviors like agnostic adaptation to tidal flooding, political engagement, or proselytizing

We found multiple statements to support Hypothesis 7. Political lobbying for erosion control by Smith Island United can be considered a form of proselytizing as a socialized response to deep cognitive dissonance like that predicted by Festinger et al. (1956). Interviewees also attempted to proselytize us directly:

> *Please, please just listen to the erosion. That's all I ask. Just listen to the people tell you about the erosion.* (Hoopers Island 3).

Our coding method revealed an unanticipated theme we believe results from cognitive dissonance. Many interviewees downplayed the inconveniences and financial expenses incurred from nuisance tidal flooding, implying that it is a normal part of living near the water.

> *But you can get where you need to get, you know, if you have got boots, or if you drive through it. We just drive through it.* (Smith Island 14).

> *They're a minor inconvenience, really. I think the last count was fifty-seven days a year we have tidal flooding out of three hundred.* (Smith Island 4).

We labeled this phenomenon "normalization" to recognize it is an adaptive social norm. We coded 145 segments of text with the normalization theme. Of the 10 most heavily coded interviews, six were from Smith Island. Although many normalized adaptations occurred within the household, they must be socially legitimated as normal to alleviate cognitive dissonance:

> *You just kind of deal with it. Living down here you just kinda learn. It's like oh, the tide's high, just drive slowly through. And like if I see the tide's high I'll take my mom so they can go to town for a couple hours and wait for the tide to go down because she's got a smaller crossover SUV.* (Ragged Point 1).

> *Deal with it. Move on. And that's what everybody is used to where I'm from. That's it. What'd you have to do? Oh, I had to go buy new boots because mine were dry rotted and my feet got wet. What else did you do? Oh, I got a sump pump. End of conversation, literally. End of conversation.* (Trappe 1).

Many normalized adaptations involve cooperation, which contributes to a sense of community and shared identity of resilient people. For example, school busses cannot drive through standing water:

> *I would pick up all the kids down here that needed to get to school. Twice a morning I'd take them up to the Phillips Crab House up there and I'd meet the bus and all the kids would get on it.* (Fishing Creek 1).

> *…it's a community effort, and the community will step up to the plate and help transport to a bus if needed.* (Church Creek 1).

We found evidence of agnostic adaptation in our interview data. Of the interviewees who denied sea level was rising, 82% engaged in some form of personal adaptation (whether simply buying waterproof boots or elevating a house) or community-based adaptation (lobbying for erosion control or driving children through flooded roads to meet the school bus). None of these interviewees expressed positive attitudes about managed retreat or relocation. In some cases, they were cognizant of their agnostic adaptation. As one interviewee put it:

> *I go to meetings. I'll wink and nod and say, 'Yes, sea level's coming up,' as long as they are giving me a shoreline.* (Crisfield 5).

Been-heres rarely made negative comments about come-heres who conform to social norms like working hard, attending church, and helping neighbors. Indeed, it appears that come-heres leveraged the risk posed to local identity by external forces to integrate into been-here culture. Most of the founders of Smith Island United, including the first president, were come-heres who were clear about their intent for the Smith Island Vision Plan to capitalize on local heritage including tourism based on waterman experiences and a waterman apprenticeship program:

> *…and within Smith Island United's plan, there's talk for, uh, economic development and growth. And we wanted to keep the watermen up front and as the main thing, we wanna preserve our culture, we wanna preserve the island itself and the birding life and just bring everything together so people can understand what we are all about.* (Smith Island 4).

Surprisingly few residents mentioned risk of flooding to home equity whether from water damage or discouraging potential buyers. Retirees who had purchased homes did not have mortgages and expressed little concern about legacies. Multigenerational homeowners had little equity in older homes that do not conform to building codes and many had been abandoned. Instead, risk to home equity was used to delineate social group boundaries. Been-heres believed people who buy or build homes as investments drive up the tax base and were complicit in the Smith Island buyout:

> *…there was this whole thing about, 'our home values will decline.' Well, that would come from come-heres, not from people that were born and raised here. Because they do not want their home value being higher, 'cause it just means their property taxes are higher and*

> *they are not planning to sell. They're just planning to live here the rest of their lives.* (Smith Island 7).
>
> *It was politics! It was one family on the island who were come-heres who bought a house and wanted to leave but had overpaid, bought the house during the real estate bubble…so they had no way out. So they went to FEMA when FEMA came and proposed this buyout … We saw that as a signal that hey, you do this, it's gonna send a message to the politicians and to the general public that we have had it and they are starting to buyout houses. So, we opposed it on those grounds.* (Smith Island 4).

In addition to Cognitive Dissonance Theory, Hypothesis 7 derives from Social Identity Theory and CTR. Behaviors like proselytizing and agnostic adaptation are perceived to be socially desirable and are a response to threats that are selected for attention based on group identity.

Discussion

We found evidence to support each of the seven hypotheses we produced through the synthesis of Cognitive Dissonance Theory, CTR, and Social Identity Theory (Table 1). Festinger et al. (1956) case study showed how disconfirmation of the belief that the world would end led to greater belief commitment and proselytization. In a similar process, our interviewees respond to environmental signals of rising sea level by denying sea level rise and engaging in proselytization about erosion and government disinvestment. Interviewees also engage in confirmation bias when determining what information to pay attention to when evaluating risk. As predicted by Social Identity Theory, interviewees made statements about their identity that were based heavily on groups they perceived they belong to. Consistent with the findings from other CTR research, group-based identity determined which threats interviewees attended to and strongly biased adaptive behaviors.

In addition to helping explain why residents do not consider managed retreat as a response to rising sea level, we hope our theoretical synthesis advances the social science of risk perception more generally. In particular, we use cognitive dissonance to explain why identity biases groups to attend to specific risks or threats as predicted by CTR. We also provide evidence for how the management of cognitive dissonance is a social process.

Although discursive data from our study elucidates mechanisms for how thought processes and social interaction lead to correlations between group identity and concern about types of risk documented by extant survey research, we recognize limits to our qualitative methodology. One limitation is that we did not directly measure commitment to membership in the four social categories predicted by CTR. Kahan (2012) and Johnson and Swedlow (2024) argue that self-identification with a group is not binary but exists along a continuum of group commitment (group) and acceptance of control (grid). In the future we could code our qualitative data for group and grid dimensions. Alternatively, future survey research might combine CTR indices with indices that measure cognitive dissonance to identify additional pathways through which risk perceptions are formed (Chassang et al., 2024). Additionally, although we provide evidence for processes that lead to beliefs and behaviors, we cannot know how these phenomena are distributed throughout the population without quantitative survey data that would be particularly useful for public policy.

Conclusion

Ecomyopia occurs when groups, including entire civilizations, use social and cognitive processes to ignore, deny, or discount important environmental information that challenges structures of power or place-based identities. In their analysis of the American Southwest, Casagrande and Peters (2013) demonstrated how communities responded to cognitive dissonance caused by the trauma of rapidly dwindling water reserves. The notion that there might be too many people and too little water was taboo. Instead, communities discussed structural solutions that could reduce water consumption and extend settlement of the region in the short term while ignoring the long-term implications. Kuh (2015) calls adapting to climate change using short-term, ecomyopic solutions that ignore the root cause or even deny the existence of climate change "agnostic adaptation."

Our goal was to provide a theoretical exposition for ecomyopia and agnostic adaptation. We have demonstrated how the evolution of social identities can bias different groups of people to attend to different types of risk and interpret and share information to support those biases. Residents of Maryland's Eastern Shore with a deep commitment to their heritage and sense of community respond to cognitive dissonance caused by the existential threat of rising sea level by focusing their attention and actions on the problem of erosion. This appears to have resulted in agnostic adaptation. All efforts are dedicated to mitigating the immediate impacts of flooding and erosion with no attention to managed retreat or mitigating greenhouse gas emissions. Floodplain managers who are intentionally avoiding the topics of climate change and rising sea level in order to encourage flood mitigation behavior are promoting agnostic adaptation. Marino and Lazrus (2015) argue that externally imposed problem definitions of rising sea level denigrate local knowledge and constrain choices. In a democracy where policymakers must adapt to the beliefs of constituents, choices like managed retreat may be constrained by agnostic adaptation.

Agnostic adaptation leads to ecomyopia by creating a dangerous illusion of addressing a problem but failing to solve the root cause of the problem with potentially dire long-term implications. Much like Festinger's cult members waiting to be rescued, the current global socio-political system has spent most of the last three decades seeking technological breakthroughs to save us from anthropogenic climate change rather than making difficult decisions like disinvesting in infrastructure and relocating populations that will be displaced by rising sea level (Pilkey et al., 2016). As our case study indicates, providing more detailed evidence of rising sea level will not change beliefs because of confirmation bias. As our quotes demonstrate, using science to frame a problem will not change opinions because it comes from a potentially threatening external group. It appears that only softening the boundaries between groups could enhance the flow and effect of information.

Data availability statement

The datasets presented in this article are not readily available because of interviewee anonymity. Requests to access the datasets should be directed to dac511@lehigh.edu.

Ethics statement

The studies involving humans were approved by the Lehigh University Institutional Review Board. The studies were conducted in accordance with the local legislation and institutional requirements. The ethics committee/institutional review board waived the requirement of written informed consent for participation from the participants or the participants' legal guardians/next of kin because the study received exempt status.

Author contributions

DC: Writing – original draft, Writing – review & editing. AL: Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Feature importance of climate vulnerability indicators with gradient boosting across five global cities

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Efforts are needed to better identify and measure both communities' exposure to climate hazards and the social vulnerabilities that interact with these hazards, but the science of validating climate risk indicators is still in its infancy. Progress is needed to improve: (1) the selection of variables that are used as proxies to represent hazard exposure and vulnerability; (2) the applicability and scale for which these indicators are intended, including their suitability for transnational comparisons. We draw on an international urban survey in Buenos Aires, Argentina; Johannesburg, South Africa; London, United Kingdom; New York City, United States; and Seoul, South Korea that collected data on: exposure to various types of extreme weather events, socioeconomic characteristics commonly used as proxies for vulnerability (i.e., income, education level, gender, and age), and additional characteristics not often included in existing composite indices (i.e., Queer identity, disability identity, non-dominant primary language, and self-perceptions of both discrimination and vulnerability to climate hazard risk). We use feature importance analysis with gradient-boosted decision trees to measure the importance that these variables have in predicting exposure to various types of extreme weather events. Our results show that non-traditional variables were more relevant to self-reported exposure to extreme weather events than traditionally employed variables such as income or age. Furthermore, differences in variable relevance across different types of hazards and across urban contexts suggest that vulnerability indicators need to be fit to context and should not be used in a one-size-fits-all fashion.

KEYWORDS

environmental justice (EJ), disaster & risk management, managed retreat, survey analyses, XGBoost (extreme gradient boosting), climate vulnerability analysis

1 Introduction

As this special issue demonstrates, there is a growing interest among policymakers, community members, and academics in designing and documenting best practices for environmentally-just climate adaptation and resilience policies, including planned relocation. Concern over the need for proactive, equity-based planning of such efforts is justifiably escalating in the face of existential climate crises. Moreover, evidence suggests that policymakers tend to default to status quo policies and decision-making – because of their own cognitive biases (Roberts and Wernstedt, 2019; Gifford, 2011), political pressures they face (Mayhew, 2008), and policy entrenchment (Wiering et al., 2018); the status quo, in turn, is likely to preserve historical inequities and injustices (Foster et al., 2024). In particular, community-driven and co-produced planning and research is needed in order to overcome

perpetuated social vulnerability and to strive toward transformational climate policies (Foster et al., 2024; Morris et al., 2024; Ajibade et al., 2022).

To this end, there is a need to better incorporate vulnerability indicators into climate adaptation policy planning. A requisite first step is understanding that *climate risk* – that is, the "potential for adverse consequences" (p. 5) stemming from climate change – is a function of *hazard events* and both *exposure* and *vulnerability* (IPCC, 2022).[1] Conversely, *resilience* is defined as "not just the ability to maintain essential function, identity and structure, but also the capacity for transformation" (p. 7). Policymakers and researchers therefore need to better understand who is vulnerable to increasing climate hazards – as well as who benefits from climate policies and why inequalities in both of these domains persist (Wilson et al., 2021). The above definitions from the IPCC are a starting point, but recent research finds that key concepts like "vulnerability" and "equity" in flood-risk management are currently operationalized in myriad ways (e.g., as outcomes like "funding" or "benefits"; as units of aggregation like "individuals" and "neighborhoods"; as justifications like "reflecting societal values" or "interpreting a policy mandate"; and more) (Pollack et al., 2024) – and also differ depending on whether multiple types of (aggregate, cascading, or compound) hazards are considered (Drakes and Tate, 2022). Additionally, salient components likely vary location to location, and country to country (Rufat et al., 2019).

All of these variations of risk clearly play an important role when designing climate adaptation interventions – such as with regard to managed retreat/planned relocation, where policymakers have to make value-laden distributional and procedural justice decisions about program design and participants' eligibility (Siders, 2022). Seeteram et al. (2023), for example, offer a two-by-two framework for climate mobility in which: (1) low exposure to sea level rise and low social vulnerability are characteristic of *stable* neighborhoods; (2) high exposure to sea level rise and low social vulnerability are characteristic of *migrating* neighborhoods; (3) low exposure to sea level rise and high social vulnerability are characteristic of *displaced* neighborhoods; and (4) high exposure to sea level rise and high social vulnerability are characteristic of *trapped* neighborhoods. The authors then use this framework to analyze a set of 13 social vulnerability indicators in one U.S. county, finding that "as [sea level rise] increases, the municipalities with the largest percentages of Trapped residents are home to high proportions of Black and Hispanic residents…as well as those residents who have fewer assets" (p. 12).

But the science of validating exposure and vulnerability indicators – let alone translating them into policy approaches – remains in its infancy (NASEM, 2024). A recent National Academies report (NASEM, 2024) distinguishes disproportionate exposure to environmental hazard from other forms of social vulnerability caused by "combinations of political, economic, social, and institutional processes" (p. 25) that also interact with environmental hazard outcomes – as well as from cumulative impacts of exposure. There are many methods for measuring these hazard exposures, cumulative impacts of exposure, and other relevant social vulnerabilities. Such indicators (e.g., the widely used Social Vulnerability Index) as well as composite sets of indicators (e.g., the White House Council on Environmental Quality's Climate and Economic Justice Screening Tool[2] or the Environmental Defense Fund's U. S. Climate Vulnerability Index[3]) can then be used as tools to advance our understanding of patterns of injustice and to determine community eligibility for government resources (NASEM, 2024; Lewis et al., 2023). Given their potential policy impacts, these tools should be scrutinized and used with caution.

The NASEM report also stresses the importance of community engagement in the design of composite indicators, which inherently involves subjective decision-making processes. In addition to community-led or co-produced processes, social science research methods can help to elicit community input on vulnerability indicators, such as via online surveys, in-person interviews, and focus groups (Small and Calarco, 2022; Groves et al., 2009). Incorporating community input can also help to identify location-specific vulnerability profiles and avoid one-size-fits-all policy approaches. Existing tools do not meet this need. For example, the Climate and Economic Justice Screening Tool (CEJST) notably does not include race or ethnicity, age, disability, or other demographic characteristics that have frequently been associated with differential outcomes to climate risk and a profusion of other environmental injustices (see Bolin and Kurtz (2018), Sultana (2021) and Wilson et al. (2021) for several helpful overviews); and neither CEJST nor the Climate Vulnerability Index (CVI) incorporate community input on the selection of vulnerability indicators.[4]

Furthermore, CEJST is a binary screening tool; that is, census tracts are recognized as "disadvantaged" if they meet the threshold for at least one of eight categories of burden (climate change, energy, health, housing, legacy pollution, transportation, water and wastewater, workforce development) or if they are located within the border of a Federally Recognized Tribe or Alaska Native Village. By contrast, CVI – which was created by the Environmental Defense Fund in partnership with researchers at Texas A&M University and Darkhorse Analytics – includes four types of social vulnerabilities (health, social and economic, infrastructure, and environment) and three types of risks exacerbated by climate change (extreme events, social and economic, and health), each with their own set of holistic

1 The IPCC Sixth Assessment Report Working Group II on Impacts, Adaptation and Vulnerability defines *exposure* as "presence of people; livelihoods; species or ecosystems; environmental functions, services and resources; infrastructure; or economic, social or cultural assets in places and settings that could be adversely affected." It defines *vulnerability* as "the propensity or predisposition to be adversely affected and encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt" (IPCC, 2022: p.5).

2 Created under the Biden Administration, but recently taken offline by the Trump Administration (and preserved here by a volunteer coalition called the Public Environmental Data Partners: https://edgi-govdata-archiving.github.io/ j40-cejst-2/en).

3 Tool website: https://climatevulnerabilityindex.org.

4 As just one example: Mullen et al. (2023) specifically consider CEJST from the perspective of Indigenous communities and offer several recommendations for better designing and contextualizing indicators. Importantly, they note: "Indigenous peoples should be engaged at every level of the development and implementation of screening tools, in ways that affirm Indigenous self-determination and the principle of free, prior, and informed consent" (p. 367). Such principles hold for other local contexts as well.

sub-categories. Census tracts are then assigned a "national vulnerability percentile" by aggregating data across indicators. Although CVI incorporates a much wider range of social vulnerability categories and more climate hazard types than does CEJST, it still only creates one vulnerability profile for any census tract no matter which risks that community faces. As Tate et al. (2025) point out, the common practice of aggregating vulnerability indicators into just one score can result in surprising obfuscations of key vulnerabilities. Instead, they recommend creating multiple vulnerability *profiles* for a given location by conducting cluster analyses with a set of vulnerability indicators.

In response to these gaps and recommendations, this paper contributes to the crafting and validation of climate hazard vulnerability indicators that can be employed in policy decision making. In particular, it fills two knowledge gaps by: (1) considering the relevance of indicators that have not been traditionally included in composite indices and that respond to appeals to incorporate community input and lived experienced into the understanding of climate hazard exposure and vulnerability; and (2) providing evidence on, as well as limitations to, the translatability of these indicators across hazard types and urban geographies – thereby contributing to comparative urban studies.

We utilized a subset of elicited participant responses from a large-scale, international survey that previously examined urban residents' preferences with regard to various flood-related policies. The online survey was translated and administered in five cities globally: Buenos Aires, Argentina; Johannesburg, South Africa; London, United Kingdom; New York City, United States; and Seoul, South Korea. We re-analyzed these survey data with a supervised machine learning approach, XGBoost, to identify feature importance of items in the survey instrument and to create a comprehensive index of vulnerability to extreme weather hazards. XGBoost uses training data with multiple features to predict a target variable; in this case, the target variable was survey participants' self-reported exposure to extreme weather events. Our analysis measured the importance that two key types of variables from the survey – self-perceptions of vulnerability and more objective demographic characteristics – had on extreme weather exposure.

2 Materials and methods

2.1 Survey items

The present study employs data from a previous international survey of approximately 645 residents per city (total $n = 3{,}224$) that gathered data on participants' exposure in urban settings to various extreme weather events, their experience with flood management interventions, their demographic characteristics, and their preferences among different policies geared toward reducing flood disaster risk. The primary analysis for the full survey instrument is currently under peer review as a manuscript with the *Journal of Environmental Psychology* (Tier et al., 2025).

Out of this larger survey instrument, we utilize a subset of items related to residents' exposure to extreme weather events and their demographic characteristics (see Appendix A for this subset of the survey codebook). We discard 829 responses, out of the total surveyed in the sample, from participants who had lived in their city for less than 3 years in order to remove responses from those who may not have had enough time to experience hazards in their city. We then discard an additional 7 responses from participants responding with a non-binary gender identity; because this category is so small, it does not allow for robust statistical conclusions. In total, we use $n = 2{,}388$ responses in this study. More specifically, we utilized the following survey items (a summary of responses to these survey items can be found in the Appendix):

- Exposure to extreme weather events. Participants rated their past exposure to each of eight extreme weather events on a 5-point Likert-type scale (1 Never; 2 Rarely - has occurred for me once or twice in my life; 3 Sometimes - has occurred for me every 2–5 years; 4 Regularly - has typically occurred for me 1–2 times each year; 5 Frequently - has typically occurred for me 3 + times each year). The eight extreme weather events were: flooding from heavy rainfall, flooding from coastal storms, flooding from river overflows, heavy winds, heatwaves/extreme heat, droughts, wildfires, and earthquakes. Seven of these hazard types were selected to represent a breadth of extreme weather events exacerbated by climate change. Earthquakes were included because, in pilot testing, participants frequently added this hazard type as a risk event that they had experienced. We utilize these elicited survey items as a proxy for participants' true exposure to extreme weather hazards in the past.
- Demographics. We use a variety of self-reported demographic items as measures of climate vulnerability. Demographic questions included: education level, income, age, gender (Woman, Man, Non-binary, or Prefer to self-describe), Queer self-identification (binary yes/no), disability self-identification (binary yes/no), and whether they speak a non-dominant language as their primary language at home (binary yes/no with a text entry if yes; what was listed as the dominant language(s) varied by city). Education, income, age, and gender are common demographic items in survey instruments and moreover, have received attention in the literature on climate and environmental inequities. We also included Queer identity, disability identity, and non-dominant primary language as demographic items in our instrument because they have been understudied as vulnerability indicators. We note that a race/ethnicity item was also included as part of the larger survey instrument; however, we do not include it as a variable in this study for two reasons. First, categorical variables such as race hold no meaning for the feature importance analysis described below; we cannot translate racial/ethnic categories into numerical measures. Second, even if we were to create a yes/no binary variable of minority racial/ethnic identity, it would be difficult to standardize this measure across our city locations and so a comparative analysis would not be possible.
- Self-perceptions of vulnerability. Finally, two survey items asked about participants' sense of their own vulnerability: (1) an ex-ante assessment of their likely *exposure to harm from flood disasters* as compared to other residents of their city and (2) an ex-post assessment of their recent *experience with discrimination* (as a self-reported measure of social vulnerability). Both items were on 5-point Likert-type scales. These two items were included to distinguish between *actual* exposure to hazard events (albeit self-reported exposure) and participants' evaluation of

their own personal exposure to harm or vulnerability to societal prejudice.

2.2 City selection and survey design

The international survey that we drew on from Tier et al. (2025) was designed through an iterative process that included exploratory work in each of the case study locations. The cities were selected based on similarities in population size, national governance type, economic standing, and experience with extreme weather events. We also selected for global geographic range, and made sure that the case locations included multiple cities in the Global South. The survey instrument was designed as follows: (1) it was first drafted in English; (2) collaborators from each city checked for cultural fit of the questions and we edited the English version as needed; (3) collaborators provided translations in conjunction with additional rounds of translation and back-translation via DeepL and Google Translate; *different* colleagues from each city edited the translations as needed and we checked for consistency across all locations and versions. The survey platform was built using Qualtrics XM software, approved by Princeton University's Institutional Review Board (#16462), and beta-tested internationally using Prolific. The actual data collection was conducted via the Centiment survey panel company.

2.3 Estimation: feature importance with XGBoost

This study aims to understand which characteristics of the survey population are more strongly associated with an individual participant's past exposure to a particular type of extreme weather event. We assess nine participant characteristics, split into three categories: four commonly referenced climate vulnerability demographics (income, age, gender, and education level), three rarely-referenced climate vulnerability demographics (Queer identity, disability identity, and non-dominant primary language), and two self-reported perceptions of vulnerability (self-perceived harm from flood disasters and self-perceived discrimination).

Feature importance indicates the degree to which these participant characteristics are present in urban populations experiencing each of the extreme weather events included in the survey. In other words, feature importance assigns a weight to different participant characteristics (self-perceived discrimination, income, etc.) based on how relevant they are for predicting a given target variable (past exposure to coastal flooding, heatwaves, etc.).

We employ a supervised machine learning approach whereby importance analysis is performed through gradient-boosted decision trees to measure the importance of each of the participant characteristics relative to each other, for a given climate hazard type. We chose to employ this method over OLS or other regression-based approaches for three reasons. First, in this case it is not appropriate to assume a linear relationship between hazard exposure and participant characteristics. Second, decision trees are a better choice for interpreting feature importance because here they rank participant characteristics based on their contribution to exposure to hazard events. In particular, our decision trees create ranks based on how much each participant characteristic contributes to the decision-making at each split in the tree. Hence, those participant characteristics that are selected for splitting higher up in the tree are interpreted as more relevant. Third, the participant characteristic variables are either ordinal (e.g., Likert-type scales, income range, etc.) or binary; decision trees, being a non-linear model, have the capability to include variables of this nature. It is also worth noting that we use gradient-boosting trees as opposed to random forests. Gradient-boosted trees allow for higher accuracy because they are trained sequentially, rather than independently, to correct on each others' errors.

We perform this analysis through the XGBoost library (Chen and Guestrin, 2016), which allows for implementation of the stochastic gradient-boosting algorithm (Friedman, 2001) with decision trees being used as the weak learner.

Like other supervised learning models, tree boosting training is done by defining an objective function and optimizing it. An additive model (Equation 1),

$$\sum_t p_t h_t\left(X\right) \tag{1}$$

is fit by stages, also called additive training. In each stage, a weak learner is introduced, which minimizes the loss with each added tree. Trees continue to be added as long as their addition improves the model output. Training stops once the loss function reaches an acceptable level, or when it is no longer possible to improve on an external validation dataset. In this case, we employ a validation set for early stopping to find the optimal number of boosting rounds.

$$F\left(m\right)=F\left(m-1\right)+n_*-\frac{\partial\text{Loss function}}{\partial\text{Previous model output}} \tag{2}$$

where (Equation 2) for any step m, ensemble step m equals ensemble step m minus 1 plus the learning rate (n) times the weak learner at step m.

The model hence continues training until the validation score stops improving; here our objective is to minimize the log loss. In other words, we employ negative log likelihood as our loss function. This measures how well the model predictions align with the data, or its capability to reproduce true data. This loss function calculates the logarithm of the likelihood of observing the data given the parameters of the model, penalizing the model when it assigns low probability to what in the data would be a correct feature. Following existing convention, the data were split for training (80 percent) and testing (20 percent).

XGBoost provides feature importance in the form of gain, cover, and frequency. *Gain* measures the improvement in accuracy brought by a feature to the tree branches it is on. *Cover* looks at the number of samples affected by the feature for each split. *Frequency* is the percentage of times a covariate is used in splitting. In this case, we employ *gain* in order to understand the contribution of our covariate of interest to the accuracy of the prediction. Once models are fitted, the weighted root mean square error (RMSE) of the model is used together with visual inspection to determine the appropriate threshold for results. Only models with a robust fit are included in the results. Out of the models represented, results that are not considered

are those hazard-city combinations with a high RMSE and poor visual fit.

Figure 1 shows how the validation of the result was conducted. The series of plots show the performance of the top trained models, where the dots represent the median prediction and the bar represents the uncertainty of such prediction for each target class. Performance in this case is measured as the model's ability to predict the true value of hazard exposure (represented in the *x*-axis) through the predictions represented along the *y*-axis. The predictions represent values from 1 to 5, which is the scale at which past exposure to each hazard was measured. For instance, exposure to heavy wind was expressed on a scale of 1 to 5, and the plot shows how accurate the model is at predicting such exposure given the inputted participant characteristics (income, gender, discrimination, etc.). The fit to the line represents the fit of the models: the closer to the dotted line, the better the model can predict exposure. The number in the top right corner of each figure is the weighted RMSE for the model. The transparency of some figures indicates that the fit of the model was not sufficiently strong.

Figure 2 shows the primary results of our study. The histogram bars represent the feature importance calculated by the best fitted model. Each bar represents a given characteristic that our model looks at. The height of histogram bars represents the relative importance of a participant characteristic with respect to the other characteristics for a given city and hazard. The error bar at the top of each histogram bar represents the range in importance when calculated with the top five best fitting models after training. For reference, a total of 1,000 models were trained. This is meant to show not only the model chosen as the best fit, but also the range of results if we had picked alternative models that constitute a good fit. This showcases that even though different training rounds can deliver different results, these are highly consistent across resulting models.

3 Results

The results show that exposure to extreme weather events is complex and that vulnerability characteristics associated with such exposure are far from homogeneous. Climate risk indicators and screening tools must consider this heterogeneity in order to achieve their intended goals. Our results first suggest that the types of variables that are most commonly associated with climate vulnerability (such as lower income, lower educational attainment, or minoritized identities) are not the only features to keep an eye out for when predicting who faces disproportionate climate risk in urban environments. We also show that different participant characteristics are relevant not only across extreme events but also across urban

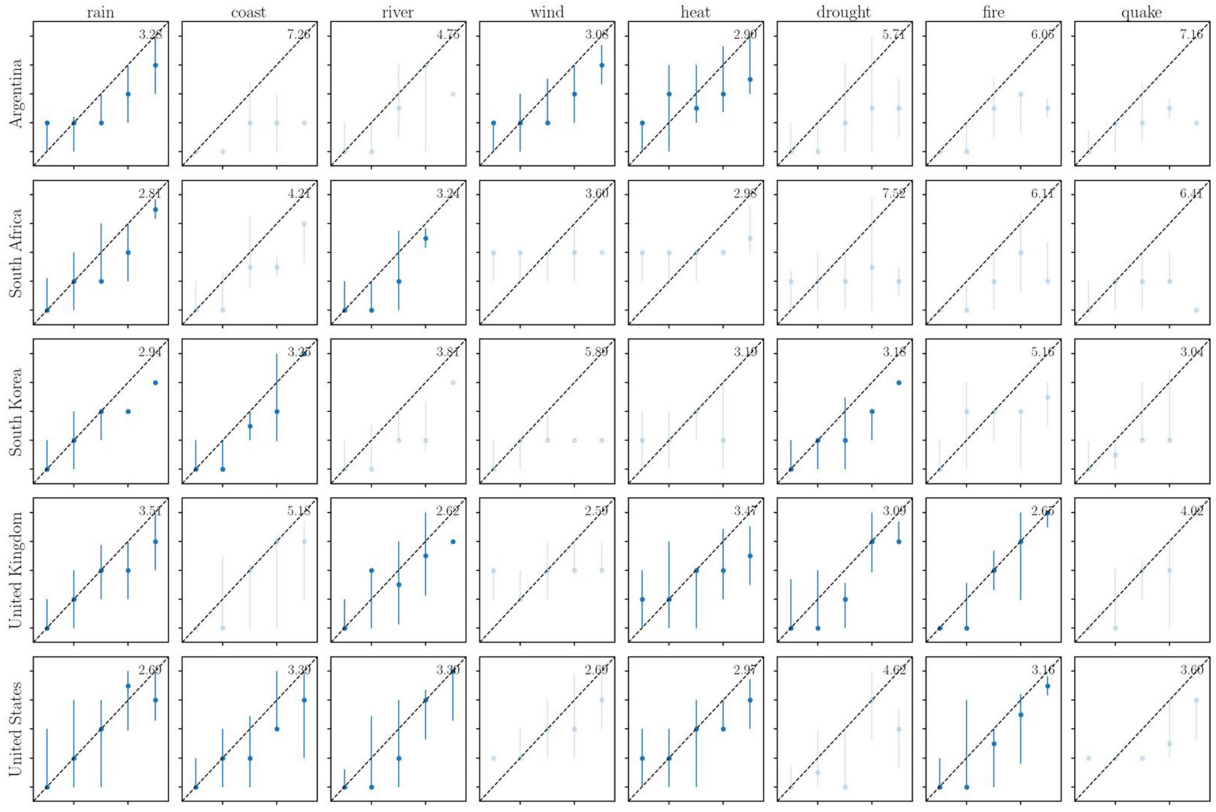


FIGURE 1
Results validation for all cities and across extreme weather hazard types. The numerical figure in the top right corner of each square is the weighted RMSE for the model. Figures that are transparent are conservatively discarded because the fit of the model was not deemed sufficiently robust. This is determined both by examining the RMSE and with visual inspection. The plot shows the performance of the predictive model. The lines are the plotted median predictions of the five best trained models and the uncertainty of such predictions for the different target classes (in this case, the 1 to 5 scale that measures past exposure to each hazard type) based on the different participant characteristics of importance. The *x*-axis is the true score, while the *y*-axis is the predicted score. The dashed line serves as a reference line where predicted values equal true values.

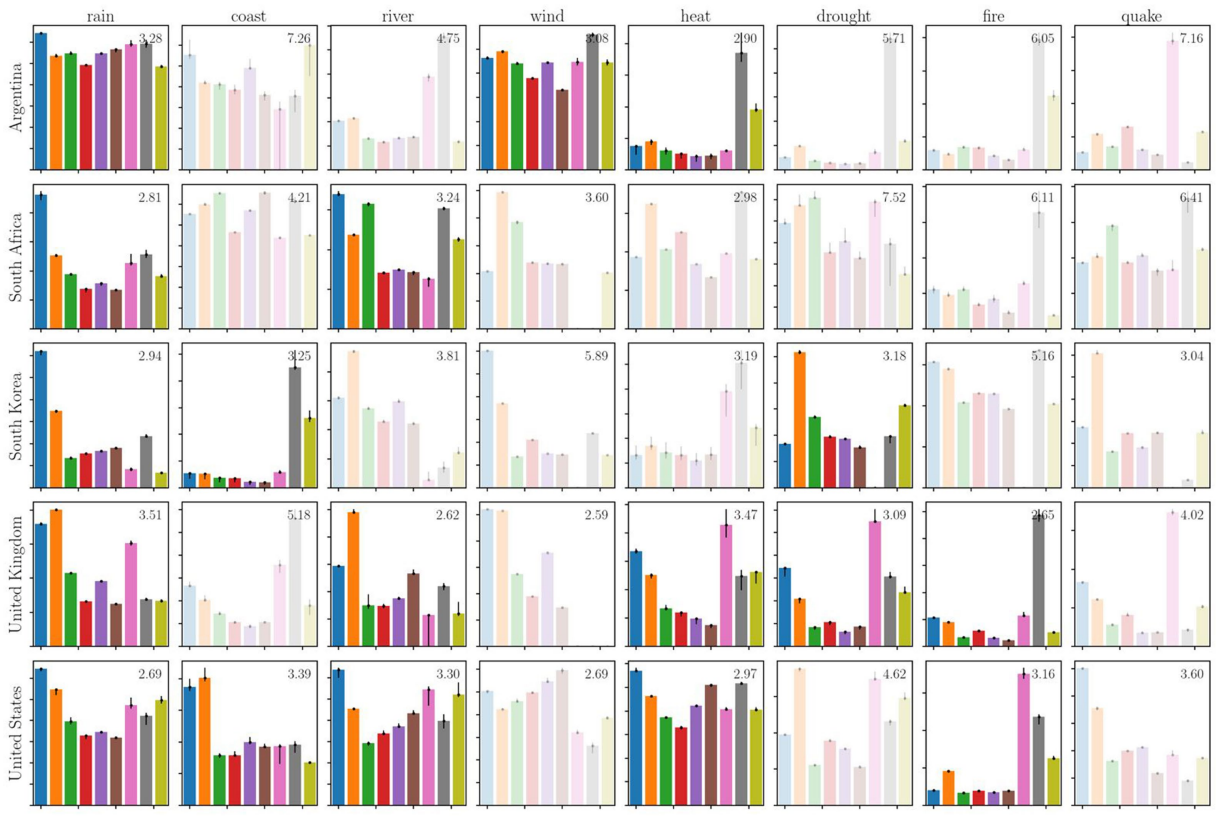


FIGURE 2
Representation of the "feature importance" of participant characteristics. The height of the bar reflects each characteristic's relative importance with respect to the other characteristics for a given extreme weather hazard type and city. As in Figure 1, the results corresponding to models not deemed sufficiently robust are transparent. The colored bars represent the following participant characteristics: self-perceived harm from flood disasters (dark blue), self-perceived discrimination (orange), education level (green), income (red), age (violet), gender (brown), Queer identity (pink), disability identity (gray), and non-dominant primary language (yellow). The error bars represent the range of results from the top five models trained.

environments. We discuss each of these findings in further detail, then turn to a policy application in the domain of managed retreat/planned relocation.

3.1 New salient features: additional demographics and self-perceptions of vulnerability

Across the 18 models deemed robust (nontransparent panels in Figure 2), some similarities stand out. First, more traditional social vulnerability indicators (i.e., education level, income, age, and gender) are less frequent among the most important characteristics for any of the surveyed city populations in our feature importance analysis. Second, some additional demographic variables from our survey were in fact more important than traditional vulnerability indicators (i.e., Queer identity, disability identity, and non-dominant primary language). Third, measures of perceived discrimination and perceived harm from flood disasters in particular were frequently the most important predictors across different types of extreme weather events and across cities.

In the Buenos Aires sample, the participant characteristic most important to exposure to flooding from extreme rainfall was self-perceived harm from flood disasters and the least important were income and non-dominant primary language (with relatively high participant characteristic importance across the board). Disability identity was the most important and gender was the least important to exposure to heavy winds (again with relatively high importance across the other characteristics). Disability identity was the most important to exposure to extreme heat, with non-dominant primary language somewhat important and all other characteristics ranked very low.

In the Johannesburg sample, self-perceived harm from flood disasters was by far the most important to exposure to flooding from extreme rainfall, while income and gender were the least important (and moderate importance across the other characteristics). Self-perceived harm from flood disasters was again the most important to exposure to flooding from river overflows, with education level and disability identity also highly important, self-perceived discrimination and non-dominant primary language moderately important, and all others ranked lower.

In the Seoul sample, self-perceived harm from flood disasters was again the most important by a significant amount to exposure to flooding from extreme rainfall, self-perceived discrimination and disability identity were moderately important, and Queer identity and non-dominant primary language ranked very low. Disability identity was the most important by a significant amount to exposure to flooding from coastal storms, non-dominant primary language was moderately important, and all other characteristics were ranked very low. Self-perceived discrimination was by far the most important to exposure to droughts, with moderate importance for all other characteristics (Queer identity was not included due to absence in the sample).

In the London sample, self-perceived discrimination was most important to exposure to flooding from extreme rainfall, with self-perceived harm from flood disasters and Queer identity also very important and all other characteristics moderately important. Self-perceived discrimination was also most important to exposure to flooding from river overflows, with all other characteristics moderately important. Queer identity was most important to exposure to extreme heat, with self-perceived harm from flood disasters, self-perceived discrimination, disability identity, and non-dominant primary language all moderately important and remaining characteristics ranked low. Queer identity was most important to exposure to droughts, with self-perceived harm from flood disasters, self-perceived discrimination, disability identity, and non-dominant primary language all moderately important and remaining characteristics ranked low. Disability identity was by far the most important to exposure to wildfires, with all other characteristics ranked quite low.

In the New York City sample, self-perceived harm from flood disasters was most important to exposure to flooding from extreme rainfall, with self-perceived discrimination as next-most important and all characteristics having moderate to high importance. Self-perceived discrimination was most important to exposure to flooding from coastal storms, with self-perceived harm from flood disasters a close second and all other characteristics moderately important. Self-perceived harm from flood disasters was also most important to exposure to flooding from river overflows, with Queer identity and non-dominant primary language as next-most important in turn and all other characteristics having moderate to high importance. Self-perceived harm from flood disasters was also most important to exposure to extreme heat, with disability identity and gender as next-most important in turn and all other characteristics having moderate to high importance. Finally, Queer identity was most important to exposure to wildfires, with disability identity as next-most important, self-perceived discrimination and non-dominant language as moderately important, and all other characteristics ranked quite low.

If we take frequency counts for which participant characteristics were ranked as most important across all 18 robust models, self-perceived harm from flood disasters is identified the *most* often (seven times), with self-perceived discrimination and disability identity both identified four times and Queer identity three times. Education level, income, age, gender, and non-dominant primary language are never the most important characteristics for any city-hazard pair. Conversely, gender is identified as the *least* important characteristic eight times – with non-dominant primary language identified as the least important three times; education level, age, and Queer identity identified two times each, and income identified once. Self-perceived harm from flood disasters, self-perceived discrimination, and disability identity are never the least important characteristic. Notably, non-dominant primary language often falls in the middle of the pack in terms of feature importance – more often than do education level, income, age, and gender.

These findings are important to highlight because composite indicators are typically built to measure proxies for exposure and vulnerability to hazard events. However, proxies are not always well fit to measure the complex relationships that lie behind them. Importantly, they are also not well suited to capture the lived experience of urban residents, which can be crucial in defining their resilience to hazard events. Our results show the importance of including measurements, either quantitative or qualitative, that can help decision-makers to have a sense of context-specific risk characteristics. Measurements of self-perception in particular are as crucial for composite indices as are other proxies of vulnerability. It is important to stress that our survey distinguishes between *actual* exposure to hazard events (albeit self-reported exposure) and participants' evaluations of their own vulnerabilities. The hazard exposure survey items queried participants about the *number of times* that they had experienced each hazard type – rather than their exposure in relation to their neighbors or peers. On the other hand, the two vulnerability questions were posed to have participants consider their *relational* vulnerability within some perceived societal average. Thus, it is a consequential finding that participants' perceptions of their own vulnerability does in fact match how their hazard exposure compares to that of others.

As previously mentioned, it is important to emphasize that the results presented here are based on the 18 models that proved to be robust based on their RMSE and visual fit. This translates into limitations on the types of conclusions that can be reached through the available results; although we can assert that commonalities and differences exist across cities and across hazards, we cannot make specific predictions for every hazard-city combination. Additionally, the scarce data related to earthquake vulnerability do not allow for applicability of the findings to this type of hazard.

3.2 Salient features influenced by different hazard types and locations

Despite the commonalities described above, we also find that there is significant heterogeneity regarding feature importance across cities and across hazard types. For example, wildfires – as well as droughts, extreme heat, and coastal flooding for certain cities – were one hazard type in which self-perceptions of vulnerability were much more subdued while Queer and/or disability identity were far more prominent. For the three extreme weather events related to flooding (heavy rainfall, coastal storms, and river overflows), the two measures of self-perceptions of vulnerability (harm from flood disasters and/or discrimination) were more consistently important.

Local context also plays an important role, especially considering pre-existing variation regarding which identities experience marginalization. For example, disability identity repeatedly ranked highly in the Buenos Aires sample – and no other city – as a predictor for the three hazard types represented in this city's robust models (exposure to flooding from heavy rainfall, heavy winds, and extreme heat), despite more variation in the other participant characteristics across hazard types for Buenos Aires. Another example is that Queer identity in the Seoul sample shows an unusual pattern compared to other cities: it ranks very low in importance for exposure to flooding from heavy rainfall and coastal storms, and has no data for droughts (i.e., no Seoul participants who identified as Queer also had experienced droughts). This could suggest that this participant characteristic is not tied to vulnerability in Seoul (unlike in other cities) – or, perhaps more likely, that participants were much less likely to self-report this identity in this location.

These results are in line with existing literature that highlights the importance of indicator weights (i.e., giving numerical importance to some indicators over others) when employing such vulnerability indicators for disaster decision-making (Papathoma-Köhle et al., 2019), as well as the importance of considering "dynamic vulnerability" to understand disaster risk (de Ruiter and van Loon, 2022). Dynamic vulnerability refers to the fact that vulnerability to a given hazard might change over time and can be influenced by

changes in context and even by compound hazards. Our results showcase that climate risks need to be understood within the contextual idiosyncrasies of a given city, and vulnerability indicators cannot fully be generalized across cities or even across hazards within the same city. This is particularly true when selecting the types of questions or measurements that will be assessed about a population. Furthermore, certain aspects key to vulnerability may not be self-reported due to cultural or contextual reasons, so other approaches may need to be considered to truly gauge relevant features and to support those that are most vulnerable.

3.3 Takeaways in the context of managed retreat

This article was written in the context of this journal's special issue titled, *Managed Retreat in Response to Climate Hazards*. In this last section we include reflections on planning for managed retreat in order to demonstrate a concrete policy area that could benefit from our findings.

With the "solution space" for managing the global climate crisis shrinking as dangerous effects of greenhouse gas emissions become increasingly "locked-in" (Haasnoot et al., 2021), ambitious and transformative adaptation planning and implementation strategies are needed now. Adaptation actions are commonly categorized as either *resistance* (such as building a seawall), *advancement* (such as creating new land through reclamation), *accommodation* (such as elevating a structure at risk of flooding), *avoidance* (such as restricting development in high-risk floodplains), or *retreat* (such as planned relocation) (Mach and Siders, 2021). Retreat, the focal point of this special issue, typically comes into play when other adaptation measures are deemed insufficient given the level of exposure or vulnerability to the hazards that a given community or household is experiencing. *Managed* retreat refers to instances when relocation is purposeful and coordinated; although managed retreat can be initiated over a variety of different temporal and governance scales using various instruments by actors such as governments, the private sector, and civil society.

Even though effective in reducing hazard exposure, managed retreat faces many other barriers to success – and even the precise terminology for this type of policy initiative is highly debated.[5] In the U. S., the limited number of climate-induced managed retreat programs that do exist have largely been tackled through buyout/acquisition strategies (Siders and Gerber-Chavez, 2021). Though there is a growing literature on these buyouts (see Greer et al. (2022) and Mach et al. (2019) for review papers), Greer and Brokopp Binder (2017) also conclude that minimal policy learning has occurred due to lack of both actionable data and formal government guidance. Evidence consistently shows that buyout programs suffer from a wide range of challenges, including: long wait times (Siders and Gerber-Chavez, 2021; Weber and Moore, 2019); inadequate federal funding (CRS, 2022; Peterson et al., 2020); complex and uncoordinated multi-level governance processes (Siders and Gerber-Chavez, 2021; Weber and Moore, 2019); lack of transparency in program procedures/structures (Greer et al., 2022); excessive focus on individual homeowners, as opposed to renters, communities, or other forms of housing tenure (Wilson et al., 2021); failure to incorporate social vulnerability indicators (Wilson et al., 2021) or to capture potential structural causes of immobility (Seeteram et al., 2023); insufficient monitoring and evaluation (McGhee et al., 2020); and misguided targets, such as measuring number of household recipients instead of favorable long-term outcomes (Manda et al., 2023).

Of particular importance to relocation programs is ensuring more distributive, procedural, and other forms of climate justice – especially given that current data suggest poor existing outcomes on these fronts. Mach et al. (2019) find that wealthier and denser counties are more likely to *implement* buyout programs – but within those counties, households in lower-income and more racially diverse areas are more likely to actually *receive* a buyout. Loughran et al. (2019) find that "the rate at which minority populations were growing" influences White households' interest in accepting buyouts. Curran-Groome et al. (2021) also note immense inefficiencies in application processes, which place a burden on lower-income and less staffed local governments. Finally, Marino (2018) contends that buyouts as currently formulated do not work well in many Indigenous communities where property ownership is not always documented and individually-focused relocations conflict with community-oriented decision-making.

The most prevalent typology of managed retreat globally is still what Ajibade et al. (2022) describe as "techno-managerial," or focused on simple hazard exposure reduction tactics. Present-day interventions lag behind not only in overcoming barriers initiate and implement a retreat process, but also in focusing on the outcomes from a justice and well-being perspective. We argue that the results of our analysis reinforce the pressing need for managed retreat efforts to include a focus on compensatory, transformative approaches that center justice. This is particularly true given the types of participant characteristics that we found to contribute to hazard exposure the most: people's sense of their own flood hazard vulnerability, their experience with discrimination, and both disability and Queer identity. These characteristics are associated with larger systemic, institutional, and social barriers that have the potential to make residents undergoing relocation even more vulnerable to hazard exposure or subject to even further discrimination in the buyout selection process or in the new locations that they relocate to. Our findings do not necessarily suggest that relocation should not take place, but instead that such initiatives should have a strong focus on justice-centered outcomes.

4 Discussion

This study illuminates the complexities that lie behind efforts to understand the components of climate risk in diverse urban settings. Our analysis shows, in line with previous literature, that exposure to environmental hazards and unequal social structures are deeply

5 Baja (2021) describes that both "being managed" and "retreat" are often seen as undesirable states, and the terms "managed," "retreat," and "relocation" all have significant negative connotations in the U. S. – especially for people of color – of past involuntary movements forced by the federal government (including via slavery of Black people, genocide and other removals of Indigenous people, internment of Japanese-Americans, redlining of various minoritized groups, etc.). Ajibade et al. (2022) also note that while managed/planned retreat is a common term in the Global North, relocation and resettlement are more common terms in the Global South.

intertwined (Adger et al., 2018). These underlying social contributors to climate risk might go unnoticed within existing vulnerability indices. Additionally, while current hazard vulnerability composite indices assume *a priori* which proxies best represent vulnerability (such as income or education), our results show that these measures need to be coupled with more novel demographic characteristics as well as measurements of self-perception – which can be elicited through surveys, interviews, and focus groups – as well as more robust community-led policy design processes.

We argue that vulnerability indices need to move away from a one-size-fits-all approach. This is in line with a recent systematic review of the literature documenting important differences in urban climate risk (hazard, exposure, and vulnerability) and adaptation strategies among countries (Wannewitz et al., 2024). Our results add the finding that the participant characteristics that are associated with higher hazard exposure differ across types of hazards and across cities. For instance, vulnerability is defined by different participant characteristics when considering extreme rain versus extreme heat. Indices should also be carefully employed with the understanding that the boundaries between resilience and vulnerability are dynamic and complex. While low-income communities might have less access to tangible resources in the face of hazard events, they might also count on stronger social networks that can be crucial to withstanding some of these events.

In practice, these conclusions might translate into efforts to cast a wider net of indicators upfront when trying to pinpoint the social characteristics that lead to climate vulnerability in a given location. To do so, interviews and in-depth knowledge gathered from citizens, grassroots organizations, and practitioners would help to expand the types of indicators to be considered beyond existing metrics. This study hopes to make a contribution in this direction by exploring social vulnerability indicators that have not commonly been considered in past indices in order to demonstrate that current indices are frequently incomplete.

It is also important to acknowledge the limitations in applicability of this study when it comes to defining vulnerability indicators across global locations. Our results are generalizable in that we demonstrate that most current vulnerability indicators are insufficiently operationalized. On the other hand, we are not able to offer a one-size-fits-all alternative that could then be utilized in additional cities for further cross-national comparisons. Instead, we recommend that researchers and practitioners build composite indices from the ground up, drawing on local expertise, when working with a new population. We acknowledge that this tailored approach comes with challenges, as pointed to in the literature – such as lack of standardization and so limits to comparability (Nguyen et al., 2016). One solution proposed by Edmonds et al. (2020) is to create indices that can be tailored to different countries by using "endogenously generated" statistical weights – thus allowing for different constructions while still facilitating meaningful comparisons.

There are also challenges of data collection through an international survey. Despite an iterative translation process to validate survey items across contexts, cultural perceptions of the same question may differ. Additionally, despite deploying a big N survey, the dataset obtained is not always large enough for the present analysis to reach conclusions for every possible way of subsetting the data (e.g., not enough experience of a certain type of hazard event among residents of a particular city). Self-reported experience with extreme weather events would also ideally be validated with comparisons to recorded events – though such validation is challenging on a hyper-local level as well as across distant global locations (especially in locations where geospatial hazard data are not collected or hard to obtain). Hence, in this study we advocate for a conservative approach in the interpretation of our results. For government officials facing resource scarcity, this might translate to the use of composite vulnerability indices when hazard data have already been collected for other ends. Policymakers could then couple this information with interviews, focus groups, or other ways of identifying the most pertinent vulnerability indicators in their communities.

Future work should focus on advancing a causal understanding of the socioeconomic and political mechanisms that generate the results we find in our feature analysis. Research should also aim to further pinpoint the links between urban resilience and vulnerability, especially in individual cities. Utilizing novel methodologies, such as our pairing of survey elicitation and a gradient-boosting framework, can then help to increase the body of comparative urban scholarship. This avenue of research can help to develop new approaches to support those most vulnerable to climate risk and to improve institutional approaches to urban climate adaptation.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation, upon request.

Ethics statement

This survey research involving human subjects was approved by the Princeton University Human Research Protection Program (IRB). Data collection was conducted in accordance with local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

LC: Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. MT: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. EW: Conceptualization, Project administration, Resources, Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fclim.2025.1521507/full#supplementary-material

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Evaluating pre-disaster subsidized relocations in coastal Louisiana via a game-theoretic approach

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Coastal communities face increasing flood risks due to sea level rise and climate change, necessitating more proactive risk reduction strategies. Pre-disaster relocations, supported by government subsidies, offer a potentially cost-effective solution, enabling at-risk homeowners to relocate before catastrophic losses occur. This study estimates the potential effectiveness and equity implications of two pre-disaster relocation strategies using an optimization framework and high-resolution flood risk and structural data from Louisiana's Coastal Master Plan. Our findings indicate that a total investment of about $8 billion US in pre-disaster relocations could achieve approximately $0.5 billion in flood risk reduction annually over the next 50 years, with greater benefits in later years corresponding to increasing hazard as sea levels rise. Subsidies are allocated proportionally to flood risk, ensuring procedural fairness, though potential distributional inequities remain. While pre-disaster relocation strategies improve cost-effectiveness and risk mitigation, they do not fully resolve barriers to relocation, including housing affordability, community attachment, and structural inequities in flood exposure. This study provides quantitative insights into relocation feasibility and trade-offs, informing future research on adaptive relocation strategies and equity-focused flood mitigation policies.

KEYWORDS

pre-disaster relocation, buyouts, coastal flooding, risk management, game theory

1 Introduction

Global climate change poses huge challenges for coastal and riverine communities facing floods. Under the Intergovernmental Panel on Climate Change's Representative Concentration Pathway (RCP) 2.6 scenario, median global sea-level rise (SLR) is projected to be 35 cm by the year 2,100 relative to a 1985–2005 reference period, leading to annual flooding for 0.2–2.9% of the global population and expected annual losses accounting for 0.3–5.0% of global gross domestic production (Hinkel et al., 2014). Global annual costs for building, updating, and maintaining dikes are prohibitively high, ranging from $12–31 billion US under RCP2.6 to $27–71 billion US under RCP8.5. Structural measures such as dams, levees, and sea walls are designed to physically alter the landscape and protect communities from inundation (US Army Corps of Engineers, 2024). Levees in the United States are commonly designed to defend against flood depths with a 1 percent annual chance of occurring or being exceeded (i.e., "100-year floods"), so they may breach or be overtopped in the event of more severe floods. In 2005, Hurricane Katrina hit Louisiana and left more than half of the state's 3,560 miles of levees damaged, breached, or destroyed, which led to flooding in 80% of New Orleans (Van Heerden, 2007). Hydraulic infrastructures also engender a false sense of security known as the "levee effect" (White et al., 2001), which encourages continuous urban development behind levees while most homeowners are unaware of the actual flood risks (Ludy and Kondolf, 2012),

possibly causing larger losses in the future. Even though structural measures are still important for flood risk management, past failures and dramatic global climate change urge decision-makers to pay more attention to nonstructural mitigation and adaptation measures.

Nonstructural flood mitigation measures, which do not alter local hydrology or hydrodynamics, aim to reduce flood losses by minimizing exposure and vulnerability rather than preventing flood occurrences. At the building level, common interventions include floodproofing, elevating structures, and home buyouts (Zarekarizi et al., 2020). Despite their benefits, floodproofing and elevation-in-place leave residual risks that are expected to become more pronounced due to climate change (Shan et al., 2022). Consequently, there is a growing consensus that managed retreat, including home buyouts, will be a necessary component of flood mitigation strategies (National Academies of Sciences, Engineering, and Medicine, 2024; Reidmiller et al., 2018). Voluntary buyout programs relocate willing homeowners from high-risk areas by acquiring properties, demolishing or relocating structures, and converting the land into open space that can provide additional community benefits, such as floodwater absorption and recreational use (Siders and Gerber-Chavez, 2021; Brody and Highfield, 2013; Greer et al., 2022). Research on buyouts spans multiple dimensions, including homeowner and community experiences (Binder et al., 2015; Bukvic and Owen, 2017; Greer and Brokopp Binder, 2017; Kick et al., 2011), implementation practices (Bier et al., 2020; Binder et al., 2020; Green and Olshansky, 2012; Wang et al., 2020), flood risk reduction effects (Atoba et al., 2021; Mobley et al., 2020; Nelson and Camp, 2020; Wang et al., 2020), and equity considerations (De Vries, 2017; Loughran and Elliott, 2019; Siders, 2019). While most studies analyze buyouts at an aggregated scale, advances in computational power, asset inventory datasets, and hydrological modeling have enabled assessments at the community or household level.

Wang et al. (2020) developed a computational framework for the government to minimize societal flood losses in Eastern North Carolina via insurance price regulation, retrofit grants, and acquisition offers. Household-level homeowner decisions were simulated by several discrete choice models and incorporated into the decision framework of the government. A total of $60 million government investment was estimated to result in $500 million damage mitigated in the event of a 100-year flood. This case study results also showed that when the government budget is limited ($20 million), more grants are allocated to retrofit programs than acquisition programs, while acquisition programs are more desirable when the government budget is higher. Acquisition programs are more cost-effective at reducing risks for very high-risk properties, but they can be more expensive. When the budget is limited, funds are exhausted sooner in acquisition programs, resulting in a smaller coverage and thus retrofit programs that can provide larger scale protection are favored. When the budget is higher, more funds are allocated to acquisition programs because of their cost-effectiveness. Nofal and Van De Lindt (2021) considered buyouts as one of the mitigation measures, illustrated its risk reduction effects, and suggested that diverse mitigation techniques should be jointly considered to achieve the best performance. These household-level and community-level quantitative methods enable policymakers to quantify the effects of applying different mitigation measures and make risk-informed decisions. However, in these analyses, all decisions are made at the beginning of the planning horizon and are not adaptive.

Although effective, buyout programs face several challenges. The majority are implemented post-disaster, when both homeowners and government agencies have already incurred substantial losses. In the United States, 89% of buyout funding is sourced from the Federal Emergency Management Agency's (FEMA) Hazard Mitigation Grant Program (HMGP), which is only available following a presidential disaster declaration, whereas just 9% of buyout programs operate independently of specific events (Weber and Moore, 2019). Federal buyouts typically require 2 to 5 years to complete (Curran-Groome et al., 2021), during which homeowners may endure financial strain, housing instability, and psychological distress due to unsafe living conditions or the burden of maintaining both mortgage and rental payments. The prolonged timeline and associated hardships contribute to program attrition, reducing the overall ability to mitigate flood risk and achieve cost efficiency (Weber and Moore, 2019).

To address limitations of post-disaster buyout programs, researchers have explored pre-disaster relocation strategies. Bier et al. (2020) developed a game-theoretic framework that leverages differences in discount rates between the government and homeowners to design a subsidized pre-disaster relocation scheme. In this model, the homeowner decides on which year to relocate by comparing future flood risks and the cost of relocation, while the government chooses which year to offer the subsidy to minimize the sum of flood losses and subsidy expenses. Using Rayleigh-distributed flood probabilities, their analysis suggested that relocation could be advanced by more than a decade, yielding substantial risk reduction benefits. Expanding on this approach, Zhou (2022) employed an agent-based model to simulate relocation decision in Brooklyn, New York, examining the influence of discount rates, relocation costs, and network effects on household relocation behavior. However, limitations in data sources – such as the incompleteness of Zillow sales data and the use of tide station-derived flood risk estimates rather than household-level assessments – introduce potential uncertainties into the model's predictions.

In this paper, we apply a modified version of the modeling framework developed by Zhou (2022) to hazard and structure data generated for Louisiana's 2023 *Comprehensive Master Plan for a Sustainable Coast* (2023CMP). This plan is a 50-year, approximately $50 billion portfolio of recommended investments in integrated coastal management to prevent land loss and reduce flood risk. By examining economically optimal subsidies for relocations using high-fidelity hazard curves and structure attributes, we intend to answer the following questions: (1) What are the potential risk reduction outcomes of pre-disaster relocation, and how do different subsidization schemes affect these outcomes? (2) Where and under what circumstances do subsidies to incentivize relocation make economic sense? In other words, how sensitive are relocation outcomes to assumed discount rates, hazard estimates and structure attributes? (3) Would any communities and/or demographic groups in coastal Louisiana be disproportionally impacted by a large-scale relocation effort?

2 Materials and methods

2.1 Study area and data

The study area is coastal Louisiana in the United States, encompassing regions with at least a 0.05% annual probability of

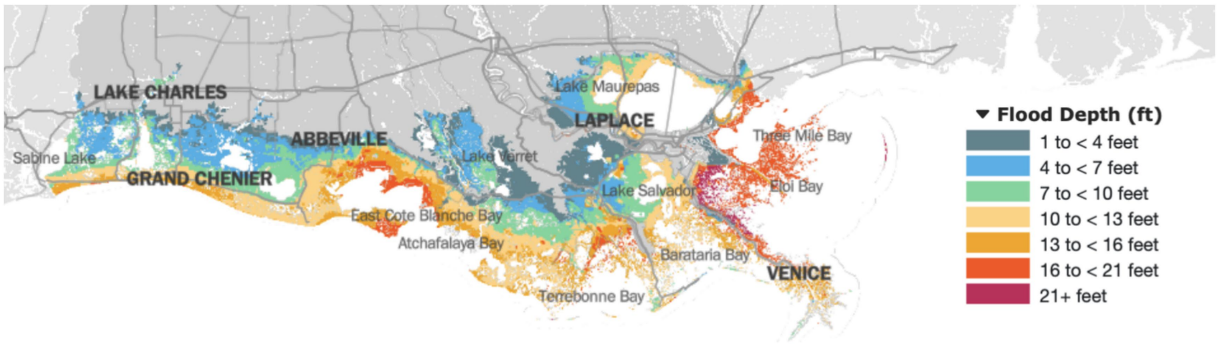


FIGURE 1
Study area and projected flood depths under a 1% annual exceedance probability (Lower Scenario in 2040 without protective action) (CPRA, 2023).

flooding (i.e., the "2,000-year floodplain"), as projected 50 years into the future (Johnson et al., 2023); see Figure 2 in this citation for a visual depiction of the model domain. The region faces severe flood risks, which are expected to intensify due to sea level rise, more extreme storms, and land loss. Figure 1 shows the flood depth associated with a 1% annual exceedance probability in the study area in 2040 if no protective action is taken; 2040 is chosen as it represents the end of the planning horizon in our analysis. Under a moderate environmental scenario, most coastal areas could experience flooding of 10–13 feet without protective measures. To address these risks, the Louisiana Coastal Protection and Restoration Authority (CPRA) was established after major hurricanes Katrina and Rita in 2005 to develop and implement the state's coastal Master Plan, a 50-year, $50 billion strategy for flood protection and coastal restoration. The plan is updated every 6 years to incorporate advances in modeling and coastal management (Coastal Protection and Restoration Authority, 2023).

The Coastal Louisiana Risk Assessment (CLARA) model, developed to support the plan, utilizes high-resolution hydrodynamic simulations and the joint probability method with optimal sampling (JPM-OS) statistical framework to estimate flood depths with an annual exceedance probability (AEP) ranging from 50 to 0.05% (i.e., the "2-year flood" to the "2,000-year flood"). The model also estimates direct economic damage AEP distributions and expected annual damage (EAD) at the structure level (EAD is calculated via numerical integration of the damage associated with damage associated with 23 return periods). Monte Carlo simulation is used to estimate risks under a range of assumptions about future environmental and economic conditions and with different combinations of structural and nonstructural risk reduction projects on the landscape (Johnson et al., 2023). The study area is divided into 126,174 grid cells, with the topographic elevation assigned to each grid calculated as the median topographic elevation of all pixels from the digital elevation model within the grid cell. A baseline structure inventory consisting of 811,871 buildings in Louisiana was derived by combining a handful of different structure- and parcel-level datasets. The inventory contains each structure's topographic elevation, foundation height, number of stories, total square footage, presence of garages, community median household income, and other attributes relevant to estimating its replacement cost and the damage that would accrue from various levels of flooding (known as a depth-damage relationship). Full details related to the CLARA model are available in Fischbach et al. (2021) and Johnson et al. (2023).

From the comprehensive CLARA datasets, we can generate useful inputs for our study. The expected annual damage of homeowner h in year i $\left(i \in \{0,1,\ldots,50\}\right)$, denoted as $EAD_{h,i}$, is calculated as described above. For homeowner h, we approximate the market value of their structure by its replacement cost RC_h, which is calculated as the product of an estimated unit cost per square foot and the total square footage (Federal Emergency Management Agency, 2021). The unit cost per square foot differs by factors such as the number of stories, construction class (economy, average, custom, luxury), presence of garages, and community median household income. The government is responsible for demolishing the structure of homeowner h if the homeowner chooses to relocate. The cost to demolish the structure of homeowner h,[1] DC_h, is approximately calculated by the sum of a fixed cost ($7,275) and a variable cost proportional to the total square foot of the structure ($12 per square foot), where these values are taken from a professional site planning company (Fixr.com, 2022). The expected annual damage, replacement costs and relocation costs are expressed in 2020 U.S. dollars, with inflation adjustments made to account for inflation up to that year. And thus, replacement costs and relocation costs are assumed to remain constant in real terms over the next 50 years.

2.2 Homeowner relocation decisions

We consider a 20-year planning horizon. From year 0 to year 20, homeowners decide whether to relocate or not by comparing the cost of relocation with future flood risks at the beginning of each year. For the purposes of this analysis, we ignore the possibility that homeowners in high-risk regions would sell their houses, assuming that either revised zoning restrictions or the loss of market value associated with high flood hazard makes this a less attractive option. Therefore, we assume homeowners who choose to relocate will forfeit the current market value of their houses and purchase a house of comparable value at a new location. Under

1 This analysis is restricted to single-family residences due to its prevalence and the fact that single-family residences are the primary recipients of buyout subsidies. We use the generic term "homeowner" for the potential seller of the property, ignoring the complexities of decision-making for owner-occupants versus non-occupant landlords.

such an assumption, the cost of relocation for homeowner h is the market value of their house, which is approximated by the replacement cost RC_h. We also assume homeowners have an annual discount rate r_h and the government has a discount rate r_g. We acknowledge that our assumption—equating relocation costs to a home's replacement cost—is a simplification, as relocation expenses often exceed structural value due to factors such as moving costs, housing market differentials, and financial burdens on homeowners (Greer et al., 2022; Loughran and Elliott, 2019; Siders, 2019). In year i, the future flood risks perceived by homeowner h are calculated as the net present value of future flood loss over a 30-year period

$$NPV_{h,i} = \sum_{k=i}^{i+29} \frac{EAD_{h,i}}{\left(1+r_h\right)^{k-i}},$$

where $NPV_{h,i}$ is the future flood loss mitigated if homeowner h decides to relocate in year i. When homeowners make their relocation decisions spontaneously without intervention from the government, we call this setting self-relocation. Under the self-relocation, homeowner h will not relocate until the first year that the future flood loss mitigated by the relocation is greater than the cost of relocation RC_h, and the relocation year of self-relocation is denoted as SY_h.

When the government wishes to influence the homeowners' decision-making process, there are two possible settings, fixed-subsidy-relocation and optimal-subsidy-relocation. Under fixed-subsidy-relocation, to motivate earlier relocation, the government is willing to offer a subsidy valued at a fixed percentage (p) of the house's market value to each homeowner. Homeowner h will not relocate until the first year that the future flood loss mitigated by the relocation is greater than the cost of relocation $(1-p)\times RC_h$, and the relocation year of homeowner h under the fixed-subsidy-relocation is denoted as FY_h. The government implicitly affects homeowners' relocation decisions under the fixed-subsidy-relocation; however, this might not be the optimal solution for the government. By tailoring the year to offer subsidy OY_h and the subsidy amount offered to each homeowner, the government can minimize the sum of flood losses and subsidy expenses. This setting is what we call optimal-subsidy-relocation, and how it works is elaborated in the Government-Homeowners Interaction section that follows.

2.3 Government-homeowners interaction

The government is interested in expanding the collective social welfare, meaning that it aims to minimize collective flood losses before relocations and the costs required to incentivize any desirable relocations. As part of the government's objective function, the collective expected flood losses are calculated as the sum of flood losses between year 0 and the relocation year for all homeowners, discounted by the government discount rate r_g. There is no interaction between the government and homeowners in the case of self-relocation, and collective flood losses of self-relocation are calculated as

$$FL_{self-relocation} = \sum_{h} \sum_{i=0}^{\max\left(0,SY_h-1\right)} \frac{EAD_{h,i}}{\left(1+r_g\right)^{i}}.$$

Note that we thus make an implicit simplifying assumption that families who relocate move to an area that does not experience flood losses over the rest of the timeline. As flood losses are a function of an expected annual damage, the left-hand side of this and other equations is an expected value, but we leave this out of the mathematical notation for clarity.

Collective flood losses in the case of fixed-subsidy-relocation are calculated in a similar way, with the self-relocation year being replaced by the fixed-subsidy-relocation year,

$$FL_{fixed-subsidy-relocation} = \sum_{h} \sum_{i=0}^{\max\left(0,FY_h-1\right)} \frac{EAD_{h,i}}{\left(1+r_g\right)^{i}}.$$

Under optimal-subsidy-relocation, suppose the government is willing to offer a subsidy $S_{h,i}$ to motivate homeowner h to relocate in year i. The subsidy $S_{h,i}$ must be at least equal to $\max\left(0,NPV_{h,i}-RC_h\right)$ to ensure that homeowner h accepts the offer, as the flood risk reduction from relocation exceeds the cost. The government can tailor the subsidy amount offered to homeowner h under optimal-subsidy-relocation. The government seeks to minimize collective flood losses and subsidy expenses by optimizing the year OY_h to offer the subsidy, which is the solution to the following optimization problem:

$$OY_h = \underset{k}{\operatorname{argmin}} \sum_{i=0}^{\max\left(0,k-1\right)} \frac{EAD_{h,i}}{\left(1+r_g\right)^{i}} + \frac{\max\left(0,NPV_{h,k}-RC_h\right)+DC_h}{\left(1+r_g\right)^{k}}.$$

Once the year to offer a subsidy is optimized for each homeowner, collective flood losses in the case of optimal-subsidy-relocation can be calculated as,

$$FL_{optimal-subsidy-relocation} = \sum_{h} \sum_{i=0}^{\max\left(0,OY_h-1\right)} \frac{EAD_{h,i}}{\left(1+r_g\right)^{i}}.$$

To prevent a large amount of subsidy from being allocated to mitigate a small amount of flood losses, we introduce a benefit–cost qualification procedure for both fixed-subsidy-relocation and optimal-subsidy-relocation. Suppose M_h is the motivated relocation year for homeowner h and S_h is the amount of subsidy offered. If the dollar value of flood losses mitigated by accepting the buyout in the given year is less than the subsidy offered, i.e., $\sum_{i=M_h}^{\max\left(M_h,SY_h-1\right)} \frac{EAD_{h,i}}{\left(1+r_g\right)^{i-M_h}} \le S_h$, then the government will not offer a subsidy to homeowner h, and instead, the homeowner may relocate later under the self-relocation setting.

3 Case study results

We evaluate the outcomes of two subsidized relocation modes under both Lower and Higher environmental scenarios, and we perform a sensitivity analysis to assess how varying discount rate

assumptions influence these outcomes. Equity considerations are integrated into the baseline results. Given the uncertainty surrounding future climate-related environmental conditions, a scenario-based approach is critical for informed decision-making. The Lower and Higher scenarios differ in their assumptions regarding future climate drivers (e.g., sea level rise, storm intensity, precipitation) and other factors like land subsidence. The Lower scenario represents a more moderate future condition, while the higher scenario represents a more severe condition (Coastal Protection and Restoration Authority, 2023) with respect to underlying flood hazard. We do not assign probabilities to either scenario but instead present relocation outcomes for both.

In the baseline case, we set the government's discount rate at 3%, a standard rate commonly applied by the U. S. Army Corps of Engineers in the evaluation of flood protection projects (US Army Corps of Engineers, 2020). The homeowners' discount rate is set at 12%, which lies between the approximate average return on real estate investments (10%) (Abdul-Samad, 2018), and the typical interest rate on credit card debts (18%), for consistency with previous work in this area (Bier et al., 2020).

3.1 Relocation number and risk mitigation

Figure 2 illustrates the cumulative number of relocations over time (top panels) and the yearly Expected Annual Damage (EAD) reduction (bottom panels) under both fixed-subsidy-relocation and optimal-subsidy-relocation. A substantial number of self-relocations (approximately 16,000 homeowners) occur earlier in the planning horizon, highlighting the considerable flood risks currently faced in coastal Louisiana. The difference between total relocations and self-relocations in any given year represents the cumulative number of motivated relocations up to that year. Overall, optimal-subsidy-relocation results in a higher number of motivated relocations compared to fixed-subsidy-relocation. However, in the later years (except the final year), there are more motivated relocations under fixed-subsidy-relocation than under optimal-subsidy-relocation, particularly under the Higher scenario. This occurs because, under fixed-subsidy-relocation, subsidies are immediately provided when projected flood risks exceed relocation coasts. In contrast, under the optimal-subsidy-relocation, the government may delay subsidies if relocation is not yet deemed optimal. In the final year, even if it is not optimal to provide subsides earlier, the government is still likely to offer subsidies to homeowners who meet the benefit–cost qualification, as doing so minimizes the government's objective within the planning horizon. This explains the sharp increase in relocations in the final year under optimal-subsidy-relocation, reflecting a degree of flexibility inherent in this approach.

The EAD reduction in year k is calculated as the difference between the sum of discounted EAD for all homeowners who have not relocated by year k under self-relocation, and the sum of discounted EAD for all homeowners who have not relocated by year k under fixed/optimal-subsidy-relocation. Both subsidized relocation strategies show substantial yearly EAD reductions within and beyond the planning horizon; keep in mind that the relocation policy offers subsidies over a 20-year period, but the decision to offer or accept a subsidy is based on the net present value of expected losses and subsidy costs over a rolling 30-year window, resulting in EAD reduction extending over a 50-year period. Fixed-subsidy-relocation achieves a stable yearly EAD reduction of approximately \$0.3 billion/\$0.4 billion under the Lower/Higher scenario, respectively. Optimal-subsidy-relocation results in a yearly EAD reduction of at least \$0.4 billion under both scenarios, with reductions reaching up to \$0.6 billion/\$0.85 billion under the Lower/Higher scenario. Notably, optimal-subsidy-relocation demonstrates superior risk reduction effects beyond the planning horizon, particularly under the Higher scenario. This is due to the large number of motivated relocations in the final year, which effectively eliminate future flood risks for a substantial number of homeowners. As a result, optimal-subsidy relocation achieves greater overall risk reduction, especially in the more severe scenario.

3.2 Benefit–cost analysis

We calculate the benefit–cost ratio for each subsidized relocation and rank all relocations in descending order based on their benefit–cost ratios. Figure 3 illustrates the relationship between the cumulative benefit–cost ratio and the cumulative subsidy (i.e., "cumulative" as subsidies are offered to marginally less attractive properties). Optimal-subsidy-relocation outperforms fixed-subsidy-relocation, as the cumulative benefit–cost ratio for optimal-subsidy-relocation is consistently higher than that of fixed-subsidy-relocation for the same subsidy budget. This underscores the superior ability of optimal-subsidy-relocation to target the most cost-effective subsidized relocations. Under the Lower scenario, the highest benefit–cost ratio for fixed-subsidy-relocation is approximately 9.0, whereas it exceeds 20.0 for optimal-subsidy-relocation. This disparity arises because flood risks for some homeowners remain stable and moderate, with future flood risks close to but not exceeding the self-relocation costs. In fixed-subsidy-relocation, the government must offer 50% of the market value of these structures to incentivize relocations. However, in optimal-subsidy-relocation, the government can strategically lower subsidies by leveraging homeowners' awareness of future flood risks, resulting in a higher benefit–cost ratio from the government perspective. For both relocation modes, the cumulative benefit–cost ratio curve shifts upward and to the right under the Higher scenario compared to the Lower scenario. This shift reflects the increased cost-effectiveness of pre-disaster relocations in the Higher scenario, where projected flood risks—due to intensified storm activity and accelerated sea level rise—lead to greater long-term damages if no action is taken. When the subsidy budget is unlimited, both subsidized relocation modes achieve an overall benefit–cost ratio of approximately 2.5, further demonstrating the overall effectiveness of nonstructural flood risk mitigation projects.

3.3 Distributional impacts by race and income

By integrating census block group-level demographic data into the relocation outcomes, we analyze the distributional impacts of subsidized relocations across racial and income groups. Figure 4 presents the estimated flood risk reduction benefits and subsidy costs disaggregated by race (Figures 4A,B) and poverty-income ratio (PIR) (Figures 4C,D). All monetary values are discounted to year 0 and

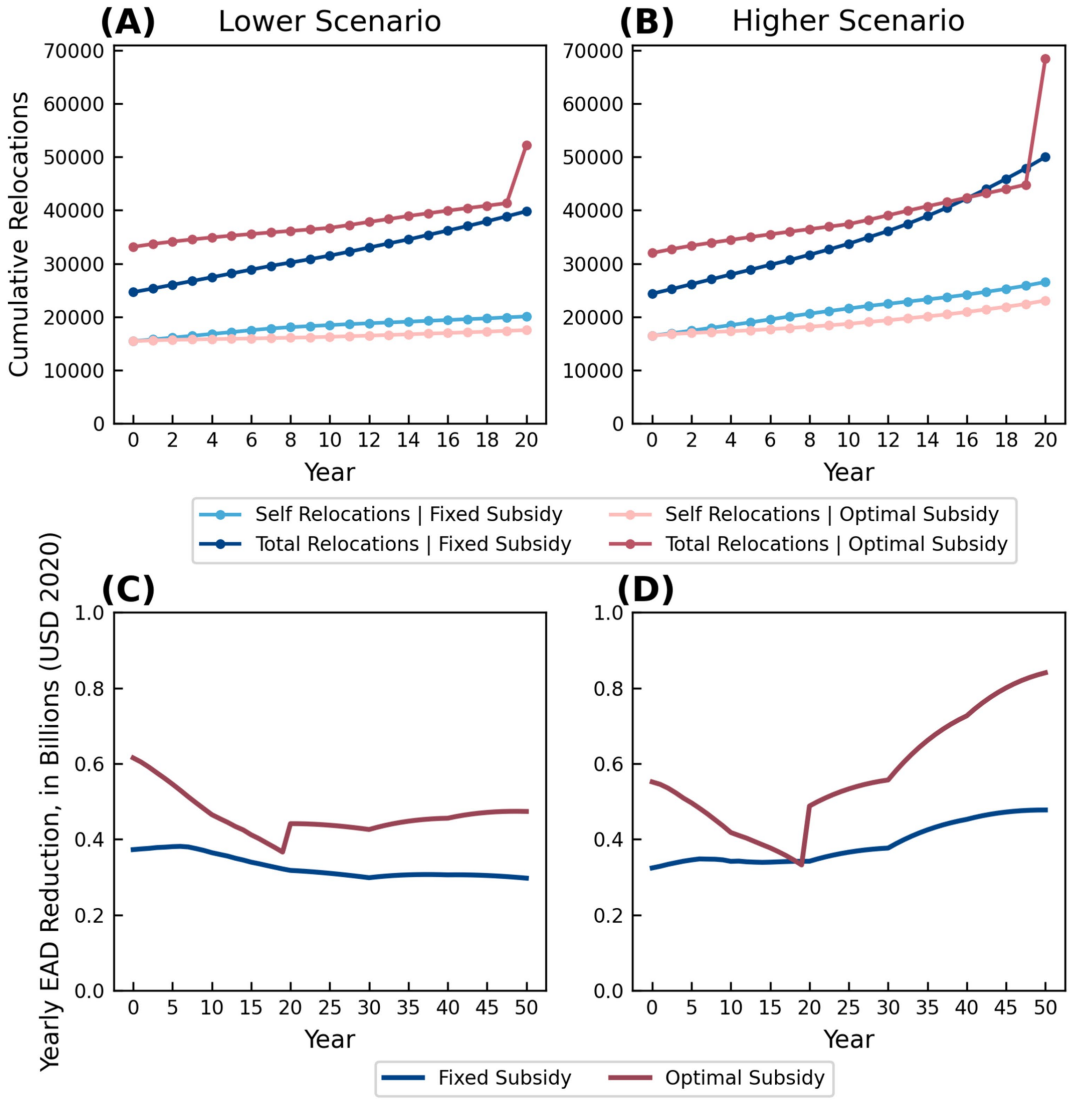


FIGURE 2
Relocation outcomes of the baseline case ($r_g = 3\%, r_h = 12\%$). Panels **(A,B)** depict the cumulative number of relocations over a 20-year planning horizon, disaggregated into self-relocations (light blue/red) and total relocations (dark blue/red) for fixed-subsidy-relocation and optimal-subsidy-relocation under Lower **(A)** and Higher **(B)** environmental scenarios. Panels **(C,D)** illustrate the yearly Expected Annual Damage (EAD) reduction (in billions, USD 2020) for fixed-subsidy-relocation (in dark blue) and optimal-subsidy-relocation (in dark red) under Lower **(C)** and Higher **(D)** environmental scenarios, respectively. The yearly EAD reduction extends beyond the 20-year planning period due to the rolling 30-year evaluation window.

measured in billions of USD (2020). To estimate the distribution of costs and benefits, this study assumes demographic homogeneity within census block groups. This means that for a block group where 40% of households have a PIR between 1 and 2, and 60% have a PIR over 2, 40% of the cost of subsidizing a household in that block group is allocated to the PIR 1–2 category, and 60% to the PIR above 2 category. This proportional allocation allows for an unbiased estimation of equity impacts when aggregated at the coastal zone level.

Our results indicate that both fixed-subsidy-relocation and optimal-subsidy-relocation predominantly benefit white households and those with a PIR of 2 or higher. These groups also receive the largest portion of subsidy allocations. For example, in the study area, 66.70% of households belong to the White population. Under the Lower scenario, this group receives $3.37 billion/$5.49 billion in subsidies and gains approximately $16.26 billion/$11.38 billion in flood risk reduction in the optimal/fixed-subsidy-relocation, respectively. This accounts for 69.66%/69.67% of total subsidies and 69.65%/69.61% of total flood risk reduction under the optimal/fixed-subsidy-relocation, respectively. Despite these differences in absolute benefits, the benefit–cost rations remain consistent across all racial and income groups, indicating that subsidy allocation does not introduce significant disparities in utility across demographic categories. Our findings suggest that subsidized pre-disaster relocations do not exacerbate existing procedural equity issues, as subsidy efficiency remains comparable across groups under both relocation modes.

Examining relocation outcomes at the per capita level provides additional insights into equity considerations. Figure 5 presents the

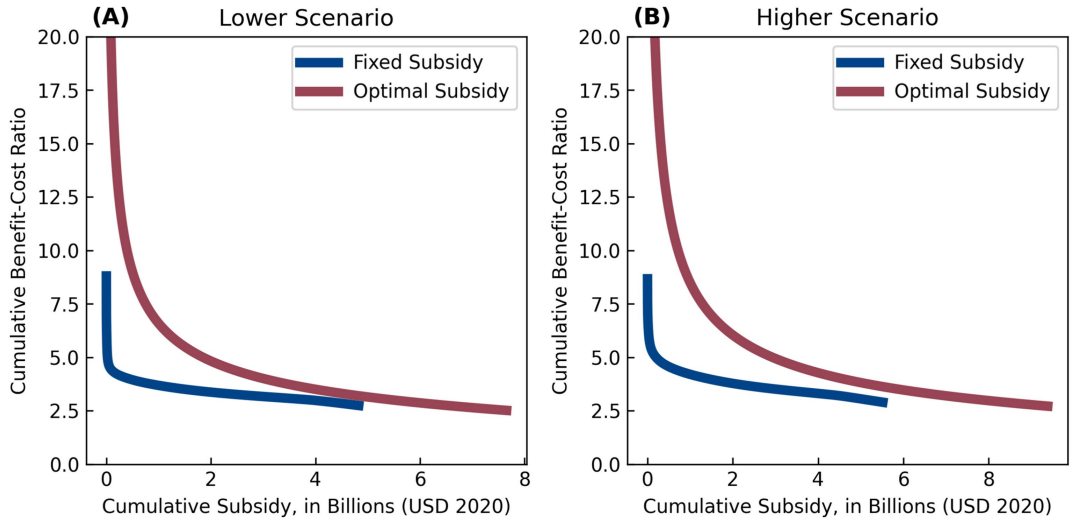


FIGURE 3
Cumulative benefit–cost ratio performance of fixed-subsidy-relocation (blue) and optimal-subsidy-relocation (red) under Lower **(A)** and Higher **(B)** environmental scenarios.

demographic composition, average expected structural damage (self-relocation vs. optimal-subsidy-relocation), average flood risks (self-relocation vs. optimal-subsidy-relocation), and average subsidy across different racial and income groups under the Lower scenario. Results for other settings are also provided in Supplementary material. Expected Annual Structural Damage (EASD) is a flood risk metric analogous to Expected Annual Damage (EAD), with the key distinction that EASD assumes uniform value or replacement cost for all structures. Specifically, EASD estimates the expected annual structural damage, expressed as a proportion of its replacement cost. By treating all structures as having equal value, EASD provides a more objective measure of flood severity across structures. Since structures may undergo repetitive floods, and the same level of damage in any given year impacts homeowners equally, the EASD value is not discounted to present value (Year 0, i.e., 2020). Instead, we sum up the yearly EASD before relocation for each structure to account for its total expected structural damage. Figure 5 shows that average flood risk reduction and average structural damage reduction are similar across racial and income groups. However, the Black and Native American populations receive lower average subsidies compared to the White and Asia/Pacific populations. Given that average structural damage levels are comparable across racial and income groups, and the relative distribution of average subsidies mirrors the distribution of average flood risks, it is the value of structures and their contents that influences resource allocation (i.e., disparities in average structure replacement costs across racial and income groups).

3.4 Subsidy allocation pattern

Funding agencies allocate resources to local administrative entities, typically at the county level (known as parishes in Louisiana), to facilitate implementation. This process necessitates fair distribution of subsidies among parishes. Figure 6 presents the subsidy allocation patterns across parishes, examining average flood loss, subsidy per household, and subsidy per relocation under both Lower and Higher scenarios. The results indicate a positive correlation between the average flood loss by homeowners in a parish and the average subsidy allocated to that parish, with Lafayette Parish and St. Martin Parish emerging as outliers. St. Martin Parish has 947 homeowners, and Lafayette Parish has 983, which is relatively small compared to other parishes that have thousands of homeowners (note that the CLARA model's domain only includes parts of these parishes, so these numbers are not reflective of the total population in the parish; Supplementary material contains a table which details the number of single-family homes in each parish within the model domain). While it is reasonable to consider them as outliers, it also prompts further investigation into the factors contributing to their distinct subsidy allocation patterns.

The subsidy per household in Lafayette Parish is lower than expected under both Lower and Higher scenarios, whereas in St. Martin Parish, it is higher than expected under the Lower scenario. This discrepancy can be partially explained by the average structural damage, as shown in the bottom two panes of Figure 6. St. Martin Parish exhibits the highest average structural damage, indicating that a massive portion of homeowners there face severe flood risks, leading to a great number of subsidized relocations. In contrast, fewer subsidized relocations occur in Lafayette Parish, likely due to the low average structural damage or because wealthier homeowners choose to self-relocate to avoid substantial flood losses. When examining the average subsidy per subsidized relocation, as shown in the middle two panes in Figure 6, we observe that homeowners in Lafayette Parish receive a higher subsidy per relocation due to the high structure values, averaging $901,395. In contrast, the subsidy per relocation in St. Martin Parish is lower than expected due to the lower structure values (averaging $595,700) and the large number of subsidized relocations resulting from high structural damage. Additionally, it is noteworthy that homeowners in Iberville Parish receive a higher subsidy per relocation despite experiencing the least flood loss. The low flood loss is attributed to the relatively low structural values,

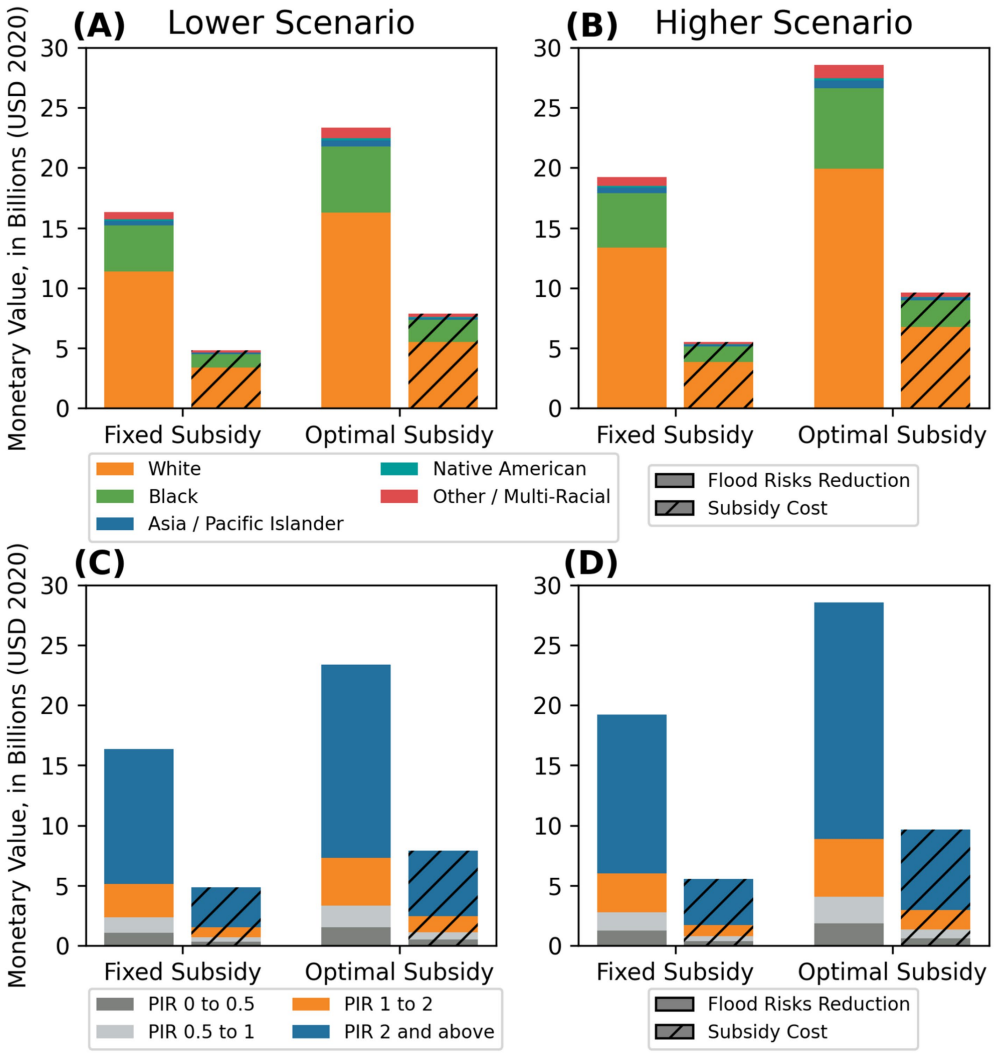


FIGURE 4
Distributional impacts of subsidized relocations by race and income group. Panels **(A,B)** show the distribution of flood risk reduction benefits and subsidy costs disaggregated by racial groups, while panels **(C,D)** present the same outcomes categorized by poverty-income ratio (PIR). Fixed-subsidy-relocation and optimal-subsidy-relocation are compared under two different future scenarios: Lower Scenario **(A,C)** and Higher Scenario **(B,D)**. The stacked bars represent the total monetary value (in billions, USD 2020), with different colors corresponding to demographic subgroups. The striped portion of each bar represents the subsidy cost, while the solid portion represents the total flood risk reduction achieved through relocation. All monetary values are discounted to 2020.

averaging $481,891, while the higher subsidy per relocation is due to the high structural damage faced by these homeowners.

Interestingly, although each parish experiences greater flood losses under the Higher scenario, the subsidy required per relocation is lower than under the Lower scenario. This suggests that homeowners are more inclined to relocate independently and require less government incentive when they perceive higher future flood risks, highlighting the importance of increasing homeowners' awareness of future risks. Our findings indicate that the current subsidy allocation method, which is based on projected monetary flood risks, generally distributes subsidies among parishes according to their flood risks. However, it is inevitable that wealthier parishes receive more subsidies, while the most flood-affected parishes receive comparatively less support. Incorporating non-monetary, equity-centric metrics into the allocation process could potentially address this disparity, as suggested by Geldner et al. (2023).

4 Discussion and concluding remarks

As climate change intensifies, reducing flood risks in the coastal and riverine communities has become a critical priority. Relying solely on structural solutions such as levees, sea walls, or dams is often either impractical or economically unattractive. While nonstructural measures such as home elevations and floodproofing can help mitigate flood risks, they may still leave considerable and undesirable residual risks. Relocating residents from high-risk areas offers a more long-term solution to elimination of flood risk. However, existing post-disaster buyout programs face well-documented challenges. To address the limitations of current post-disaster buyout practices, pre-disaster relocations supported by government subsidies (Bier et al., 2020; Zhou, 2022) have been developed and theoretically demonstrate superior cost-effectiveness in reducing future flood risks.

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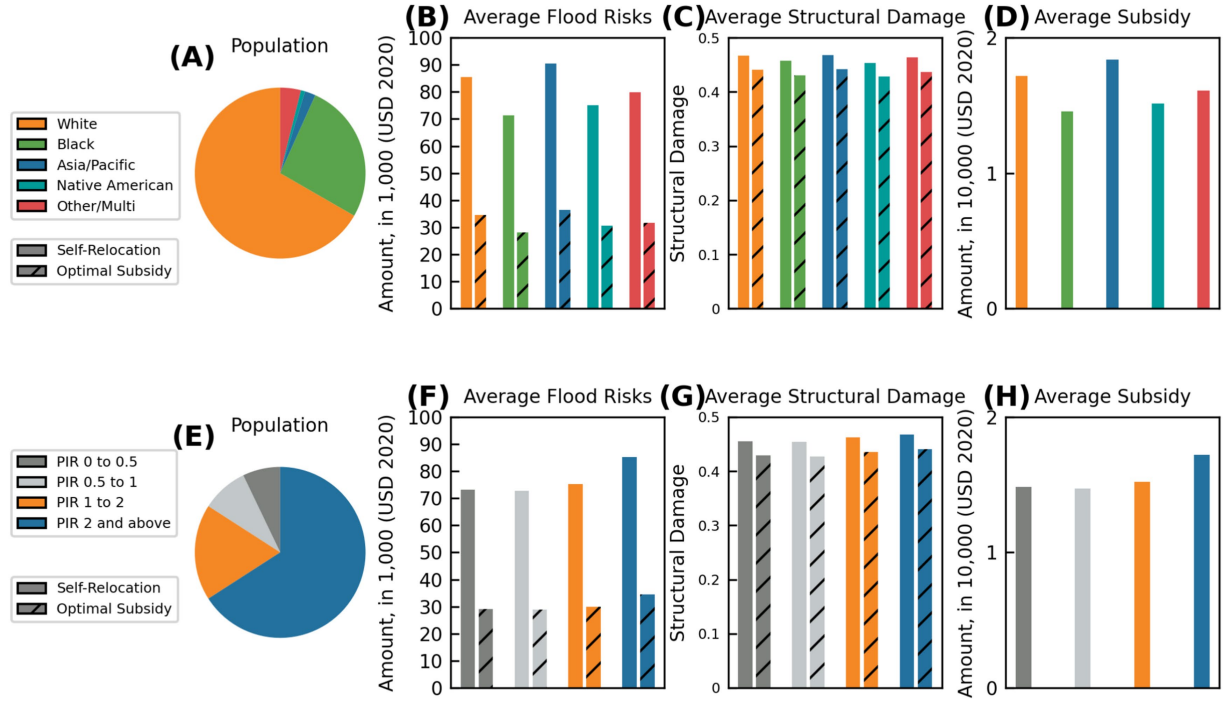


FIGURE 5
Population composition, average flood risks, average structural damage, and average subsidy allocation under optimal-subsidy-relocation in the Lower scenario. Panels **(A,E)** display the racial composition **(A)** and poverty-income ratio (PIR) composition **(E)** of the study area. Panels **(B,F)** present the average flood risks across racial and income groups, while panels **(C,G)** illustrate the average expected annual structural damage (EASD), a standardized measure of flood severity expressing structural damage as a percentage of replacement cost, rather than the monetary value of flood damage. Panels **(D,H)** show the average subsidy allocation under the optimal-subsidy-relocation. The solid portions of the bars indicate self-relocation outcomes, while the striped portions represent outcomes under the optimal-subsidy-relocation.

Leveraging comprehensive datasets from Louisiana's Coastal Master Plan, this paper evaluates the effectiveness of pre-disaster subsidized relocations under both lower and higher environmental scenarios using game-theoretic optimization with high-resolution structural-level flood risk and relocation cost estimates. Our findings indicate that both fixed-subsidy-relocation and optimal-subsidy-relocation effectively incentivize homeowners to advance their relocation timelines, yielding benefit–cost ratios of at least 2.5. The more severe the anticipated future environment conditions, the more advantageous these earlier relocations become. The results further demonstrate that optimal-subsidy-relocation leads to more frequent and earlier relocations while preventing excessive subsidy offers, resulting in broader coverage and higher cost efficiency.

Pre-disaster relocations address some of the major inefficiencies in post-disaster buyout programs, such as reducing hardships associated with both disasters and relocations and allowing sufficient time for lengthy implementation processes (Curran-Groome et al., 2021). However, several limitations remain. Recipients of pre-disaster buyout offers still face significant challenges, including patchwork implementation across jurisdictions (Zavar and Hagelman III, 2016) and the possibility that homeowners move to other flood-prone areas due to affordability constraints or a lack of available housing in lower-risk regions (Hotard and Ross, 2025; McGhee et al., 2020). Moreover, many individuals rely on local job markets and social networks (Greer et al., 2022, 2019), and psychological factors such as home/community attachment (Cooper et al., 2022) are not well considered in the current framework. Despite these limitations, this study remains a valuable contribution because its goal is not to prescribe specific policy recommendations but to evaluate the potential feasibility and overall performance of pre-disaster relocation as a risk-reduction strategy.

Several interesting research directions can thus emerge from this work. The decision-making process employed in this study is primarily based on economic comparisons. However, we recognize that relocation decisions are also influenced by non-monetary factors, such as attachment to one's home, proximity to work, and the demographic characteristics of homeowners. Incorporating bounded rationality and alternative decision heuristics into the modeling framework could make the model more realistic by accounting for these factors. In our time of exploring this body of work, we have not come across studies that address any differences in rationality that the participants might display. While there are some promising starting points to talk about biases toward environmental risk, this work adds a step in the direction of modeling these biases and including them in decision frameworks to inform policymakers. Additionally, homeowners and the government may have differing perceptions of future flood risks, which could significantly impact relocation outcomes. Some pieces which we are already working to tackle in future work are the community impacts and neighborhood peer effects on buyout decisions. Coupled with ideas of bounded rationality and Bayesian learning in games, future work could address a major limitation

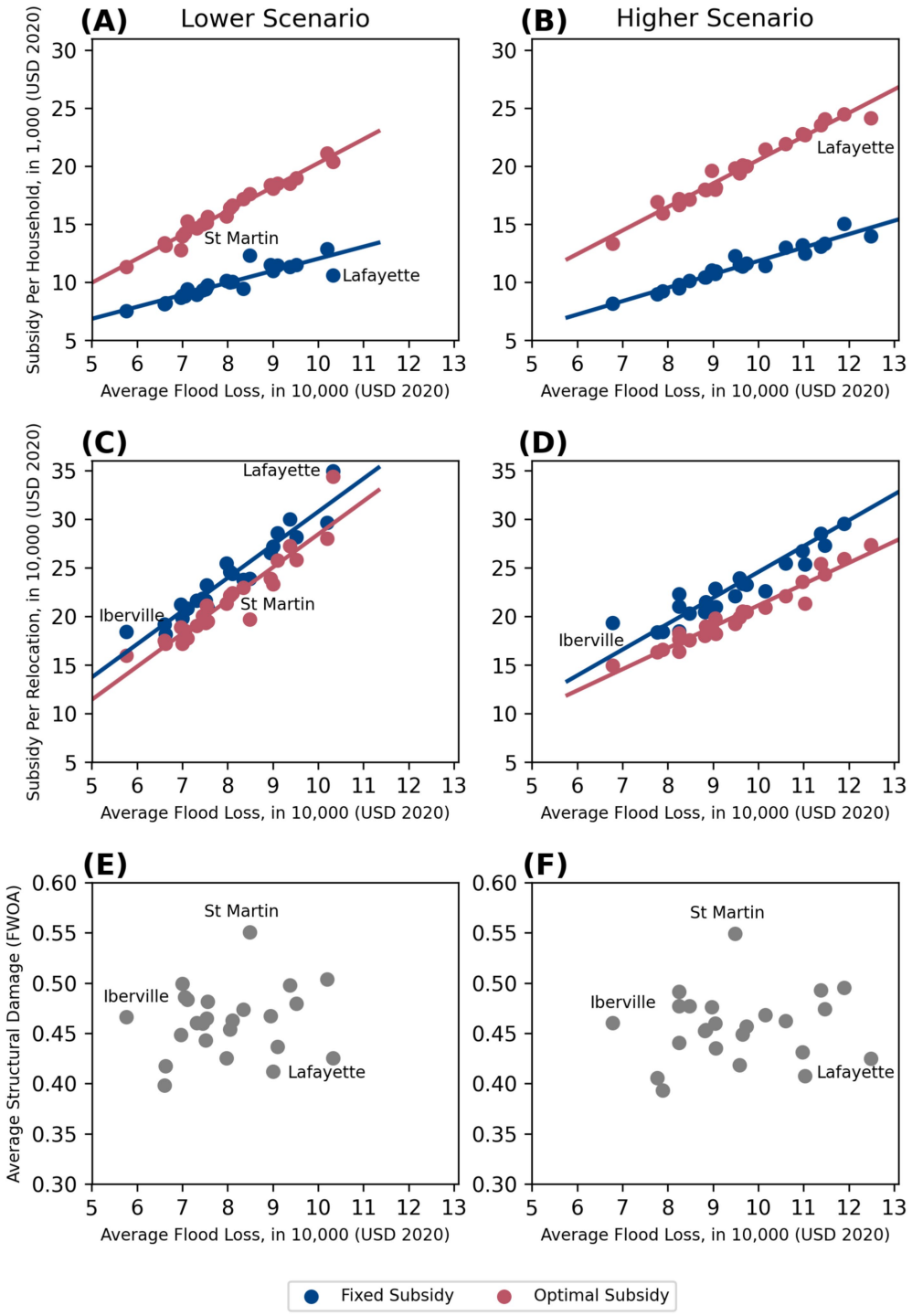


FIGURE 6
Parish-level subsidy allocation patterns under fixed-subsidy-relocation and optimal-subsidy relocation. Panels **(A,B)** illustrate the relationship between average flood loss per household and the average subsidy per household under Lower **(A)** and Higher **(B)** scenarios, highlighting discrepancies in allocation patterns for certain parishes. Panels **(C,D)** present the average subsidy per relocation, showing variation across parishes. Panels **(E,F)** depict average structural damage in the future without action (FWOA), offering insights into how flood risk severity influences subsidy distribution. Lafayette, St. Martin, and Iberville Perishes are labeled in each panel as notable cases for further analysis.

of the study, making it closer to a policy-informing analysis. Investigating how these divergent perceptions influence the effectiveness of relocation subsidies presents an intriguing area for further research. Beyond the perspective of risk reduction, the government also faces a complex tradeoff between mitigating flood risks through resident relocations and the potential loss of tax revenue, which offers yet another avenue for future exploration. This opens an opportunity to explore hierarchical funding from the federal government versus local government in managed retreat policies. Another version of this opportunity

could talk about increasing visibility of community grievances by inviting community leaders as stakeholders to the discussion around policymaking.

Our findings reveal that the distribution of subsidies and flood risk reduction benefits does not undermine the existing status of equity. However, the assessment of equity is influenced by the assumption of demographic homogeneity within census block groups. If demographic data were available at the structure level, the impact of relocation outcomes on different racial and income groups might vary slightly. Nevertheless, census blocks are the smallest geographic unit for which we have demographic data, and the presence of population migration dynamics further complicates the accurate and timely capture of structure-level demographic information. Aggregating data at the census block level, therefore, provides a balanced approach. For these reasons, we believe that our equity analysis remains robust and credible.

Our analysis confirms that pre-disaster relocations allocate resources to parishes basically in proportion to their flood risks, aligning with principles of procedural equity. However, it is important to recognize that fair resource distribution based on flood risk reduction alone may inadvertently reinforce pre-existing structural inequities, as communities historically subject to underinvestment and disproportionate flood exposure may continue to bear a greater burden of relocation (Stanley et al., 2023). This phenomenon has been widely observed in buyout programs, where funding mechanisms – though objectively risk-based – can still result in justice and equity challenges in implementation (De Vries and Fraser, 2012; Loughran and Elliott, 2019; Siders, 2019). A similar pattern emerges in our findings, where some parishes with high values of structural risk receive less subsidy support due to the underlying allocation framework. This underscores the reality that equity cannot always be achieved solely through equal distribution measures. To better account for these concerns, alternative equity-focused risk metrics, such as those proposed by Geldner et al. (2023), could be integrated into future analyses. These alternative metrics would help to ensure that policy feasibility is not achieved at the cost of social equity, providing a more comprehensive approach to just flood risk mitigation.

Global sensitivity analyses provided no insightful patterns or conclusions. However, the numerous local (i.e., one at a time) sensitivity studies, help us infer that the numbers of relocations in fixed subsidy mode and optimal subsidy mode are sensitive to both government and homeowners' discount rates. We also conducted exploratory analyses to identify the factors driving variations in relocation behaviors. Specifically, we examined whether certain structural characteristics, such as square footage, elevation, and foundation height, as well as flood risk-related factors, including 100-year flood depths and the probability of flooding, consistently lead to specific types of relocations. The details of these exploratory analyses are provided in Supplementary material.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found at: https://mpdap.coastal.la.gov/.

Author contributions

FL: Conceptualization, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. PJ: Conceptualization, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. DJ: Conceptualization, Data curation, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Writing – review & editing.

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Supplementary material

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Reconciliation or restoration? The ecological futures of floodplain buyout sites

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What happens to floodplain buyout sites after demolition of structures? Does ecological restoration or reconciliation of the floodplain occur? By what criteria should we assess what is on the site? Under what conditions do government programs promote more ecologically dynamic land management? We explore these questions in the context of four exemplary buyout programs in the United States that implement relocation out of flood risk zones through buyouts: Austin's Watershed Protection Department, Texas; Harris County Flood Control District, Texas; Charlotte-Mecklenburg's Stormwater Services, North Carolina; and Washington State's Floodplains by Design. The analysis draws on staff interviews and GIS mapping, satellite imagery for 3,416 buyout parcels spanning 2,811 acres, and selected field verification. We test a framework for assessing buyouts that includes both pre- and post-buyout considerations as indicators along a spectrum from reconciliation to restoration. Our findings show that the status of most buyout parcels is "in-waiting," as land management practices evolve to decide on their long-term use. Federal buyout requirements prevent redevelopment, but it is local and state priorities, goals, capacities, partnerships and levels of community engagement that shape land management outcomes and long-term human-nature relations. While the reconciliation-restoration debate often pits social against ecological goals, we find that they are mutually reinforcing, and that deep community engagement yields better outcomes overall. Floodplains are high value landscapes and should be prioritized for repair. State and federal governments can help achieve greater ecological and social outcomes from buyout sites by issuing more explicit guidance, technical assistance, and funding support to achieve these aims.

KEYWORDS

ecological repair, floodplain restoration, buyouts, floodplain reconciliation, land management

1 Introduction

Floodplains are some of the most biodiverse and human-impacted environments in the world (Ward et al., 1999). As climate change increases the frequency, severity, and reach of floods (Crimmins et al., 2023), some people are relocating out of flood-prone areas. While policymakers and many departing residents hope that this sacrifice will leave behind restored landscapes (Koslov, 2016), little is known about what actually happens to sites after people leave and structures are demolished (Zavar and Hagelman III, 2016). Do the lands become restored? To what? By what criteria should we assess their condition? Under what circumstances do programs repair more sites to an ecologically dynamic condition?

We explore these questions in the context of four programs in the United States that implement relocation out of flood risk zones through government acquisitions or buyouts in Austin, Texas; Houston, Texas; Mecklenburg County, North Carolina; and Washington State. We argue that there is no singular goal or strategy for repair, but a spectrum of options, from ecological "restoration" to "reconciliation," driven by local social and developmental conditions. We analyze satellite imagery and use field verification to assess the extent to which the 3,416 buyout parcels spanning 2,811 acres in these four regions implement diverse land management strategies. We interview buyout program land managers to clarify and confirm results.

We find that each program adopts a different management strategy, resulting in distinct social and ecological outcomes. Nearly all sites meet the national standards set by the Federal Emergency Management Agency (FEMA) in its Hazard Mitigation Grant Program for buyouts, regardless of whether a particular parcel is purchased with funds from that program. That is, after the program purchases the property, structures are demolished and subsequent redevelopment is prohibited. This should permit the return of floodplain plant communities, processes, and functions. Some also try to minimize checkerboarding, or scattered buyouts sites, by mandating contiguous buyouts through eminent domain or incentivizing neighbors to participate in voluntary buyouts simultaneously. However, simply removing structures does not result in a restored floodplain. Our findings show that the state of the land correlates with other program goals for flood management and risk reduction, habitat restoration, recreation, or some combination, along with the capacity to maintain and manage these now vacant lands. A program that uses buyouts as a way to create new wildlife habitat tends to return sites to a more dynamic state, while those that prioritize social outcomes tend to create amenities like trails, benches, and recreational facilities.

These findings show that while federal requirements have helped prevent development on buyout properties, the tremendous variation in the long-term state of these lands is driven by the distinct goals of state and local buyout programs. Given the social inequities in where buyouts take place (Siders, 2019; Elliott et al., 2020), the different end states of repaired sites also have important implications for socio-economic impacts for remaining neighbors and relocated residents (Shi et al., 2023). State and federal governments can help achieve greater ecologically reparative or socially equitable outcomes for buyout sites by issuing more explicit guidance, technical assistance, and funding support to achieve these aims. Below, we first review the imperative of repairing buyout sites and the gap in achieving this goal, present our assessment framework and typologies of programmatic approaches, and then consider programs' challenges and needs. Addressing these gaps and needs will help repair floodplain functions and habitats and promote climate adaptation for human and non-human species.

2 Floodplains, buyouts, and the gap in repair

2.1 The ecological value, growing impairment, and inequity of floodplains

Floodplains are ecologically important places (Opperman et al., 2013). Floodplains are lands defined by periodic flood disturbance where ecological and human systems often collide (Opperman et al., 2010; Tockner and Stanford, 2002; Ward et al., 1999). These landscapes have been described as among the most valuable and threatened ecosystems in the world (Opperman et al., 2017; Tockner and Stanford, 2002; Weigelhofer et al., 2020). Floodplains provide major ecological and economic benefits, including sediment and nutrient reduction, carbon sequestration, groundwater recharge, fisheries, recreation, biodiversity, seasonal agriculture, water quality improvement, and cultural placemaking (Opperman et al., 2017; Christin and Kline, 2017) but are degraded faster than any wetland type (Tockner and Stanford, 2002). In terms of per-hectare value to society, floodplains are second only to estuaries, providing 25% of all nonmarine ecosystem services on only 2% of the terrestrial surface area (Opperman et al., 2017; Costanza et al., 1997). Sheaffer et al. (2002) note that the ecological and natural values of floodplain lands, such as pollution abatement and groundwater recharge, can be worth up to 10 times the cost savings achieved through buyouts and flood risk reduction. Many floodplain ecosystem services are driven by a river's dynamism, including periodic flooding, where rivers overtop their banks and spill over into adjacent low-lying lands (Ward et al., 2002; Stanford et al., 2005). The magnitude, frequency, duration, timing, and rate of change of water flows collectively create a river's "natural flow regime" (Poff et al., 1997; Poff and Zimmerman, 2010; Zhang et al., 2012). The floods that modern society views as a problem to be fixed are part of this natural flow regime and necessary to maintain a river's ecological integrity.

Floodplains have been highly developed (Opperman et al., 2017; Tockner and Stanford, 2002). Globally, 1.6 billion people were affected by flooding between 2000 and 2019, at a cost of $651 billion (UNDRR, 2025). Between 2011 and 2015 in the U. S., an estimated 30 million people were living in the combined flood risk zone, or the 1 and 0.2% annual chance of flooding, formerly known as the 100-year and 500-year flood risk zones, respectively (Peri et al., 2017). Wing et al. (2018) find that this number is grossly underestimated due to outdated flood maps. Over the last two decades, an additional 2.1 million acres of U. S. floodplains were developed (Samoray et al., 2024). A number of factors have led to an intensification of floodplain development in the U. S., despite the increasing magnitude of flood disasters. The National Flood Insurance Program (NFIP), once intended to disincentivize people from living in floodplains, inadvertently makes development in flood risk zones more palatable by shifting the costs of rebuilding onto the government (Browne et al., 2019; Christin and Kline, 2017; Silvis, 2018). Historically, the U. S. Army Corps of Engineers (USACE) and FEMA's Hazard Mitigation Grant Program favor the construction of gray infrastructure such as levees (Walls and Liao, 2023; Sperl, 2022), which in turn gives the false impression of a development-safe zone in an infrastructure-protected area (Miao and Davlasheridze, 2022; Knox et al., 2022; Sutton-Grier et al., 2015). These federal supports have prevented real estate markets from internalizing the costs of repeated flood damages (Pappas and Platt, 2021). Outdated flood maps mislead prospective homebuyers regarding risk (Wing, et al., 2020), and cities continue to build in floodplains even as they remove some repetitively flooded properties through buyouts (Hino et al., 2024).

Globally, flood risk exposure and risk reduction are highly inequitable (Hallegatte et al., 2016; Winsemius et al., 2016). An estimated 19 million people in the U. S. live in census tracts with both a 1% chance of annual flood risk and high social vulnerability (Tate

et al., 2021). More affordable housing is likely to be located in inland floodplains compared to other types of housing (Samoray et al., 2024). At the same time, flood risk reduction efforts also can be inequitable, with lower-income homeowners more likely to be offered a buyout while wealthier residents are offered home elevation grants, levees, or seawalls (Siders and Keenan, 2020). Mach et al.'s, 2019 study found that buyouts across the U. S. are more likely to occur in less densely populated areas that are relatively poorer, with lower education, more racial diversity and lower English language proficiency. Lower-income and minority residents receive fewer payments, have longer wait times, and move farther away, thereby distancing them from past social networks (Siders, 2019; Kraan et al., 2021; Elliott et al., 2021). For these households, the question of what happens with the land after a buyout can be all the more important in shaping decisions about whether to take a buyout, recovering from trauma, and sustaining social networks (Shi et al., 2023).

2.2 Evolving debates about how to repair floodplains

The field of ecology has evolved from a focus on preservation and conservation, to one on restoration, to increasingly a focus on reconciliation (Hobbs et al., 2014). Preservation and conservation aim to minimize the harms of human use and intervention. Advocates see restoration as a way to return land to its natural, "pre-development" state, often without regard for thousands of years of indigenous inhabitation and extensive land management (Grenz and Armstrong, 2023) and the deeply social, cultural, and political dynamics that have long shaped watersheds (Elias et al., 2021). The concept of reconciliation suggests that a negotiated outcome is acceptable, taking into account historical realities, ecological function, and social needs. In reality, restoration and reconciliation exist on a spectrum of overlapping options with no clear boundary between the two; this evolution reflects shifting balances of ecological and social values over time.

Ecological restoration efforts assist the recovery of an ecosystem that has been degraded, damaged, or destroyed (Gann et al., 2019). The Society for Ecological Restoration positions restoration projects along a continuum of increasing required inputs, from "reduced societal impacts" to remediation, to rehabilitation, and finally ecological restoration (Gann et al., 2019). A strong case can be made for supporting efforts to restore floodplains due to their high ecological value. Floodplains are highly productive ecotones supporting far more species than adjacent uplands (Tockner and Stanford, 2002). Restoration sets targets for a desired state that can be measured along two spectra: ecological integrity and historical fidelity (Higgs, 2003). The former is a holistic term related to ecosystem structure and function (Wurtzebach and Schultz, 2016), the latter considers not one fixed state but a historical range of variability, since no ecological system is static (Higgs, 2003). Restoration efforts in urbanized floodplains could involve actions such as restoring hydrologic connectivity via levee setbacks or removal, or reconstructing wetlands by removing fill soils and recreating microtopography. Restoring ecosystems to previous states requires knowledge of what was there before or close analogs, known as reference sites (Gann et al., 2019; Higgs, 2003; Higgs, 1997; Rosgen, 1998).

Restoration approaches, particularly in urban settings, raise numerous concerns and challenges. In places where human settlements and river floodplains coincide, full restoration of floodplain ecosystems and natural flow regimes may be difficult, if not virtually impossible, at least in the near-term. Achieving historical fidelity is challenging in part because although floodplains throughout the world have been altered and managed, sometimes for thousands of years, floodplain ecosystems were not studied extensively prior to their development and there is little site-specific data to draw from to set appropriate targets for restoration (Opperman et al., 2017). Urban floodplains and their watersheds have undergone extensive transformation (Walsh et al., 2005) including the channelization and concretization of rivers and creeks, addition of fill and numerous structures that decrease flood storage area, and removal of vegetation. Dramatic increases in ground compaction, impervious surfaces, and curb and gutter roadways funnel stormwater quickly, resulting in faster and higher peak flows in waterways (Konrad, 2003; O'Driscoll et al., 2010; Dunne and Leopold, 1978). And while buyouts "undevelop" the floodplain, waterways in cities are major amenities and there is an expectation that waterfront and public open space within urban areas is used, sometimes intensively, by the people who live there. These factors make goals of historical fidelity and ecological integrity challenging in urban floodplains (Figure 1).

Accordingly, many scholars and practitioners increasingly advocate the idea of "reconciliation." In a 1997 paper, Eric Higgs warned of approaches to the nascent field of ecological restoration that are too technocratic and absolute, and instead advocated for more process-based approaches that bring people with diverse interests together to negotiate creative solutions. In doing so, he argued, authentic engagements between people and ecosystems heighten "place awareness" (Higgs, 1997). Higgs folded communities and cultures into the restoration process in a measure he called "cultural fidelity" that considers factors such as social justice, health and wellbeing, and traditional knowledge (Higgs, 2003). Before the early 2000s, most ecologists were preoccupied with studying "pristine" habitats as untouched by industrialized societies as possible. In a 2003 paper titled "Reconciliation Ecology and the Future of Species Diversity," ecologist Michael Rosenzweig made an urgent call to adapt anthropogenic habitats so that they could be shared by more species, including humans. He used species-area equations to demonstrate that if we rely only on preservation/conservation and restoration, "we are doomed to lose nearly every species alive today" (Rosenzweig, 2003). Rosenzweig (2003) called the ecology that works with and in human-dominated habitats "reconciliation".

Applying this idea to floodplains, Opperman et al. (2017) proposed reconciliation as an alternative to full-scale floodplain restoration, such that people are part of the ecosystem as active managers and participants, working toward a set of goals defined in relation to management needs and societal values. Many traditions worldwide have developed sophisticated ways to sustain rice cultivation, aquaculture, and rangelands in flood-dependent landscapes (Liu et al., 2022; Gebrekidan et al., 2020; Michael et al., 2023; International Livestock Research Institute, 2021). The Walking Wetlands project by the U. S. Fish and Wildlife Service (USFWS) floods farm fields for several consecutive seasons to provide wetland habitat for waterfowl. Farmers lose yields during this period but cite benefits such as the suppression of soil pathogens and better soil fertility (USFWS, 2021). These examples demonstrate how tradeoffs

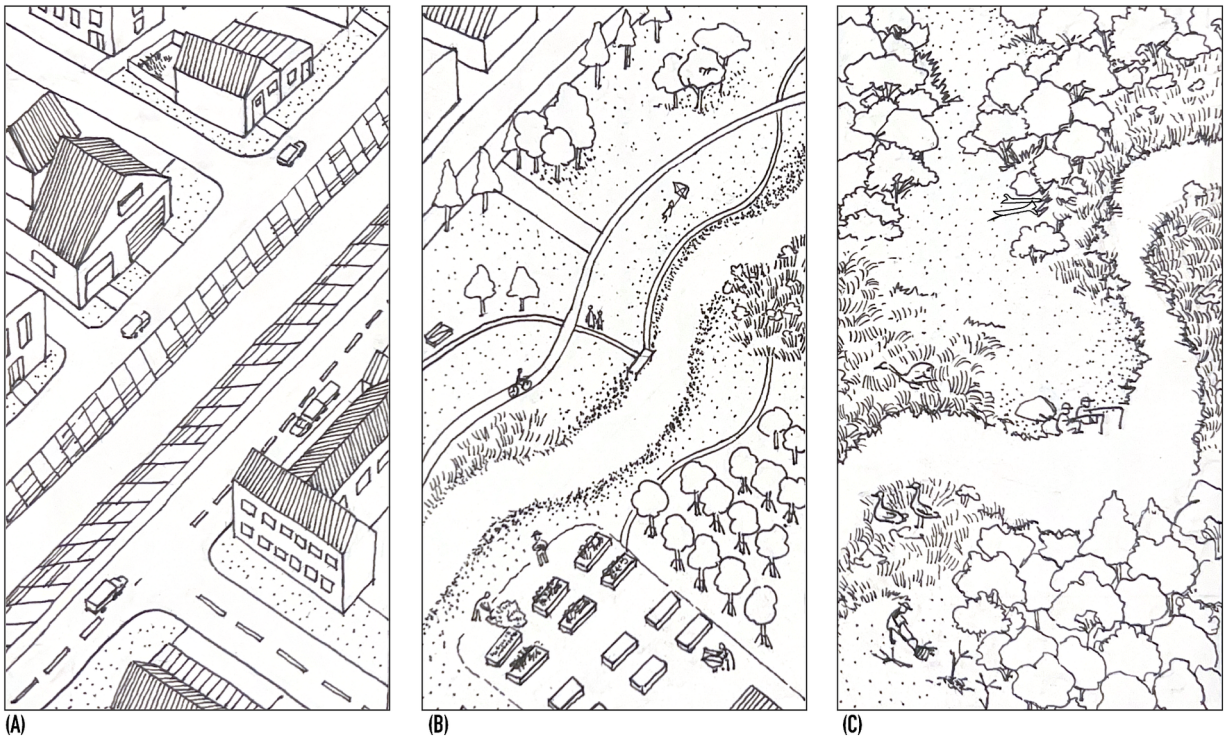


FIGURE 1
A spectrum of possible floodplain landscapes. Reparative actions can shift lands from developed and largely impermeable flood risk zones **(A)** to a reconciled floodplain **(B)**, with trails and greenways and other community uses such as community gardens and playing fields, to a restored floodplain **(C)**, where ecological value is high, community use is secondary to habitat for non-human species, and floodplain functions maintain a creek's ecological integrity. (Drawing by Xueting Jin).

can be made to accommodate both people and functioning ecosystems in a shared space. Fully restoring the processes that sustain floodplains, as described by Beechie et al. (2010), may not be possible given the extent of watershed change, but building green infrastructure to counter the effects of impervious surfaces is an example of reconciliation. There is a real need to increase the performance of urban landscapes to support biodiversity and ecological function (Colding, 2007; Standish et al., 2013a, 2013b). In fact, more researchers are suggesting that human intervention is increasingly necessary to build resilience in landscapes due to the outsized disturbance of climate change (Besterman et al., 2022; Bilkovic et al., 2017; Palik et al., 2022).

2.3 Opportunities and gaps of buyouts in advancing floodplain repair

Floodplain repair provides an opportunity to restore floodplain ecosystems while improving equitable community resilience (FEMA, 2024). Given the social inequities of flood risk exposure and risk reduction efforts, the repair and stewardship of floodplains after buyouts can both support community-wide decision-making and facilitate the health and well-being of those who relocate or who remain (Shi et al., 2023). The long-term intended use of buyout land has been identified as an important factor in facilitating decision making, closure, and recovery (Baker et al., 2018; Binder and Greer, 2016; Binder et al., 2020), and knowing they are contributing to community open space eases stress for people who move (Baker et al., 2018; Reguero et al., 2018). Expediting the process of converting land to open space, or having a plan in place to do so, may alleviate concerns of more hesitant floodplain landowners in considering buyouts, thereby minimizing checkerboarding and negative socio-economic impacts of vacancy (Baker et al., 2018; Siders and Gerber-Chavez, 2021). Public education, engagement with community organizations, and inclusion of diverse local knowledge traditions in land management can also help build a sense of agency in the face of trauma.

However, buyouts programs are not doing enough on restoration (Zavar and Hagelman III, 2016). In a 2002 report, a Congressional Task Force on the Natural and Beneficial Functions of the Floodplain concluded that "restoring the natural and beneficial functions of floodplains will not only reduce flood damages, but also contribute to a community's social and economic well-being… natural functioning floodplains will become increasingly critical community assets" (Task Force, i). The Task Force recommended updating and expanding national policies on the protection and restoration of floodplain functions, drafting a proactive and long-term approach to floodplain management, increasing capacity for planning processes, and focusing efforts on those areas of floodplains with the greatest risks and significant natural and beneficial functions (Task Force on the Natural and Beneficial Function of the Floodplain, 2002). It also cited the post-disaster opportunity to relocate structures, restore rivers and wetlands, and expand greenways.

Nevertheless, restoration of post-buyout land is hindered by a lack of funding and willing partners, lack of leadership and organizational capacity, conservation organizations prioritizing intact habitats, and checkerboarding (Kodis et al., 2021; Zavar and Hagelman, 2016). Federal funding for buyouts does not include additional money to restore the land. This leaves many buyout properties in a state of limbo. Zavar and Hagelman's, 2016 study of land use change on federally funded buyout project sites between 1990 and 2000 found that 34.2% remained vacant lots. The FEMA Hazard Mitigation Grant Program turns buyouts over to municipalities, leaving them with the task and cost of mowing a scattershot of parcels, often to meet the esthetic preferences of remaining neighbors. Floodplain managers surveyed as part of a Zavar and Hagelman's (2016) study revealed that a lack of guidance and open space planning caused buyouts to remain underutilized, or even end up being redeveloped (Schwab, 2021).

For the time being, most programs prioritize reducing risk using benefit–cost analysis in selecting which sites to buy out. Prioritizing risk reduction, along with a voluntary process, can result in checkerboarding, which is regularly cited as a key challenge to restoring buyout lands (Kodis et al., 2021; Schwab, 2021; Zavar and Hagelman, 2016). Connectivity of habitats is a key to ecological function – smaller isolated patches are often sinks, with declining biodiversity and more extirpations (Salizzoni and Pérez-Campaña, 2019; Stoffers et al., 2022). Contiguous land is also essential for trail design. The recent shift from post- to pre-disaster hazard mitigation opens the door for more proactive planning. Since 2013, FEMA allows post-buyout climate resilience activities such as floodplain restoration and flood diversion and storage to be factored into benefit–cost analysis and buyout selection, with updates expanding that policy in 2015, 2016, and 2020 (FEMA, 2020). These steps are significant in beginning to consider post-buyout parcel uses, including restored habitats and amenities. Quantifying the ecological value that post-buyout lands provide can increase benefit–cost ratios. Programs that consider post-buyout use as part of the selection process increase the likelihood that these homeowners will participate, and that buyout lands will lead to gains in ecosystem services and recreation value for communities (Atoba et al., 2021; FEMA, 2020; Nelson and Camp, 2020).

3 Methodology

3.1 Data and methods

As this review highlights, there is growing advocacy and policy making that is leading to the "undeveloping" of floodplains, but limited research on the effectiveness of current policies and initiatives. In response to this research gap, we developed a four-part, mixed methods study. First, we created a framework for measuring outcomes on buyout parcels. We reviewed the literature on restoration and reconciliation, then juxtaposed that against what available satellite and other geospatial data would allow us to measure. This resulted in nine indicators (see Table 1) that guided the rest of the analysis. All indicators can be measured using datasets readily available at the national, county, and sometimes local data, such as zoning and management plans for buyout parcels. The use of publicly available datasets allows for this assessment framework to be replicated in other locations.

Second, we studied prominent programs in four locations: Harris County Flood Control District (HCFCD) in Houston, Texas; Watershed Protection Department (WPD) in Austin, Texas; Charlotte-Mecklenburg Stormwater Services (CMSS) in North Carolina; and Floodplains by Design (FbD) in Washington State. These programs are widely recognized as exemplary programs and have implemented numerous buyouts. Each draws on a distinct mix of federal, state, and local funding that allows them to operate continuously and not only after a disaster declaration (Shi et al., 2022). These characteristics result in a large sampling pool of buyout sites and a relatively long timeframe across which to measure ecological change. We reviewed each program's available management plans and websites and interviewed managers who implement buyouts and/or manage resulting properties to understand their goals and strategies for land management. This surfaced an array of challenges that programs face and response strategies they have developed in trying to repair buyout sites.

Third, we reviewed the satellite imagery of 3,416 parcels where buyouts related to flooding (excluding other types of disasters, such as landslides) have been implemented in these locations between 1995 and 2016. Some parcels did not contain buyout date information. We chose a parcel-level analysis to provide a more fine-grained picture of post-acquisition outcomes for buyouts. Using both FEMA natural disaster buyout data and buyout data acquired from buyout program managers, we developed a merged data table and maps that include parcel location information, land cover categories and observation source, land cover details, known restorative action (if any), community outreach (if any), and funding source (if known).[1]

Building on Zavar and Hagelman's (2016) buyout project-level assessment, we used the most recent satellite imagery from Google Maps, including Google Street View, and Google Earth to categorize each buyout parcel as one of the following land cover types: paved or bare ground, house or building, lawn, community garden, meadow/grassland, lawn with trees, meadow with trees, early successional forest, wetland, successional forest, and established forest. We ground-truthed parcels for those lacking adequate aerial imagery and a random sample of all others by sending graduate student researchers to each of these sites to photograph them. In total, we ground truthed 529 parcels or about 17% of all buyouts studied. For each parcel, we assigned a score of 1 or 0 for each of the metrics in the framework. As we proceeded with this research, questions about parcel maintenance emerged and revealed five categories of parcel land management shared across the four case study locations.

Finally, we typologized the four programs' overall strategies in relation to their goals, results of the reconciliation and restoration framework assessment, and status of buyout sites. The aim of these typologies is not to cast any particular approach as better or worse, but to demonstrate the diversity of objectives and approaches to managing buyout sites, and raise questions about whether and how to assess, support, or align these efforts. We reviewed the literature on what the ecology of these places was in pre-industrial times to get a sense of what is ecologically "possible," or at least historic, and compared that against the current land cover of the site. We also drew on programs'

1 The sources and descriptions of the GIS datasets used in our study can be found in supplemental data.

TABLE 1 Restoration and reconciliation assessment framework on a spectrum from reconciliation (top) to restoration (bottom).

	Indicator	Rationale	Metric	N = 0	Y = 1	Data used
Reconciliation ↑	Building removed from flood risk zone (only metric of 9 required by FEMA)	Reduces development in hydrologically fluid places	Parcel is in FEMA's Special Hazard Area	Not in 1% annual chance flood zone	In the 1% annual chance flood zone	FEMA National Flood Hazard Layer
	Parcel has recreational or other amenities for people	Reconciles site with community needs	Presence of recreational amenity on parcel	No amenity	Has amenity	Google earth and case study datasets (greenways, trails, water bodies)
	Parcel is covered by management plan	Establishment of plan indicates proactive planning	Parcel is included in a plan	No plan	Has plan	Intersected management plan areas + buyouts
	Parcel contributes to contiguity with other buyout parcels	Contiguity allows greater areas for non-human species to migrate	Another buyout parcel within 1000'	No other buyout within 1,000 ft	Another buyout within 1000'	Tax parcels
	Parcel contributes to contiguity with conserved spaces		Parcel within 1,000′ of existing conserved open space	No conserved open space within 1000'	Conserved open space within 1000'	National Conservation Easement Database; Protected Areas Database of case study datasets
	Parcel is conserved via zoning change (enhanced protection)	Prevents further development of site	Parcel is protected using zoning change	Parcel is not protected through zoning	Parcel is zoned open space	Local zoning
	Parcel contributes to a riparian buffer	Allows for re-establishment of riparian ecosystems	Parcel within 100′ and 350′ of a waterway	Does not contribute	Contributes/ within 100′ and 350′ and 350′ of a waterway	USGS National Hydrography dataset + local surface water data
	Parcel is hydrologically connected	Allow water to return to site	Levee protected zone	Within levee protected zone	Not in levee protected zone	National Levee Database
Restoration ↓	Land cover is dynamic	Site allows for dynamic ecological change over time	2 categories of land cover and vegetation	Land cover/ vegetation is static	Land cover/ vegetation can change with flood disturbance	Google Earth and Google maps (in time); a sample of parcels ground truthed

Metrics and data sources are included.

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websites and management plans to develop a case study of each program's goals, strategies, and outcomes. Between 2020 and 2023, we interviewed two program managers from each case study to help correctly characterize their priorities and strategies and to review our findings, sometimes multiple times. These conversations were conducted over Zoom and generally took 30–60 min.

3.2 Proposed criteria for measuring buyout site restoration and reconciliation

For this study, we developed the following set of criteria to evaluate where a parcel or group of parcels sits on the restoration – reconciliation spectrum. Indicators are ordered from reconciliation to restoration.

1 *Removes property from flood risk zone*.[2] We focused on the benefits of buyouts to communities that come from reducing the land designated as part of FEMA's Special Flood Hazard Zone (SFHA), including reduced future damages, insurance burdens, and loss of life.
2 *Offers amenities*. The creation of amenities, such as trails and greenways, parks, community gardens, and ecological sanctuaries, is an important sign of floodplain reconciliation.
3 *Has a plan for management*. Management of vegetation during a restoration or recovery period is critical to success via measures such as definition of targets, biodiversity monitoring, and control of invasives. We noted which parcels are included in documented plans for management, what kinds of actions are covered and whether or not local residents were involved in establishing targets for management. While most all buyout parcels are managed in some way, having a management plan associated with a parcel is indicative of inclusion in a broader plan and/or project.
4 *Under conservation*. Most buyout programs make use of deed restrictions to limit or prohibit future development on buyout parcels, but rezoning parcels so they have conservation land status helps to avoid "collective amnesia" and ensure protections against future development (Schwab, 2021). We used the National Conservation Easement Database, Protected Areas Database of the United States, and local zoning data to assess the conservation status of each buyout parcel.
5 *Hydrologically connected*.[3] Since, by definition, a floodplain must have access to periodic flooding, this indicator measures the freedom of a river to overtop its banks into adjacent areas. Sometimes levee setbacks or removals are required actions to restore this connection. We used the National Levee Database to identify areas protected by levees, while recognizing that this database is incomplete and might not account for smaller, undocumented flood control infrastructure.
6 *Contributes to a riparian buffer*. Riparian buffers directly adjacent to waterways are critical in a developed floodplain to provide ecological services such as sediment and nutrient capture and associated water quality improvement (Wegner, 1999; Coelho et al., 2014), bank stability (Beeson and Doyle, 1995; Hasselquist et al., 2024), reducing erosion due by lowering energy flows and stream shading (Rutherford et al., 1997), protecting against channel incision (Naiman et al., 2005), and corridors between isolated habitats (Henry et al., 1999). These effects lead to monetary benefits calculated at $10,000 per acre per year for services such as carbon capture and storage and reductions in water treatment costs and damages from flooding (Rempel and Buckley, 2018).[4] We used both 100- and 350-foot distances around waterways to define the riparian buffer, drawing from Wegner's literature review (1999) and conversations with land managers. Buffer areas sometimes overlap with floodway designations and higher risk of dangerous flooding.
7 *Contributes to connectedness to other conserved lands*. We assessed connectedness between buyouts parcels and between buyouts and nearby open spaces and conserved areas using a 1,000-foot buffer distance around parcel perimeter.
8 *Has dynamic land cover*.[5] Because floodplains do not have a clear reference land cover but are shifting habitat mosaics shaped by periodic disturbance (Stanford et al., 2005; Ward et al., 2002; Tockner et al., 2010), we used dynamism as a measure of whether vegetation is allowed to change in response to changing hydrology, ecological succession, and flood disturbance. This dynamism contributes to typically high biodiversity in floodplains (Hauer et al., 2016; Ward et al., 2002).

These indicators try to measure the ecological and social outcomes of buyout sites with the hope for refinement in future research (Prach et al., 2019). The framework is designed to: (1) include indicators necessary for risk reduction and basic floodplain function; (2) respond to buyout outcome shortcomings discussed in the literature; (3) be measurable using remote data; and (4) include some indicators that go above and beyond to support community use and biodiversity. Table 1 lists the metrics associated with each indicator.

4 Results

4.1 Post-buyout land management reflects distinct approaches

The four programs we studied adopt distinct approaches to managing bought out lands. Their approaches reflect the mission of

2 Not all buyouts occur within the SFHA. This is usually because of outdated mapping or mapping limitations associated with models that do not account for streams and creeks, or because the buyout was triggered by damage not from overbank river flooding but a flash flood or levee failure.

3 Vertical connectivity (from subsurface to surface and the reverse) is also a critical measure (Poole et al., 2008), but we were not able to measure it with data available.

4 Note the study done by Rempel, Austin, & Buckley was specific to the Delaware River Basin.

5 In a concluding set of maxims for floodplain managers, Opperman et al. include: "Floodplains need to be dynamic and diverse physically to be diverse biologically." (p. 217).

the organization or agency that leads the buyout work, as well as the missions of their key partners, and the type and extent of community involvement they support (Table 2). All four seek to remove buildings from flood prone areas and reduce flood risk, but their efforts vary in the extent to which they prioritize ecological restoration and how they define what counts as restoration. They also vary in the extent to which they engage with their communities, with greater involvement sometimes resulting in more restoration or greater reconciliation. We typologize their efforts as follows: community-led reconciliation in Austin; engineer-led reconciliation in Houston; creek-centered restoration in Charlotte-Mecklenburg; and habitat-centered restoration in Washington.

4.2 Austin watershed protection department: community-led reconciliation

The City of Austin, Texas straddles the transition between "hill country" of the Edwards Plateau and the endangered Blackland Prairies ecological regions. Prior to settler development, bottomland woodlands consisting of Eastern Cottonwood, Bur and Shumard Oak, Pecan, and Sugar Hackberry grew near waterways like the Colorado River (Olinde et al., 2021), alongside wetlands and tall-grass prairies. People of the Coahuiltecan, Tonkawa, Comanche, and Lipan Apache used areas along creeks extensively for hunting and travel (Peña-Martinez, 2025). Archeological studies find a long history of Indigenous occupation along Shoal Creek dating back 11,400 years, including "turning trees" slashed or tied down by Comanche to indicate direction for travel (Gelo, 2000). Today, Austin is one of the fastest growing cities in the U. S., with a population of just under 1 million (United States Census Bureau, 2020a). It is also located in what is known as "flash flood alley" (City of Austin, 2021a), one of the most flood-prone regions on the continent due to atmospheric conditions, steep topography, and karst geology (Saharia et al., 2017; Hill Country Conservancy, 2025; Baker, 1977). Climate in Austin is classified as humid subtropical, affected by tropical air from the Gulf of Mexico and tropical and extratropical cyclones (Saharia et al., 2017). Flood events in Austin are projected to increase in frequency with climate change (City of Austin, 2021b). Some 36,572 parcels, or 10% of the city's total land area (City of Austin, 2023a), is subject to flooding (Figure 2). According to our mapping efforts, there are 4,740 buildings in FEMA's designated Flood Risk Zone A, with a 1% chance of flooding in any year, while the City of Austin estimates that there are 7,000 buildings at risk of flooding in the city (City of Austin WPD, 2023b). Significant flood events occurred in 2013 and 2018 on Onion Creek and Lake Travis respectively, damaging over 900 homes (City of Austin, 2021b; Figure 2).

Austin's buyout program is administered by the Watershed Protection Department (WPD). It focuses on reducing the impact of flooding, erosion, and water pollution through flood risk reduction projects, maximizing areas of public use within floodplains, and maintaining their natural and traditional character to the extent possible (City of Austin, 2023b). We examined 1,046 buyout parcels spanning 261.5 acres.

The WPD combines engineering, education, and ecology and takes a community-centered approach to post-buyout land repair. The

TABLE 2 Overview of each program's land management approach and stated goals related to restoration.

	Buyout programs' partners, funding and restoration goals			
	Austin WPD: Community-led reconciliation	HCFCD: Engineer-led reconciliation	Charlotte-Meck CMSS: Creek-centered restoration	Washington FbD: Species-centered restoration
Year established	1st buyout project in 1980's	1937	1999	2013
Management agency	City Watershed Protection Department	Harris County Flood Control District	Charlotte-Mecklenburg Stormwater Services	State Department of Ecology
Key partners	Prioritizes community partners, so goals vary by project + neighborhood; Public-private partnerships	Army Corps of Engineers, Natural Resources Conservation Service (NRCS), US Geological Services (USGS)	Department of Parks and Recreation and a coalition of watershed, stewardship and flood monitoring groups	WA Fbd itself is a partnership of The Nature Conservancy (TNC), WA Dept of Ecology, Bonneville Environmental Foundation and Puget Sound Partnership; FbD establishes public-private partnerships with farmers, Tribes, and local governments
Restoration/land management funding	Stormwater fee, municipal bonds, voter-approved bonds, federal grants	Local bonds, Federal Emergency Management Agency (FEMA), Housing and Urban Development (HUD), The US Army Corps of Engineers (USACE)	Funds generated from stormwater fees paid by landowners on impervious surface area	State funding
Program goals related to restoration	Reduce flooding, erosion, and water pollution while maximizing public use and preserving natural character of floodplains	No division has responsibility for restoration, risk reduction prioritized	Ensure buyout properties become community assets and functioning floodplains.	Restoration and post-buyout use is built-in to application process

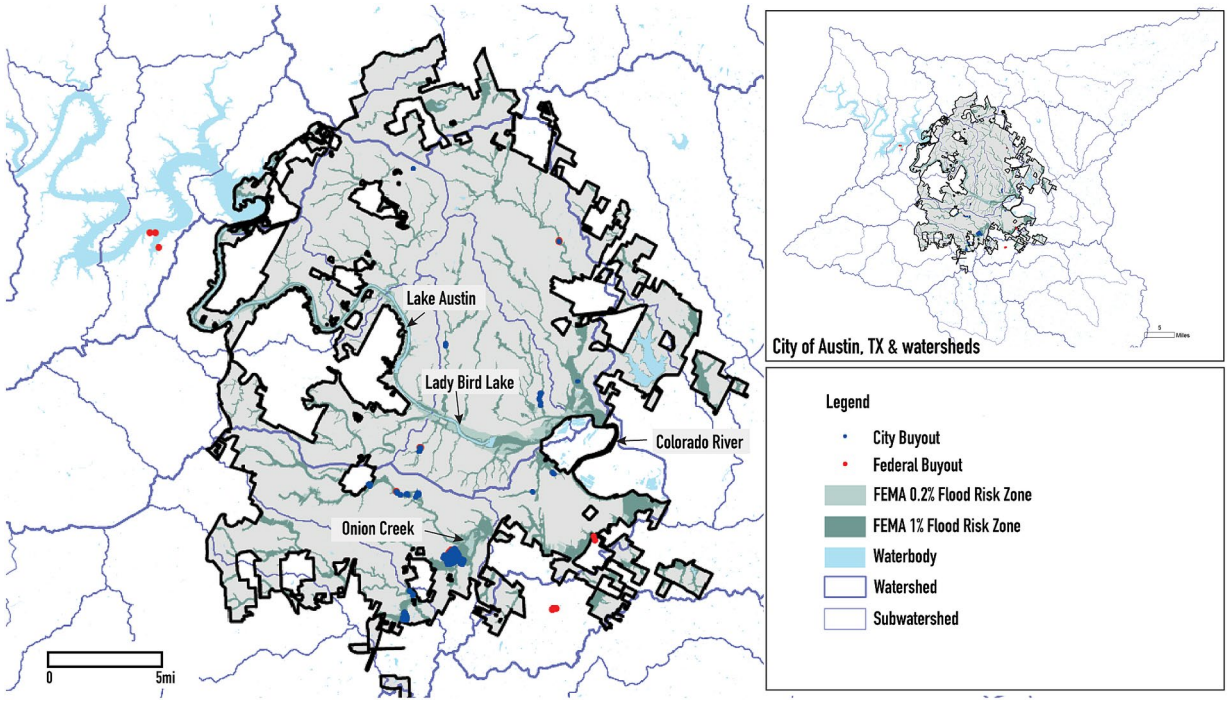


FIGURE 2
Map of the City of Austin's' subwatersheds, waterways and flood risk zones.

WPD approach has shifted from mowing every buyout parcel to creating a palette of standard best management practices such as wildflower and native grass seeding, undeveloped natural areas and enhanced practices including grow zones, rain gardens, orchards and community gardens (Gibson, 2023). The WPD uses adaptive management, actively monitoring stream health and biodiversity to improve their restoration strategies. Standard practices are funded by a drainage utility fee on impervious surfaces established in 1991 that allows the local government to decide what collected fees can fund, while simultaneously incentivizing removal of pavement. Enhanced practices require partnerships and additional funding. Community members play a strong role in determining post-buyout uses. Engagement is important for gaining community support and accounts for the diverse range of enhanced practices, as different communities value different outcomes. Austin's WPD uses a wide range of tools to interact with residents, including public surveys to address preferences and concerns, volunteer days, the drafting of land management plans and maps, signs, and public art to keep the community engaged and informed regarding projects. In some cases, community preferences have led to outcomes that align with esthetic norms rather than biodiversity gains, such as manicured lawns. As the Watershed Protection Manager Leah Gibson shared, "sometimes a community makes it clear they do not want restoration" (Gibson, 2023).

Austin has also invested in long-term maintenance of its post-buyout lands. In 2021, the WPD established the Austin Civilian Conservation Corps, with a vision of building an equitable, green workforce, representative of local communities, to care for community residents and the environment and adapt to challenges such as climate change (City of Austin, 2024). As part of the natural resources pathway to employment, WPD partners with Parks and Recreation and Developmental Services to support job training in forestry and land management and green stormwater infrastructure. Two six-person crews perform essential management such as the removal of invasive vegetation, forestry and restoration. Austin's Civilian Conservation Corps employed 128 individuals the first year and in 2023 that number rose to 387 (City of Austin, 2024).

4.3 Harris county flood control district: engineer-led reconciliation

Houston lies in the relatively flat Northern Humid Gulf Coastal Prairies region of the Western Gulf Coastal Plain, which is characterized by a humid subtropical climate, grasslands, fluvial soils with low infiltration capacity, and meandering bayous (Juan et al., 2020). Prior to colonization, people of the Akokisa, Karankawa, and Atakapa harvested fish and shellfish from the bayous and used controlled burns to ensure a continuous supply of young prairie vegetation to attract bison (Worrall, 2021). A floodplain here would have had extensive bottomland hardwood forests and woody riparian vegetation, such as Eastern Cottonwood, Bald Cypress, and Black Willow along the bayous (Farge, 2018). Today, Houston's population of 2.3 million (United States Census Bureau, 2020b) sprawls across 640 square miles, with 56.2% of its land area located in the combined 1 and 0.2% flood risk zones (Figure 3). According to First Street Flood Lab (2024a), 62.6% of properties in Houston are at risk of flooding within the next 30 years. Climate change is causing the Houston-Harris County region to get warmer and wetter, with a 24% increase in the precipitation associated with the heaviest 1% of rain events between 1901 and 2016 (Greater Houston Community Foundation, 2025). Climate models predict that the return period for the 1% rain

event will increase significantly (Stoner and Hayhoe, 2020). Houston's risk of flooding is compounded by land subsidence and sea level rise. The rate of sea level rise (and simultaneous land subsidence) in some areas managed by the Harris County Flood District is among the highest in North America at roughly 1-inch per year, second only to Louisiana (Stoner and Hayhoe, 2020; Figure 3).

The Harris County Flood Control District oversees buyouts in the city and county with the aim to "return properties in the floodplain to natural and beneficial floodplain function, including storage of floodwaters" (HCFCD, 2024). The District takes an engineering approach to risk reduction and land use, working with federal agencies like USACE, FEMA, U. S. Geological Service, Department of Housing and Urban Development, and the Natural Resources Conservation Service that are responsible for infrastructure development, engineering, and hydraulic operations (HCFCD, 2024). None of these agencies are explicitly responsible for restoration. Risk reduction is prioritized both pre- and post-buyout. Structures at the highest risk (in floodways, 10% flood risk zone, or highest depth of flooding) are eligible for buyouts. The District has created large detention basins throughout the county that should have a substantial impact on reducing future risk. While we did not measure the increase in flood storage due to lack of consistent data across all cases, it is a significant floodplain service and an important measure of reconciliation.

In recent years, the District has shifted its approach from a singular focus on flood control infrastructure, such as channelization, concrete bank stabilization, and detention, to include additional public uses, such as walking and biking trails between stormwater basins that create a unique user experience. Because recreation is not part of their mandate, the HCFCD partners with other county precincts and the City of Houston to incorporate recreation (Wade, 2023). Its "Guidance for Maintenance of Buyout Lots" calls for changing the frequency of mowing depending on location, with most frequent (monthly) mowing happening only in dense urban areas (HCFCD, 2020). The District's Property Acquisition Services Manager James Wade (2023) described how the Facilities and Maintenance Department devises management strategies for each buyout parcel, which may include mowing, tree trimming and cleaning up dumped trash, and the Environmental Division works to decrease mowing required through water quality plantings in flood storage basins and tree plantings. HCFCD's community engagement is limited to addressing complaints, as engineers decide the best use for buyout parcels (Wade, 2023).

4.4 Charlotte-mecklenburg stormwater services: creek-centered restoration

Mecklenburg County is located in the Southern Outer Piedmont ecoregion, a dissected plateau of eroded and heavily metamorphosed rock, with irregular plains and mostly red clay soils (McNab and Avers, 1994). Floodplain forests in this region include oak-hickory flats, large river levee forests with American Elm and bottomland and swamp forests with abundant Willow Oak (North Carolina Wildlife Resources Commission, 2025). For 6,000 years pre-colonization, people of the Catawba Nation inhabited the area, eventually cultivating crops on the banks of the Catawba River and building settlements near floodplains (Catawba Nation, 2025). The county population was 1.1 million in 2020 and grew at a rate of over 1.2% between 2010 and 2020 (United States Census Bureau, 2020c). The climate is humid subtropical, and projections suggest a wetter climate with more intense precipitation events, hurricanes, and tropical storms in the future (Kunkel et al., 2020).

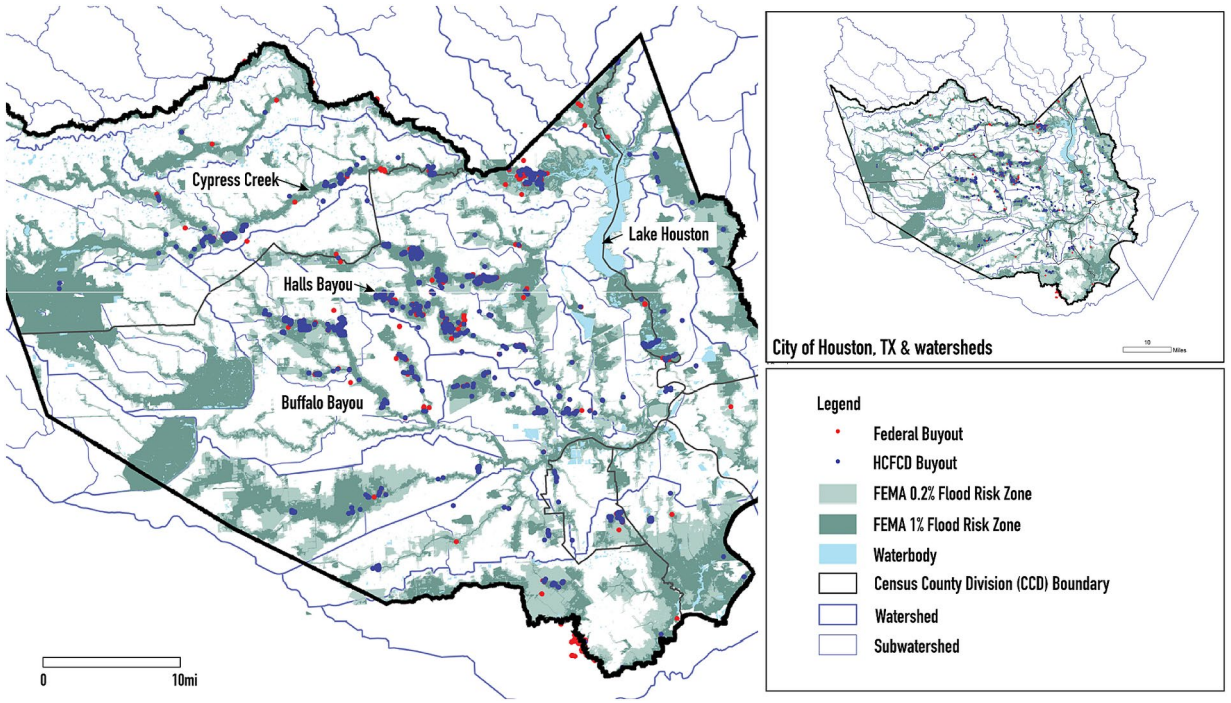


FIGURE 3
Map of Harris County's subwatersheds, waterways and flood risk zones.

There are 167,779 acres of wetland in the county, with 11% of land area in the regulatory floodplain and 10% of properties are at risk of flooding over the next 30 years (First Street Flood Lab, 2024b). While three major rivers flow through the county (Upper Catawba, Lower Catawba, Rocky River) (Figure 4) and the area is subject to tropical cyclones and extratropical systems, most of the floods are associated with thunderstorm systems and smaller creeks (Zhou et al., 2017). Major floods occurred in 1989 (Hurricane Hugo), 1995, and 1997 (Figure 4).

Charlotte-Mecklenburg Stormwater Services (CMSS), a regional utility, is responsible for overseeing land development, floodplain mapping, flood mitigation, floodplain development, and managing the county's buyout program. Its goals include the preservation and restoration of the natural and beneficial functions of a floodplain. It has built a coalition of watershed, recreation (e.g., Mecklenburg County Parks and Recreation), stewardship, and flood monitoring groups and uses collaboration and coordination to address issues that expand beyond silos and boundaries to the scales of watersheds and ecosystems (CMSS, 2021a). A Creek Coordination Committee involves any county or municipal department that "touches surface water" and meets quarterly to support clear communications. The focus of post-buyout land management in Charlotte-Mecklenburg is on greenways along creeks, where CMSS works with Mecklenburg County Parks and Recreation to incorporate buyouts into recreation planning. Greenway planning has involved discussions intersecting infrastructure, social benefits, recreation and water quality and connectivity. CMSS has restored miles of stream channels. Demonstrating the area's leadership in flood mitigation, the City of Charlotte is a Class 3 Community in the national Community Rating System for flood risk reduction, indicating its performance is among the top 1% of participating communities.

The success of CMSS is in part due to a hydrological model developed to localize and finetune risk maps that incorporates future risk based on land use and zoning. The flood risk zone is remapped every 3 years to stay current with land use changes and the GIS Department updates and shares data layers among departments regularly. Their Risk Assessment and Reduction Tool (RARR) prioritizes buyouts based on a flood risk property score, risk reduction recommendations, and mitigation priority scores (CMSS, 2021b). This tool is used to update parcel status annually and an annual implementation guide directs efforts toward buyouts and other measures (Spidalieri et al., 2022). The CMSS buyout program has a strong community engagement component. For instance, CMSS has frequently asked communities to prioritize uses for buyout sites in community charrette events. This has led CMSS to prioritize buyouts on parcels that connect to existing greenways, expand public open space, and preserve historic places.

4.5 Washington state floodplains by design: habitat-centered restoration

Steep environmental gradients make Washington State home to a wide array of distinct ecoregions: ranging from the temperate rainforests in lowlands of the Coast Range, to alpine zones of the Cascades, and dry sagebrush steppe of the Columbia Plateau. The rivers draining the Cascade and Olympic mountains of western Washington State flow within the vast Pacific Temperate Forest ecoregion, one of 238 ecoregions that (if properly conserved) would help preserve the most outstanding and representative habitats for biodiversity across the globe (Olson and Dinerstein, 2002). Floodplains in this region support

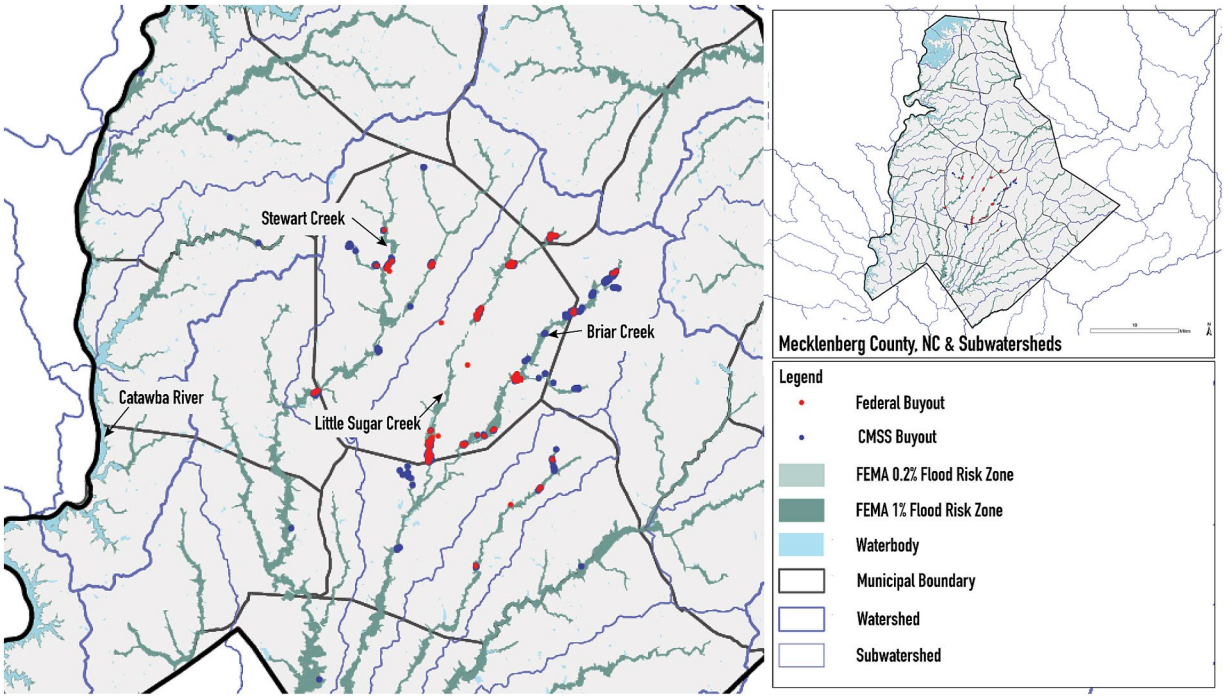


FIGURE 4
Map of Mecklenburg County's subwatersheds, waterways and flood risk zones.

some of the most productive coniferous forests in the United States, dominated by Douglas Fir (*Pseudotsuga menziesii*) (Quinn, 2010). Throughout this ecoregion, there is a reciprocal relationship between forested floodplains and river habitats for salmon: trees fall into the river and alter flows, creating aquatic habitats, while forests benefit from the many fish that make their way upstream to spawn and later die, increasing the nutrients available for trees (Schindler et al., 2003). Nine sovereign Tribes of the Coast Salish peoples have occupied the basin for thousands of years and continue to have a strong presence in the area (Angelbeck, 2024). The Puget Sound Regional Council works with Tribes to integrate indigenous land management knowledge into basin planning and continue sustainable practices such as "cultural burns" to manage forests (Puget Sound Regional Council, 2025).

Similarly, on the eastern side of the state, Tribes have a strong relationship with Pacific Salmon and are actively engaged in river and floodplain restoration throughout the Columbia River basin, which drains the entirety of Washington east of the Cascade Mountain crest. The population of the state was 8 million in 2024, with a growth rate of 1.1% (Washington State Office of Financial Management, 2024). Like other case study locations, floods are predicted to increase in magnitude with climate change; a 12% increase in the frequency of the top 1% of rainfall events in the Northwest U. S., and the shift northward of so-called atmospheric rivers, will accompany more frequent droughts and forest fires (Adelsman and Ekrem, 2012). The five most flood-prone counties in the state – Skagit, Snohomish, King, Pierce, and Lewis – run along the eastern side of Puget Sound (Figure 5). Of the combined total of 1,372,156 properties in these counties, 13.4% are at risk of flooding in the next 30 years (First Street Flood Lab, 2024c; Figure 5).

Floodplains by Design (FbD) is a public-private partnership led by the State Department of Ecology (current and past founders and funders include The Nature Conservancy, Puget Sound Partnership, U. S. Environmental Protection Agency, USGS, National Oceanographic and Atmospheric Administration, and Bonneville Environmental Foundation) and allies with Tribes, farmers, and local governments. It aims to improve flood protection, conserve and restore salmon habitat, preserve farmland, improve water quality and enhance outdoor recreation by re-establishing floodplain functions in Washington's major river corridors. Established in 2013, FbD is not a buyout program but an effort to integrate and accelerate restoration and flood risk reduction efforts statewide using diverse strategies, including buyouts. FbD is a competitive grant program providing local governments and Tribes with capital funds for large-scale flood mitigation and habitat restoration projects. It promotes the concept of integrated floodplain management, "a holistic and collaborative approach to decision making that brings together multiple interests to find common agreement on local floodplain visions, strategies, and actions that achieve multiple benefits" (The Nature Conservancy, 2016). Given the program's goals, restoration that combines risk reduction with ecological goals is built into projects to protect bay habitats that support salmon and orca.

FbD's approach to integrated floodplain management and buyout restoration are community-driven and at scale. FbD Grant Manager Scott McKinley described the shift away from piecemeal federal funding to state funding and large-scale, integrated projects: "Floodplains by Design said we've got to go big from the start and do it all at once, otherwise you get half-baked projects, or what we call 'postage stamp' restoration projects (Gibson and Kearfott, 2020). At the same time, it has had to work to reach and serve the diversity of communities across the state. For instance, while most of the parcels we examined were undeveloped lands in more rural areas, some of FbD's more recent allocations benefit large cities and urbanized

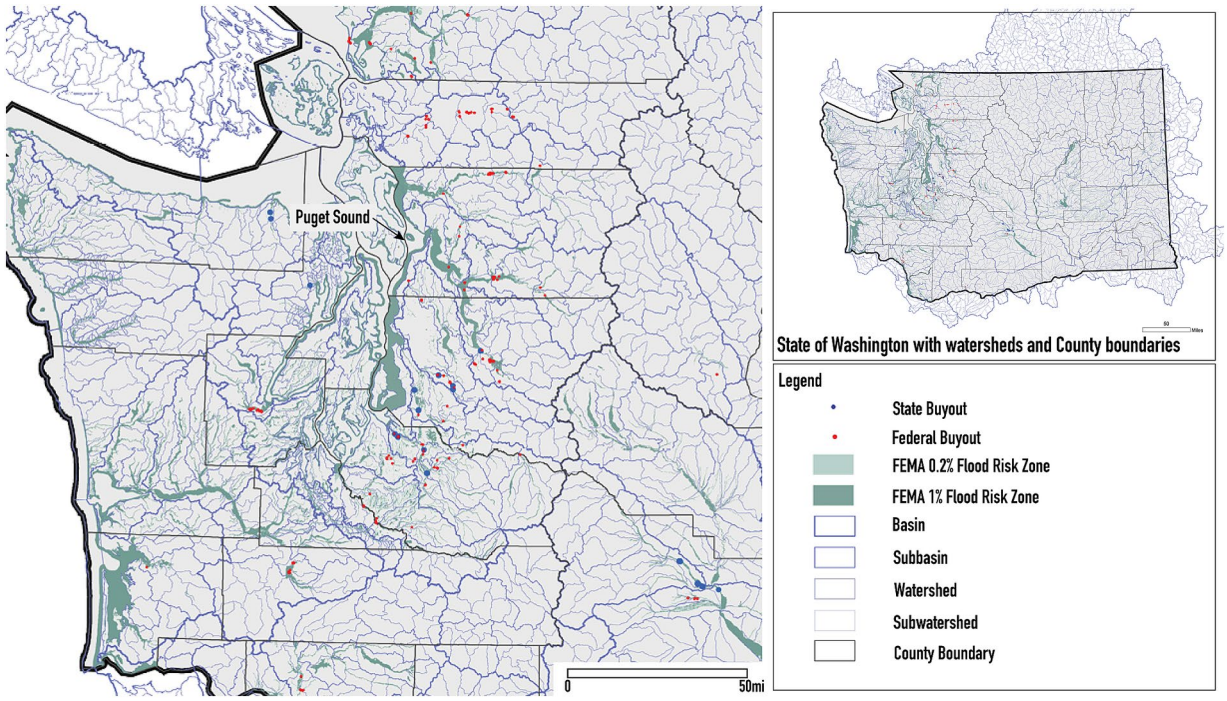


FIGURE 5
Map of Washington State's watersheds, waterways and flood risk zones.

TABLE 3 Results of assessment framework applied to buyout parcels across the four case study programs.

		Austin WPD	HCFCD	CMSS	WA FbD
Total Buyout Parcels (#)		1,046	1,543	389	438
Total Buyout area (in acres)		261.5	425.6	176.4	1947.8
Indicator					
Removes building from flood risk zone	Parcels	1,041 (99.5%)	1,216 (78.8%)	354 (90.8%)	315 (71.9%)
	Acres	260.35 (99.6%)	334.07 (78.5%)	159.95 (90.7%)	1734.26 (89%)
Provides amenities for people	Parcels	570 (55%)	292 (18.9%)	174 (45%)	216 (49.3%)
	Acres	128.46 (49%)	97.70 (23%)	80.52 (46%)	1083.03 (55.6%)
Parcel is covered by management plan	Parcels	953 (91.1%)	513 (33.2%)	67 (17.2%)	277 (63.2%)
	Acres	229.72 (87.8%)	122.97 (28.9%)	37.95 (21.5%)	1202.4 (61.7%)
Zoning reflects conservation status	Parcels	1,046 (100%)	60 (3.9%)	204 (52.4%)	55 (12.6%)
	Acres	261.51 (100%)	35.27 (8.3%)	79.11 (44.8%)	83.7 (4.3%)
Hydrologically connected	Parcels	1,041 (99.5%)	1,536 (99.5%)	389 (100%)	378 (86.3%)
	Acres	260.35 (99.6%)	421.0 (98.9%)	176.42 (100%)	1216.31 (62.4%)
Contributes to riparian buffer (100 ft)	Parcels	194 (18.5%)	65 (4.2%)	319 (82%)	112 (25.6%)
	Acres	78.36 (30.2%)	32.81 (7.7%)	154.20 (87.4%)	928.23 (47.7%)
Contributes to a riparian buffer (350 ft width)	Parcels	425 (41%)	715 (46%)	387 (99%)	208 (47%)
	Acres	137.30 (52.5%)	223.02 (52.4%)	175.84 (99.7%)	1483.32 (76.2%)
Parcels contribute to contiguity with other buyouts (within 1,000 ft)	Parcels	1,044 (99.8%)	1,479 (95.9%)	381 (97.9%)	398 (90.9%)
	Acres	234.47 (89.7%)	395.67 (93%)	169.12 (95.9%)	1689.69 (86.7%)
Parcels contribute to contiguity with conserved lands (within 1,000 ft)	Parcels	1,046 (100%)	78 (5.1%)	336 (86.4%)	115 (26.3%)
	Acres	261.51 (100%)	39.85 (9.4%)	147.52 (83.6%)	301.36 (15.5%)
Land cover is dynamic	Parcels	67 (6.5%)	66 (4.3%)	62 (15.9%)	137 (31.3%)
	Acres	46.04 (17.6%)	27.93 (6.6%)	47.20 (26.8%)	1005.19 (51.6%)

counties, as well as Tribes, rural areas, and small towns (FbD, 2024). It has also sought to delegate more autonomy to funding recipients to mitigate top-down programmatic demands that do not meet local needs.

4.6 Setting long-term goals influences land management outcomes

This study makes clear the importance of ongoing management for what happens to the land after a buyout and for establishing clear long-term goals, no matter where programs lie in the reconciliation-restoration spectrum. Floodplains by Design sets the firmest goals for ecological outcomes (restoring salmon and orca habitat) and its programmatic funding structure and monitoring and evaluation is designed to support the achievement of these goals. Buyout programs serving more urban areas like Austin and Charlotte tend to set different goals that blend ecological and recreational aspirations. The more clearly defined the goals, the more likely programs can organize the partnerships, funding, and engagement processes necessary to achieve them. We found that it is often through land management and related community conversations that clearer visions for floodplain lands are continuously negotiated.

These results demonstrate that, despite their differences, each program is making progress toward its stated goals. Table 3 provides the results of the application of our assessment framework to each programs' buyout lands. For example, Austin, which we characterize as "community-led reconciliation," aims to reduce flooding, erosion, and water pollution, maximize public use, and preserve natural character. Our analysis shows that Austin does indeed achieve high scores in providing amenities for people (49% of buyout land area) and riparian buffer building (52.5% of buyout land is within 350 feet of a waterway). "Preserving natural character" suggests that visual quality and esthetics are highly valued, and this is reflected in Austin's deferral to community preferences for buyout treatments. HCFCD, which focuses on "engineering-led reconciliation," does not have clear restoration goals but their mandate to reduce risk is reflected in high scores for removing buildings from risk zones (78.5% buyout land area,[6] including 29% of buyout parcels located in the highest risk floodway zones) although conservation zoning to protect from future development in risk areas only represents 8.3%of buyout land area. Charlotte-Mecklenburg, which focuses on "creek-centered restoration," scores well on providing amenities (46%) and parcel contiguity (96%), reflecting their goals to make floodplains community assets. A second goal to restore floodplain function can be measured by their success in restoring riparian buffers (almost 100%), which in turn creates contiguous space for greenways along creeks. Since habitat and floodplain restoration is the foundation for Washington's FbD, it scores

6 Based on FEMA Flood Insurance Rate Maps (FIRMs).

TABLE 4 Land cover analysis results.

	WA FbD	HCFCD	Austin WPD	CMSS	Cases combined acres per land cover type	Cases combined % land cover type	Cases combined – WA FbD % land cover
Land cover	Buyout land area (in acres)						
Lawn	110	111.8	2.7	15.9	240.4	9%	17%
Lawn with trees	74.1	83.5	4.45	88.3	250.4	10%	24%
Lawn with large trees	12.3	122.3	170.8	1.5	306.4	12%	39%
Meadow/Grassland	499.7	2.9	0	4	506.6	20%	1%
Meadow with trees	36.6	0	44.6	0	81.2	3%	6%
Early successional forest	362.3	7.4	15.2	12.9	397.8	15%	5%
Successional forest	680.8	5.9	15.6	3.2	705.5	27%	3%
Forest	32.6	7.3	1.7	12.9	54.5	2%	3%
Community garden	12.1	0.6	1.2	2.9	16.8	1%	1%
Constructed wetland	0	0	0	8.8	8.8	<1%	1%
Total acres	1820.5	341.7	256.2	150.3	2568.8	100%	100%

See a graphic representation of the land cover analysis in Figure 6. Parcels that still had homes were excluded from this study.

highly on restoration indicators, including hydrological connectivity (62.4%), riparian buffers (76.2%), parcel contiguity (86.7%), and has by far the most acreage with dynamic land cover (51.6%).

4.7 Restoration is limited, but gaining importance

Despite progress on programmatic goals, few programs are making significant progress on restoration. Table 4 shows the results from our land cover evaluation. While our findings echo Zavar and Hagelman's (2016) study, we find substantially more restored land cover than they did. Their study found that only 0.6% of buyout land was restored to native vegetation, while our programs (excepting Washington's FbD) had 19% of buyout land[7] in planted and volunteer vegetation including meadows, constructed wetlands and forests.[8] Native vegetation is found in seeded meadows in Austin and Washington, and constructed wetlands in Charlotte-Mecklenberg. By contrast, Floodplains by Design has 88.5% of buyout land undergoing restoration. Excluding sites in Washington, lawn or lawn with trees were by far the dominant cover types (80% buyout land area). This "naturalization" is often conflated with demolition of the house and removal of impervious surface, but this does not equate to improving the ecological condition to one that reflects a floodplain's shifting habitat mosaic, local biodiversity, land cover dynamism, and vertical layers of habitat, including understory, shrub, and canopy. Figure 6 illustrates the degree of patchiness (land cover diversity) and relative dominance of land cover types per case.

Nevertheless, site conditions at the time of our analysis reflect both the evolving priorities of management as well as inherent contradictions between stated goals and approaches. All land managers we spoke to were well aware of the need and benefits of reducing mowing frequency and have taken steps to do so. For instance, Austin's program increasingly advocates for best management practices, such as wildflower meadows, native grasses, and grow zones. As yet, however, 69% of its buyout sites that we studied are lawns with trees. Charlotte-Mecklenburg County strives to conduct an annual review of 5–10% of all the remaining unrestored buyout parcels to consider higher-value interim uses until longer-term plans are developed (Trautman, 2023). In Harris County, less than 14% of buyouts located within 100 feet of waterways and 4% of parcels within 350 feet are forest or successional forest, though their own "Guidance for Maintenance of Buyout Lots" (HCFCD, 2020) calls for "return to nature" areas along bayous and tributaries. While HCFCD does have tree farms and planting programs, a lack of reforested parcels along bayous may be in part due to guidelines limiting woody vegetation on levees and the banks of engineered channels (USACE, 2014). Finally, although Washington's FbD is going a long way to restore floodplains, whether these lands will be actively managed to ensure long-term success is a significant question. The program's Director Kaz Guillozet called management "ulcer festering," because plans for long-term management are not required in funding applications and FbD staff are left to hope that municipalities have the capacity to do it (Guillozet, 2023; Figure 7).

4.8 Community and multi-stakeholder involvement and responsiveness deepen both ecological and social repair

Compared to their restoration efforts, programs paid far greater attention to community needs. Around half of buyout parcels in Austin (55% of all parcels), Washington (49%), and

7 Percentage is calculated using total acreage included in land cover analysis and excludes lands where the house has yet to be demolished.

8 If ecological succession is the primary mechanism of reforestation, then the tree species present are likely a mix of native, non-native, and potentially invasive species.

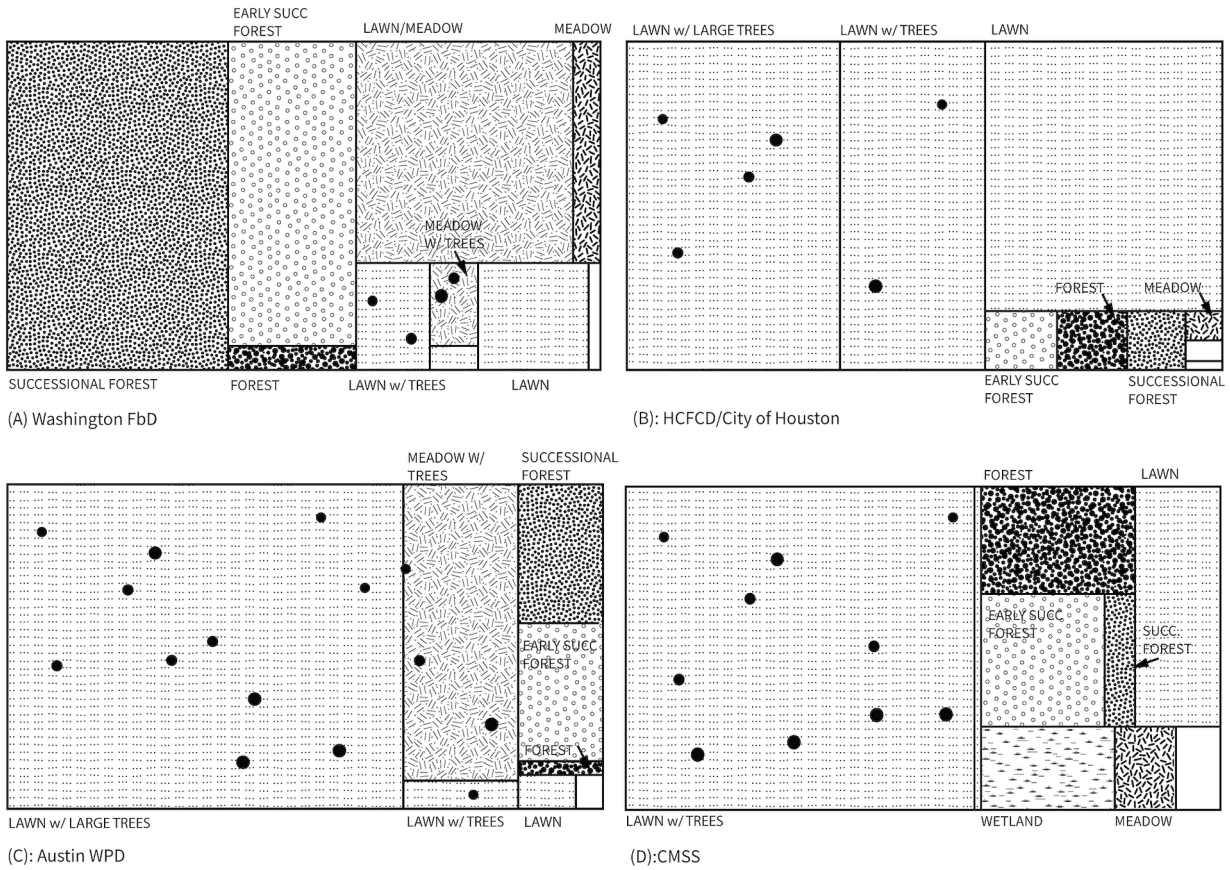


FIGURE 6
Land cover mosaics for each case study locations' buyout land area. Diagrams illustrate the degree of patchiness and relative dominance of each land cover type. Note that Washington's Floodplains by Design buyouts land area **(A)** is distributed more evenly across all land cover types, indicating higher land cover diversity (and more evenness) compared to Houston HCFCD buyout land **(B)**, which is dominated by lawn land cover types.

Charlotte-Mecklenburg (45%) provide public amenities, from community gardens, to trails, to fishing rights (Figure 7). Many buyout sites have an associated project-level management plan to direct ongoing maintenance for these amenities (e.g., for 88% of Austin sites, 62% of Washington sites). Recognizing that managing and restoring buyouts for public use is not within their purview, HCFCD has partnered with county precincts, the city, and the Houston Parks Board to manage a portion of buyout land and provide amenities. These actions, along with the construction of infrastructure, such as large detention basins to increase flood storage, are indicative of a reconciliation approach.

Over time, programs have developed thoughtful and patient engagement practices to help each community evaluate reconciliation and restoration options and overcome tensions and conflicts. Esthetic preferences for lawns conflict with messier habitats like successional floodplain forests or wetlands. In Austin, for instance, managers dream of restoring buyout sites to native grasslands where buffalo could one day roam, and feel constrained by the environmental preferences among remaining residents (McKinley, 2022). At the same time, they recognize that people's mistrust reflects the multi-decadal disinvestment that some communities have suffered. Rewilding is a laudable restoration goal, but "wild" nature in lower-income communities may contribute to the perception of dereliction and decreased property values, further damaging wealth accumulation. Responding to resident concerns is therefore key to building trust and assembling the collaborations needed for more transformative projects. Volunteer days and the Civilian Conservation Corps actively engage residents in planting and management, positioning residents to better understand the intentions behind and value of restored lands while supporting their collective role as land stewards.

At an organizational level, each program achieves their goals by establishing strong partnerships with other implementation and funding partners. These partnerships present additional institutional learning opportunities, and have expanded the programs' approaches to land management over time, resulting in their support for a wider array of ecological, social, and economic strategies, and more holistic and integrated approaches to buyout uses. As Shi et al. (2022) noted in their review, these buyout programs are standing programs, while most buyout programs are temporarily created in the aftermath of a disaster. Over time, these standing programs have built a network of partnerships with private partners and landowners, conservation organizations, federal and state agencies, and municipal and county governments that facilitate the flow of information and maps. Partnerships provide programs with more staff capacity to leverage resources, which in turn broaden the range of actions they can fund and expand buyout programs' influence. Through their partnerships, FbD has been able to change the state's policy and regulatory

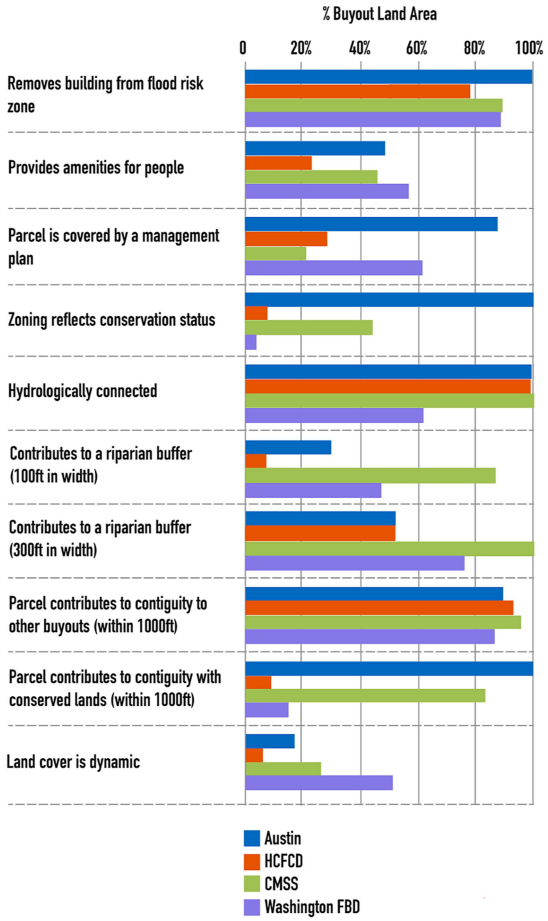


FIGURE 7
Results of indicators applied across the four case study program buyouts. Bars measure % buyout area (in acres) scoring '1' for each indicator compared to overall buyout area (in acres).

framework to streamline funding for restoration and achieve state and regional goals for habitat restoration via locally-driven projects.

4.9 Buyouts are an emergent space requiring collective conversation

At the same time, our research shows that most buyout sites are in a state of waiting. Based on our analysis, we found five common management strategies (see Figure 8), with some parcels fitting into multiple categories. There are indeed (1) *lots restored*, where parcels have been reforested or wetlands restored. Sometimes, these are not active restorations, but (2) *lots "let go,"* where nature does most of the work because maintenance has ceased or is reduced significantly to operations such as invasive species management and trash removal. These lots can change over time via ecological succession and flood disturbance. Conversely, there are (3) *lots stuck in maintenance*, where mowing must be continued regularly and indefinitely due to neighbor preferences or neighborhood restrictions. There are (4) *lots reconciled*, where green infrastructure such as shallow flood retention basins have been constructed or amenities such as parks, community gardens, trails, and greenways increase the functional capacity of former buyout parcels to provide services, such as flood water storage and recreation.

But, interviews revealed a surprise: with the exception of Washington's FbD, most buyouts are (5) *lots in-waiting* for their final purpose or "target state" to be determined. Sometimes, a plan is in place but properties, funding, and partnerships have not been fully assembled. Other times, a plan has not yet been created and the site is indefinitely in limbo. Interviewees cited numerous barriers as the cause of this limbo status: lack of funding for restoration, grants that restrict what money can be spent on, and limited staff capacity. Practically speaking, programs are reluctant to invest in more permanent restoration actions, such as tree planting, until it is known whether lots will become part of greenways, detention basins, or constructed wetlands. Hence, mowing and other impermanent measures are common because they are an effective control for invasive species and an important "cue to care" for residents living nearby. Unfortunately, mowing is also expensive, suppresses floodplain vegetal regrowth, forest succession, and other "free" restorative processes associated with many of the potential community benefits of floodplains.

5 Discussion: making progress toward restoration and reconciliation

In summary, we find that long-standing programs for floodplain home buyouts have taken important steps to steward these lands. They have embraced a range of approaches, from those that are more community versus more expert and engineer centered, those that focus on waterways to those that center habitat more holistically, and those that are oriented more toward restoration or toward reconciliation. By establishing clear goals and management plans, these programs have been able to implement policies and projects that advance social and ecological goals, monitor and assess progress, and seek out necessary partnerships to advance their goals. Restoration is still very much a work in progress, with limited on-the-ground ecological evidence to show active changes toward fully functioning floodplains. Program managers are interested in advancing greater restoration, but also face limitations in mandates, resources, and community support.

In relation to the literature, we find that deep community engagement elevated *both* ecological and social outcomes. While the reconciliation-restoration debate often pits social against ecological goals, this study suggests that they are mutually reinforcing. In Charlotte-Mecklenburg, CMSS surveyed residents and held charettes to understand their preferences. Community feedback directly informed CMSS's prioritization to use buyouts to expand continuous greenways. Meanwhile, CMSS realized that greenways were increasing surrounding land values and threatening to escalate gentrification, causing them to return to communities to seek advice. Their reflectivity is more likely to engender community trust for future greenway projects. In Austin, WPD uses multiple educational tools like signage, maps, public art and an informative online presence, and also adopts federal standards for urban relocation assistance that helps people find replacement housing, thereby reducing buyout patchiness. They also work closely with community members using tools such as neighborhood planning meetings and surveys to identify desired uses and assess



FIGURE 8
Examples of buyouts within each category of management. Representatives from each buyout program shared examples of buyouts falling into each management category. Each buyout parcel has a unique history, story following acquisition, and reasons why it is managed the way it is, such as plans in process, neighbor and community input, HOA maintenance requirements, and restoration projects.

public concerns. This has led them to prioritize mowed buffer strips at the edge of wildflower meadows as "cues to care" (Gibson, 2023). In Washington, FbD's integrated restoration goals are deeply intertwined with social outcomes – salmon is crucial to Indigenous peoples of the Northwest and a pillar of the state's economy. Prioritizing ecological goals is the result of decades of contestation over dam removal, agriculture, and Indigenous rights. Conversely, the absence of deep community engagement is associated with some of the lowest restoration and reconciliation outcomes. In Houston, HCFCD's communication with residents is usually limited to addressing community complaints (Wade, 2023). It has the lowest proportion of buyout parcels with amenities (23%) as

well as the lowest proportion of sites under conservation status (8%) or with dynamic land cover (7%).

Conceptually speaking, these practices show how the reconciliation-restoration spectrum is fundamentally socially determined and that a virtuous ecological system requires attending to residents' needs and aspirations (Shi et al., 2023). The process of how programs decide parcels' permanent use both reflects existing social relationships and informs the long-term health of these sites and their relationship to people. The experiences of these programs highlight the importance of listening to communities first, building a relationship with them, and coming back to listen and revise repeatedly. Austin, for example, is addressing residents' concerns about vacant lots first, and waits about a year for community members to adjust to buyout sites' conditions before making efforts to engage in visioning processes. These practices also reflect a process of community and organizational learning and evolution to rethink what it means to "undevelop" land and remove it from capital productivity. It is also taking time for conservation organizations (including land trusts) that mostly prioritize conserving intact, rural lands to look at buyout sites as opportunities for urban ecological repair (Kodis et al., 2021). Deciding what should be done with the land takes time to understand, define, organize, and implement. In these cases it is only possible because these are standing programs, with the ability to reflect, evolve, and sustain relationships.

This study does face important limitations. The assessment framework we provide here is meant to start a conversation about how and what to evaluate as a measure of repair, specifically on floodplain sites. Indicators chosen were constrained by the use of remote data (satellite imagery and GIS data), the availability of information across all case locations, and the level of detail recorded in available datasets. Because we did not have the capacity to do fieldwork beyond ground truthing, we could not include indicators requiring substantial parcel-level fieldwork, such as increased flood water storage, percent land cover of invasive species, and vertical structure of vegetation, important measures of floodplain function and the quality of habitats. A future study could look at these factors across a sample of buyout sites in each of the categories listed in Figure 8.

6 Conclusion

As Opperman and colleagues note (p. 1), "Floodplains also present some of the best opportunities throughout the world for innovative management that reconciles human uses and environmental conservation." While much research has focused on the lengthiness of buyout processes (on average, 5 years), this research illustrates the indefinite, open-ended nature of long-term care required for buyout sites. Their long-term management is not a transaction, like a buyout, but an ongoing negotiation reflecting education, engagement, visioning, funding, staff training, and community priorities. Buyout sites provide urban spaces for experimentation and innovation that reimagine the distinctions between conservation and development, reconciliation and restoration. Rather than manicuring urban green space for recreational uses while leaving wildlands to the fringes, cities can use buyout sites to pilot small spaces for citizen science, children's education, nurseries, silviculture, rewilding, or other ways of living with nature representing the country's diverse knowledge traditions. Buyout parcels can contribute to a mosaic of dynamic habitats, greenways, trails, gardens, and more. The "in waiting" status of most buyout sites reveals that most communities have yet to decide the long-term futures of this growing category of lands. This is an exciting moment where more intentional and adaptive management, including thinking holistically (across the wider floodplain) about how buyout lands can be coordinated, along with active stewardship, can challenge esthetic preferences and cultural norms and rework human-nature relations in real-time. This process can not only enhance ecological resilience but also allow for emergent, community-driven visions for the future.

State and federal governments can support these efforts by encouraging or requiring localities to set long-term management goals and funding reparative projects, monitoring, and evaluation. Above, we highlight the importance and benefits of setting clear goals and processes of engagement. Our study also reveals the challenges of trying to create ecological and social benchmarks and criteria, especially without extensive fieldwork. More research and experimentation is needed to help establish shared indicators and assess the social, environmental, and fiscal impacts of different management policies (such as ceasing to mow). FEMA can also streamline funding across conservation programs and buyout sites, so that local buyout programs can more easily access funding for repairing buyout sites.

The question of "what to do with the land" can be a healing, generative, and positive one if it is well designed and engages communities as partners in the process. Far from arguing that reconciliation or restoration is better, this study shows that both are possible together and that these strategies can mutually reinforce one another. Different goals result in diverse management and maintenance needs, costs, land cover, impacts on surrounding property value, and the wellbeing of people who have relocated or who remain. Taking a more integrated and holistic approach to prioritization means more "just buyouts" (Freudenberg et al., 2016; Brody and Highfield, 2013), where ecological goals like habitat restoration are considered alongside flood risk reduction and flood mitigation, equity and social justice, positive impacts on households and communities (Binder and Greer, 2016) at block, neighborhood, and community scales. Deepening and expanding this kind of community engagement helps avoid the trap of "pop-up and leave" restoration (Grenz and Armstrong, 2023) and places community members in the role of co-creator. In this way, buyout lands can work in service of neighbors, non-human and human, rivers, forests and wetlands, and our own health and wellbeing through an ethic of care and repair (Samuelson et al., 2023).

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

JV: Conceptualization, Data curation, Investigation, Methodology, Supervision, Visualization, Writing – original draft, Writing – review & editing. LS: Conceptualization, Funding acquisition, Project administration, Supervision, Writing – original draft, Writing – review & editing. CH: Conceptualization, Project administration, Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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The authors declare that no Gen AI was used in the creation of this manuscript.

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Retreat in real time—Nantucket's balancing act along a changing coast

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Nantucket, an island about 30 miles off the coast of Massachusetts, has long embraced retreat in response to coastal hazards. This community case study examines how Nantucket is enhancing its resilience by adapting to increasing coastal storms, erosion, and sea level rise through strategic retreat and relocation. Nantucketers have historically moved structures such as lighthouses and homes away from the coastline, but the increasing frequency and intensity of storms demand more comprehensive and adaptable solutions. Through resilience planning and policy efforts, the Town of Nantucket is addressing these challenges by balancing short- and long-term objectives, public and private interests, and equity considerations. Lessons learned from Nantucket's experiences are applicable to other communities facing similar coastal risks, highlighting the importance of strategic planning, community support, and capacity building for effective retreat and relocation.

KEYWORDS

retreat, Nantucket, resilience, climate change, coastal hazards

Introduction

Nantucket is no stranger to the concept of retreat. Since the island was settled, Nantucketers have been grappling with coastal hazards which, in many ways, are an accepted part of island life. Formed after the retreat of the Laurentide ice sheet, most of the island is composed of glacial outwash materials, including sand and gravel, which are especially prone to erosion (USGS, n.d.). Over time, Nantucketers have adapted to coastal hazards by moving lighthouses, homes, roads, utilities, and other structures away from the coastline in both managed (i.e., planned) and emergency situations. However, with climate change, coastal storms are increasing in frequency and intensity and erosion of the island's bluffs, dunes, and beaches is becoming more rapid with sea level rise, bringing storm surge impacts to Nantucketers' front doors and threatening their homes, infrastructure, and natural resources.

This community case study explores how, in the context of broader resilience planning and policy, the Town of Nantucket (the Town) is navigating the complexities of managed retreat. Different coastal hazards dominate across the island, necessitating a variable approach to planning for retreat and relocation. Along Nantucket's Baxter Road, atop the Siasconset ('Sconset) bluffs, retreat is unfolding in real time. Over time, the area on top of the bluffs has been developed and now faces an uncertain future. While the debate over the best long-term plan for erosion along Baxter Road continues, the Town is balancing varied and competing interests including near- and long-term objectives, public and private priorities, and considerations including equity and evolving science. In the historic Downtown, nuisance flooding is a regular reminder of the vulnerability of Nantucket's economic core, prompting near- and long-term planning efforts and challenging conversations about the balance between preservation and adaptation. Meanwhile, on the south shore, erosion imminently threatens

the island's wastewater treatment facility, triggering emergency responses while a long-term approach is developed. Though the relatively high ground found mid-island may, in some ways, be ideal for relocation, the island's history of conservation and fraught relationship with densification pose challenges.

To build a resilient future that embodies Nantucket's unique history and built heritage, supports healthy coastal and ecological resources, and bolsters thriving communities, a comprehensive, adaptable, and community-supported approach is necessary. Beginning with the 2019 update of their local hazard mitigation plan, 2021 release of the Town's first *Coastal Resilience Plan* (CRP), and with half of the CRP's recommendations complete or underway as of July 2024, the Town has laid the groundwork for upcoming strategic retreat and relocation planning efforts. Lessons learned so far on Nantucket are widely applicable to other communities as they build the policy and funding pathways, capacity, and community support required of coastal retreat.

Island context

More recently known as a vacation spot for the wealthy and elite, Nantucket's focus on tourism is a relatively new chapter in its rich history. Home to indigenous peoples for thousands of years, the island was more recently home to the Wampanoag. After the island was settled by the English in 1659, the settlers turned to whaling, learning from and utilizing the labor of the Wampanoag who had long harvested stranded whales as a valuable source of fat and meat (Harrison, n.d.). From the 1690s until the 1850s, whaling was the primary business on Nantucket, enabling the growth of industry, accumulation of wealth and expansion of the island's population. In the mid-1800s, a variety of factors led to the whaling industry's decline, notably including the formation of sand bars near the entrance to Nantucket Harbor which made passage difficult for the larger vessels necessary for offshore whaling following the collapse of nearshore populations (Stackpole and Harrison, n.d.).

For nearly 50 years after the decline of the whaling industry, the island experienced significant population decline, leaving Colonial-era residences and other structures neglected. In 1894, the Nantucket Historical Association was founded and began leading efforts to preserve the island's historic structures, establishing the foundation of the island's ongoing legacy of historic preservation. In 1955, Nantucket established a local historic district which was ultimately expanded to cover Nantucket County including Nantucket, Muskeget and Tuckernuck islands. In 1966, the local historic district was designated a National Historic Landmark.

Though tourism initially helped support the island's recovery after the fall of the whaling industry, preservation efforts in the mid-20th century supported further growth of the industry as visitors were attracted to the island's natural beauty and historic charm. Today, tourism dominates Nantucket's seasonal identity with nearly two-thirds of housing units in the County considered "for seasonal, recreational, or occasional use" (US Census Bureau, 2020a).

Though Nantucket's year-round population is only 14,255 (US Census Bureau, 2020b) the population can swell to over 80,000 during the summer season (Town of Nantucket, n.d.). The racial composition of Nantucket County is analogous to the state of Massachusetts, though the Asian population is smaller (2% on Nantucket vs. 7% in Massachusetts) and a larger share of Nantucketers identify as two or more races or another race (US Census Bureau, 2020b). The median household income for Nantucket County is higher ($135,590 on Nantucket vs. $99,858 in Massachusetts), and the cost of living on island is also higher. Though only 1.1% of Nantucket's households are classified as limited-English speaking, rates may be much higher during the summer months with the influx of seasonal workers. Nantucket also has higher rates of educational attainment of bachelor's degrees or higher, higher rates of employment, and lower rates of poverty than Massachusetts (US Census Bureau, 2022).

Though census data offer one lens for understanding the composition of the Nantucket community, it fails to capture the many nuances of year-round Nantucketer's lived experiences. While Nantucketers face many of the same challenges as communities across the country, including high housing costs and food insecurity, Nantucket's unique island context exacerbates some of these challenges and introduces others.

With the five-year average median sale price of single-family homes coming in at $2.75 million (Allen, 2023), high housing costs are a consistent challenge for Nantucketers. When considering the high cost of housing, it is notable that on Nantucket there are nearly three times as many homes as there are year-round households. Though supply outpaces year-round demand, housing demand overall is largely divorced from the island's year-round population due to the substantial demand for vacation homes (University of Massachusetts Amherst Donahue Institute of Economic Public Policy and Research, 2023). Housing prices are subsequently divorced from local salaries, with teachers, police officers, and firefighters earning $70,000–$100,000 annually. Fifteen percent of the fire department lives off-island due to the lack of affordable housing (Lindner, 2023), exposing another layer of the island's vulnerability and highlighting the challenge of being located 30 miles off the mainland. During the summer season, the issue is further exacerbated with a significant portion of seasonal employees and labor force necessary to support the tourism industry living off-island, commuting approximately 2 h each day via ferry from Hyannis, a port town on Cape Cod. High housing costs also help drive widespread food insecurity. Nationally, one in eight households faces food insecurity. For year-round households on Nantucket, this number is one in three (Lindner, 2024).

Nantucket, named by the Wampanoag tribe, translates to "the faraway land." 30 miles from the southern coast of Cape Cod, the many cascading risks associated with isolation are a major challenge for Nantucketers, especially within the context of emergency preparedness and response. The island is only reachable by boat or aircraft, with most vehicles, individuals and freight, including essential supplies like food and fuel, arriving via ferry from the mainland. At best, travel from the mainland via ferry takes about 1 h. In the event an emergency on island surpasses the capacity of emergency responders present, there is no immediate lifeline or additional capacity available. Travel time forces the island to be largely self-reliant in emergency situations. When severe weather shuts down operation of the ferries and aircraft, the island is essentially cut-off from the mainland, except for limited emergency services offered by the U.S. Coast Guard and other first responders. Due to the size of the year-round population and the ballooning of the population during the largely concurrent tourism and hurricane seasons, evacuation off the island is not practical or feasible (Town of Nantucket, 2019a).

History of retreat

Since the early days of Nantucket's inhabitance, the natural environment and coastal hazards have been a consideration in where and how the built environment is established. Traditional indigenous homes on the island were often built into the landscape with reinforcements that offered protection against strong coastal winds (Nantucket Historical Association, n.d.). Sherburne, Nantucket's original settlement, was once located west of the current Downtown along the north shore near what is now Capaum Pond. By 1730, the Capaum Harbor entrance closed due to longshore drift, spurring the relocation of Downtown to its current location.

More recently, several structures on the island have been relocated in response to coastal hazards (Figure 1). Notably, in 2007 the Sankaty Head Lighthouse was moved over 400 feet away from the shoreline after decades of storms and erosion claimed hundreds of feet of the bluff. Though the lighthouse's relocation was planned, most of the island's previous retreats have been unmanaged and reactionary. For example, portions of roadways including Madaket Road and Sheep Pond Road have been retreated following erosion-induced breaches. Though not well-documented, numerous residences, predominantly along the south shore, have also been relocated. Anecdotally, residential relocations have increased over time as erosion rates rise.

Currently, the Town is exploring questions related to proactive, managed retreat and relocation in three diverse contexts across the island: bluff erosion threatening a roadway and homes along Baxter Road, nuisance flooding threatening the historic Downtown neighborhood, and erosion threatening a critical facility along the south shore (Figure 1). Since 2019, hazard mitigation and resilience planning efforts undertaken by the Town have laid the foundation for productive community conversations around retreat and relocation.

Laying the foundation for retreat and relocation

With approximately 88 miles of shoreline, coastal hazards like flooding, erosion and high winds are, in many ways, an accepted part of island life on Nantucket. While this mindset has influenced how Nantucketers approach emergency preparedness, hazard mitigation, and long-term resilience, recent storms and a growing awareness of climate change impacts have resulted in the increasing recognition that the solutions of the past may not be adequate in the future. The planning efforts described herein are building awareness and capacity within the Town, and the community more broadly, to support conversations about the impacts of coastal hazards on Nantucket and the mounting need for strategic planning around retreat and relocation.

Before 2019, limited efforts explicitly addressed coastal hazards on Nantucket. In 2014, the Town released a *Coastal Management Plan* to establish priorities and procedures for protecting and managing Town-owned infrastructure and public access points (Town of Nantucket, 2014). In early 2018, Nantucket experienced two major nor'easters and a blizzard. At the time, five of the top 10 flood elevations ever observed on Nantucket were measured in the first 3 months of 2018 (Town of Nantucket, 2019b). Around this time, the Town was in the process of updating their local hazard mitigation plan, as required by 44 CFR 201.6, and recent flood experiences



FIGURE 1
Locations of select historic and anticipated Town-led retreat efforts [Basemap by Esri, "World Imagery." Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community].

helped shape recommendations to create a new staff position to lead coastal resilience efforts and to develop an island-wide coastal resilience plan.

In early 2019, the Town hosted a Community Resiliency Building workshop to solicit stakeholder participation and input as a part of the Massachusetts Municipal Vulnerability Preparedness (MVP) program. Funding for this workshop was provided by the MVP program. A key recommendation realized by this effort was the establishment of a municipal resilience coordinator position to facilitate resiliency initiatives across departments and conservation groups on island (Town of Nantucket, 2019a).

As a result of recent flood impacts, ongoing planning efforts, and growing public recognition of increasing climate impacts, the Town appointed a Coastal Resilience Advisory Committee (CRAC) and hired a full time Coastal Resilience Coordinator in spring 2019. Both the CRAC and Coastal Resilience Coordinator played key roles in development of the *CRP*, as recommended by the *2019 Natural Hazard Mitigation Plan*, and continue to drive the implementation of coastal resilience efforts across the island (Town of Nantucket, 2019b).

In January 2020, Nantucket released the *Coastal Risk Assessment and Resiliency Strategies Report* which provided a cursory review of current and future coastal hazards, evaluated risks within each neighborhood, and made broad recommendations for adaptation (Town of Nantucket, 2020). The report highlighted the range of global and local sea level rise projections available from Federal and State sources. In response, in July 2020, Nantucket's Select Board adopted the use of National Oceanic and Atmospheric Administration (NOAA) high sea level rise projections for planning purposes at the recommendation of the CRAC. Recommendations made in this plan also suggested the development of a managed retreat policy, consisting of regulatory and zoning tools, to empower and encourage residential retreat from eroding shorelines.

Building on previous planning efforts, Nantucket launched the *CRP* planning process in September 2020 to develop a united vision and roadmap for advancing coastal resilience across the island. After a comprehensive resilience planning process, including broad stakeholder engagement and completion of a risk assessment which considers multiple hazards over several time periods, the *CRP* was released in November 2021. The plan ultimately recommends 40 near- and longer-term resilience approaches and strategies at various scales from island-wide to site-specific. As of July 2024, half of these recommendations have been implemented, are currently underway, or are actively under development.

One of the *CRP* high priority recommendations is the development and administration of an island-wide approach for pursuing strategic retreat and relocation in areas of highest risk. To help guide near-term decision-making with respect to this recommendation, an island-wide risk framework was developed within the *CRP*. Recognizing that coastal risk can be complicated, the island-wide risk framework is a decision-making tool developed to guide near-term resilience decisions made on Nantucket based on the results of the risk assessment conducted for the *CRP*. The framework can be used by private property owners, Town officials, and other decision-makers to determine whether a particular type of resilience approach is appropriate given what is known about the project area's current and future coastal risk. The goal of this framework is not to prevent new construction across the island but to direct future investment to areas of the island with the lowest coastal risk (Town of Nantucket, 2021).

Over the last 5 years, these various hazard mitigation and resilience planning efforts by the Town have contributed to the development of broad awareness about increasing coastal risks and growing capacity to address these risks within the Town and among Nantucketers more broadly. Creation and maintenance of the CRAC, an entity devoted to implementing the *CRP*, and the Coastal Resilience Coordinator position have formalized the Town's capacity to act on issues related to coastal resilience. Through these plans, the Town has also started to introduce retreat to the local vernacular, familiarizing staff and the public with both the terminology and the concept. Cumulatively, these efforts have laid the foundation for an ongoing conversation about how strategic retreat and relocation may unfold in an effective and equitable manner on Nantucket.

A tailored approach

A forthcoming island-wide retreat and relocation planning effort led by the Town will build on the previous hazard mitigation and resilience planning efforts to identify priority retreat areas, evaluate potential receiving areas, and codify engagement best practices. Reflecting on the Town's recent experiences will be critical to informing the development of an island-wide approach to managed retreat. This section details how conversations around town-led retreat and relocation are unfolding across the island in real-time, highlighting many nuances that other communities may face as they engage in these topics.

Nantucket's formation due to glacial retreat and the resultant unique geology and topography has caused different coastal hazards to dominate in different areas of the island. Along the island's eastern shore, steep bluffs like those running along Baxter Road are threatened by largely unpredictable episodic erosion. In areas of lower topography and gently sloping shorelines, like the Downtown area, tidal flooding and storm surge are the primary threats to the built environment. On the southern shore, erosion during storm events poses an increasing threat as storms become stronger and more frequent. Its island location, glacial geology and topography allows Nantucket to serve, in many ways, as a real-time case study. In the context of retreat and relocation planning, it provides the opportunity to document and learn from three very different experiences unfolding concurrently within one municipality.

Baxter Road

Along Nantucket's Baxter Road, on top of the 'Sconset bluffs, retreat is unfolding in real time (Figure 2). The 'Sconset bluffs are subject to episodic erosion which can be infrequent and unpredictable. When erosion happens, large pieces of the bluff face can slump off, resulting in the loss of an unpredictable number of feet between a given structure and the bluff's edge. Already, 27 homes along Baxter Road have been relocated as the bluff collapses and more have been demolished. Interestingly, when the land along Baxter Road was originally sub-divided, the alleged intent was for a single parcel to span both sides of the road, extending landward perpendicular to the



FIGURE 2
Homes along Baxter Road on top of 'Sconset bluff in Summer 2023.

bluff face, allowing property owners the opportunity to relocate their property landward if necessary (Brace, 2010).

Between 2013 and 2015, nearly 950 feet of geotubes (large, permeable sand filled tube shaped containers) were installed by the Siasconset Beach Preservation Fund with permission of the Town as an emergency measure to help protect the toe, or base, of the bluff and prevent additional erosion and loss of property along a particularly vulnerable stretch of Baxter Road. Since the geotubes were put in place, proponents have sought to expand the project resulting in an ongoing debate about how to best address erosion in this area in the long-term. In June of 2021, the Nantucket Conservation Commission (local regulatory authority over wetland and environmental permitting) voted to remove the geotubes, triggering a series of events that are still unfolding. As of July 2024, the geotubes have not been removed but the Town has taken steps to identify and begin to implement a practicable long-term plan for this high-risk area.

In October of 2021, in response to the Conservation Commission's vote to remove the geotubes, the Town released the *Baxter Road Long-Term Planning Summary of Findings Memorandum* (Arcadis, 2021). This effort sought to compare technically feasible alternatives for providing bluff protection and develop a prioritized action plan to adapt the area over time based on the results of an alternatives analysis and significant stakeholder engagement. This memorandum served as a conversation starter and was the first time that Baxter Road was framed, publicly, as a retreat area. To support the alternatives analysis, adaptation pathways were developed (Figure 3). Adaptation pathways are sequences of actions implemented progressively and dependent on future dynamics. For Baxter Road, the adaptation pathways illustrate various alternatives, recommend short-term actions, and identify tipping points that may result in changes to the preferred long-term alternative. Prior to introducing the adaptation pathways, many stakeholders felt there was a binary choice to be made between removing the geotubes to allow for an immediate retreat and leaving the geotubes in place to continue providing protection. Stakeholder-informed development and subsequent socialization of this tool provided a common framework for how to think and talk about parallel planning efforts necessary in the short-term regardless of whether the geotubes are removed or not. Further, the tool proved to be effective in demonstrating that all potential pathways eventually lead to strategic retreat from the shoreline. This finding reinforced the importance of continued proactive planning for retreat and relocation along Baxter Road.

To support the eventual retreat of this area, engagement of stakeholders is ongoing as the Town develops an *Alternative Access and Utility Relocation Plan for Continuity of Services for Baxter Road Residents* (Town of Nantucket, n.d.). This plan will provide longer-term alternative access and utility services to residences along the northern, most vulnerable stretch of Baxter Road. As of July 2024, a shovel ready final design is expected in Summer 2025. The plan does not include the relocation of any private residences but does include demolition of Baxter Road and provision of landward alternative access.

Additionally, in January 2024, the Town released an *Emergency Readiness Plan for Baxter Road from the Sankaty Head Lighthouse to*

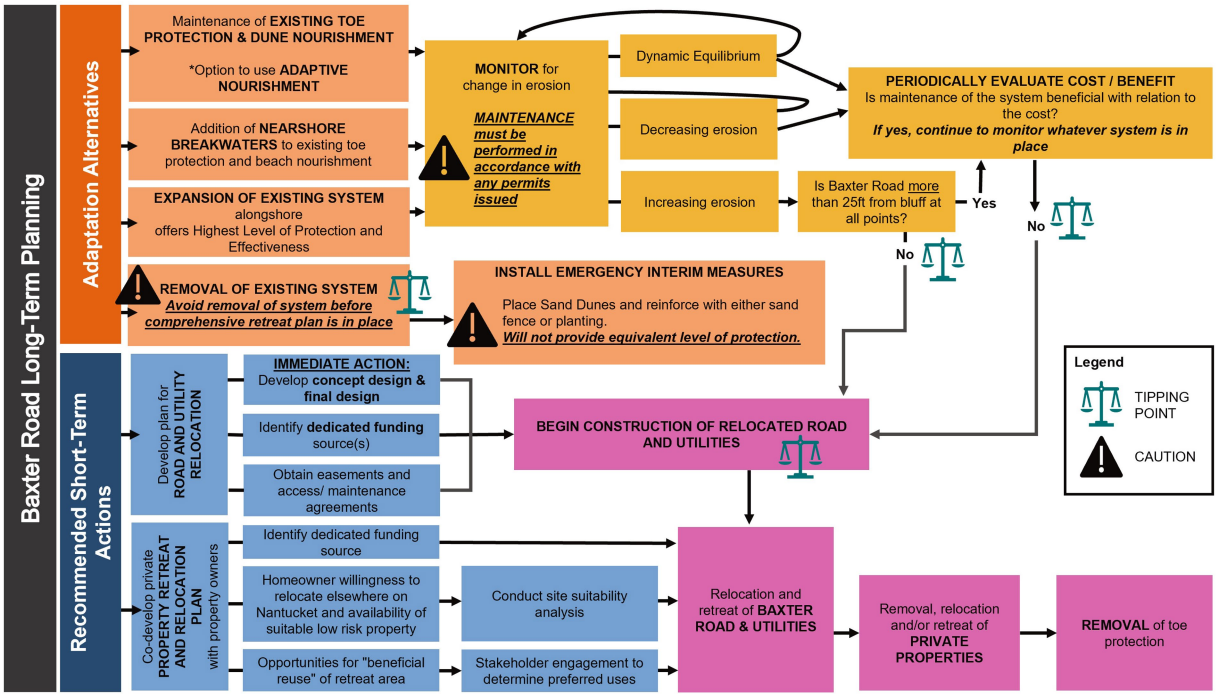


FIGURE 3
Adaptation pathways developed to support retreat and relocation planning along Baxter Road.

Bayberry Sias Lane (Town of Nantucket, 2024). This plan establishes recovery procedures for when Baxter Road is no longer passable due to coastal erosion and highlights the Town's responsibilities with respect to maintaining safety and provision of utility services if the roadway is unpassable.

The Town has not yet begun co-development of a private property retreat and relocation plan with property owners in the area. However, engagement has played a critical role in guiding the development of both the alternative access and emergency readiness plans. Given the small and largely seasonal population that may face the decision to retreat, it is anticipated that advancement of this planning is likely to happen in conjunction with the development of an island-wide retreat and relocation strategy.

Downtown

Nantucket's Downtown neighborhood epitomizes the island's unique historic character and is the economic, cultural, and historic hub of the island. Due to the relatively low topography of the area, Downtown is highly vulnerable to flooding (Figure 4). In 2022, a Town report documented a six-fold increase in the frequency of tidal flooding Downtown over the last 40 years (Larson, 2022). Between 1965 and 2023, NOAA tide gauge records indicate that Nantucket Harbor has experienced approximately 9.2 inches of sea level rise (NOAA, 2025). At-risk structures in the Downtown neighborhood include structures designated historically significant, cultural institutions, essential facilities and services (Steamboat Wharf, Hy-Line Cruises Terminal, the Downtown supermarket, and primary electrical substation for utility provider National Grid), in addition to dozens of businesses and services that support the local economy. According to the *CRP*, 325 structures and 3.5 miles of roadway Downtown are within priority action areas of extreme coastal risk per the island-wide risk framework. Assets within these areas are likely to be exposed to high-tide flooding or erosion as soon as 2030. Due to the extreme coastal risks faced in these areas today or within the next decade, the island-wide risk framework generally recommends a proactive reduction of density and minimization of large structural investments (Town of Nantucket, 2021).

However, despite the high level of flood risk Downtown, the Town has determined that, for now, structural protection is justified given the density of critical facilities and economic, social, cultural and historic assets. To preserve and enhance quality of life in Downtown, the Town is pursuing a series of structural approaches that reduce risk to the neighborhood's core while prolonging the service of critical transportation facilities and corridors, as recommended in the *CRP*.

The Easy Street Flood Mitigation project and Washington Street Resilience Framework & Francis Street Beach Improvement Project, both currently underway, represent critical steps in building the long-term resilience of the historic Downtown and the entire island. The projects include the lowest lying roads in Downtown which play an essential role in providing access and egress to and from the island's ferries and the many structures in the vicinity. Completion of these near-term projects will not eliminate flood risk to Downtown but will buy the Town time while determining the appropriate long-term adaptation pathway to transform Downtown in the face of increasing coastal risks, including significant groundwater rise, by the end of the century.



FIGURE 4
Flooding in Downtown Nantucket in Winter 2021.

South shore—Surfside Wastewater Treatment Facility

Along Nantucket's south shore, the Surfside Wastewater Treatment Facility (WWTF), built in the 1970s, is responsible for treating wastewater from the Town Sewer District which services about 60% of the island. When the facility was first built, it is estimated that there was up to 400 feet of beach between the wastewater treatment filter beds and the water. Over the past 2 years, there has been almost 150 feet of erosion. Notably, over the winter of 2023–2024, more than 50 feet of dunes eroded, imminently threatening the southernmost filter bed. While the bed was not operational, there were concerns that saltwater intrusion would impact operations of the other beds. In response, the Town filled in and closed the southernmost bed, allowing it to serve as a sacrificial sand source, buying some time before erosion progresses further inland and threatens facility operations (Treffeisen, 2024).

Now the Town is wrestling with how to protect the WWTF in the long-term. The *CRP* recommends the installation of reinforced dunes in front of the facility to provide additional protection while strategically relocating operative filter beds further back on the facility property. Other ideas discussed include installation of protective steel sheeting and relocation of the facility altogether. With uncertainty around the continued rate of erosion in this area, steep price tags (the *CRP* recommended project was estimated to cost between $33–38 million), the critical importance of this facility, and the dearth of low-risk land available for relocation, the decision is not likely to be straightforward. Communities and other critical assets, including the airport, along the south shore face similar challenges necessitating the assessment of trade-offs and acceptance of compromise in determining the appropriate long-term adaptation approach.

Relocation

As an island with inherently limited space, discussions of retreat on Nantucket are unfolding in parallel with discussions of relocation. Through Nantucket's long-standing commitment to conservation, approximately 16,419 acres, or about 55% of the island's total land area, are managed as conservation lands. These conservation lands are owned by various entities including the Nantucket Conservation Foundation, Massachusetts Audubon Society, Madaket Land Trust, 'Sconset Trust, Nantucket Land Bank, Nantucket Land Council, The Nature Conservancy, the Trustees of Reservations, the Town, State and Federal governmental agencies, and other conservation groups (Town of Nantucket, 2019a). Though the limitations placed on conservation lands vary from property to property, new development is often not feasible for legal reasons or

otherwise. Given the abundance of conservation land located in the relatively low coastal hazard risk areas mid-island, the trade-offs between conservation and opportunities for on-island relocation will need to be considered in the development of Nantucket's strategic retreat and relocation plan. The identification of areas suitable for relocation will also need to consider the growing demand for year-round affordable housing on-island. In a recent affordable housing lottery for local non-profit Housing Nantucket's latest project, 176 lottery applications were received for just six affordable apartments (Graziadei, 2024).

Discussion

Despite a noteworthy lack of guidance at State and Federal levels, since 2019, the Town has made great strides in laying the foundation for an ongoing, inclusive, and productive conversation around strategic retreat and relocation. As the Town prepares to take the next steps by developing an island-wide strategic retreat and relocation plan, there is an opportunity to document the many dimensions of this formidable challenge, as described in the previous sections, and to recognize lessons learned to date.

Through the Town's recent experiences considering retreat in the diverse contexts of Baxter Road, Downtown, and the wastewater treatment facility, it has become clear that there is no one-size-fits-all approach. Retreat and relocation planning must be highly tailored and dynamic. However, there are lessons learned that resonate across these contexts and may be relevant to other communities engaged in conversations around strategic retreat.

- Capacity, support, time and funding are critical to sustain ongoing conversations on strategic retreat. Beginning in 2019, Nantucket gradually built capacity within Town government by demonstrating the need for a coastal resilience coordinator position and developing the public awareness necessary to support establishment of the position. However, the lack of affordable housing on island threatens the Town's ability to maintain and expand staff capacity to lead proactive resilience planning efforts. Support for resilience work broadly, both within Town government and among the public, has been garnered over time through dedicated engagement and establishment of the CRAC as an entity devoted to implementation. Developing a steady funding source for proactive planning is a perennial challenge. On Nantucket, increasing public awareness and demand for action to address coastal hazards has served as a motivating force in the acquisition of funding through municipal, grant, and private sources.
- Engagement is key in all resilience planning but especially when planning for retreat and relocation (Mach and Siders, 2021; Kraan et al., 2021). The work on Baxter Road has demonstrated the necessity of approaching engagement as an enduring conversation, communicating early and often, and the reality of consensus-building as an ongoing process. Across various efforts, the Town has learned that communication, both internally and to the public, can be misinterpreted, highlighting the necessity of checking in consistently to ensure the intent of communication is heard. Education through various engagements has also helped foster shared understanding of climate change, coastal hazards and resilience, and the use of shared terminology across the island. Though engagement inevitably leads to pushback and differing ideas of success, Nantucket has leveraged this as an opportunity to make a better plan moving forward rather than viewing it as a setback or an excuse not to proceed.
- One of the major challenges in discussing retreat and relocation is the lack of certainty around what the future looks like. Nantucket's experiences have demonstrated repeatedly the importance of transparency and expectation setting. To help set expectations, Nantucket has found success in communicating things that are known or can be defined. In the case of Baxter Road, the Town worked with stakeholders to define what failure and success looked like (while acknowledging the necessity of compromise), define the process (recognizing that it may change), and identify key decision points and decisionmakers.

As the Town embarks on the development of a strategic retreat and relocation plan, these lessons learned will be incorporated into the process to support a productive community conversation as critical decisions are made about how retreat and relocation can help realize a resilient island home for all Nantucketers, today and in the future.

Constraints

This community case study is based on the experience of one municipality. Their experience with retreat and relocation may not be representative of other municipalities. Further, Nantucket's approach to retreat and relocation is ever evolving and, as such, may change following publication.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

VM: Conceptualization, Funding acquisition, Writing – review & editing. LH: Conceptualization, Writing – review & editing. DM: Writing – original draft, Writing – review & editing, Conceptualization.

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Conflict of interest

DM was employed by Arcadis, U.S., Inc., a consultancy hired by the Town of Nantucket to support several of the initiatives mentioned in this article.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declare that no Gen AI was used in the creation of this manuscript.

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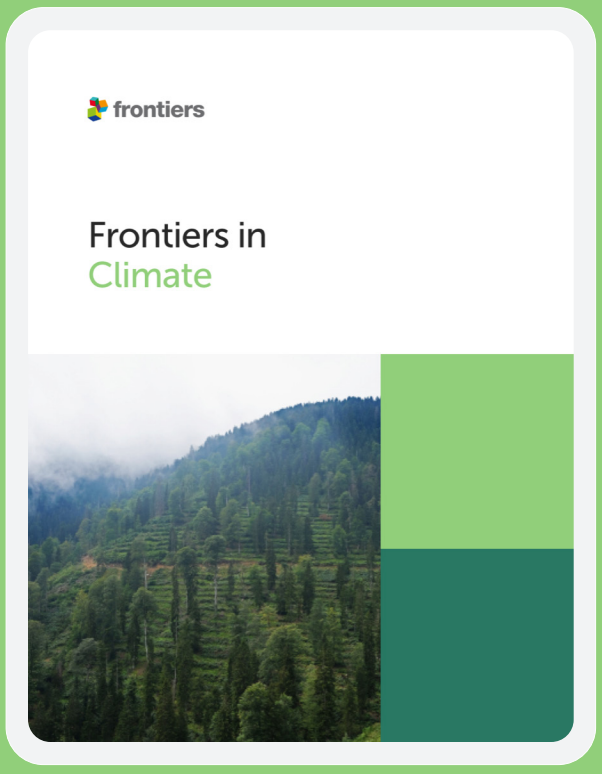
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