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From Analysis to Action: Strategies for Promoting Climate Justice when Implementing Nature-based Solutions to Coastal Risk

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Research on Social and Economic Co-Benefits of Nature-based Solutions Used for Coastal Flood Protection

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Chapter 1. Introduction

1.1. Purpose

The purpose of this project was to better understand how nature-based solutions (NBS) to reduce coastal flood risk in the Northeast can be planned and implemented in a way that promotes climate justice. At their core, NBS are interventions or landscape projects that use or mimic "nature" to provide solutions to environmental challenges, such as flooding or coastal erosion, that have been historically addressed with conventional engineering approaches that attempt to control or override natural processes. NBS redefine the approach, purpose, and scope of benefits from such interventions. NBS aim to restore, expand, or improve ecological systems, which in turn offer environmental, economic, and social co-benefits. The promise of NBS are that they offer more resilient and sustainable solutions to environmental challenges and hazards. NBS are being rapidly adopted and promoted around the world, and within the US by federal and state agencies, as well as private institutions, to adapt to climate change.

Climate change affects everyone, but not everyone is affected equally. Climate justice is a movement to acknowledge and address the unequal responsibility and impacts of climate change. Greenhouse gas emissions at the root of human-induced climate change have been driven primarily by more affluent and privileged sectors of society, but it is the less affluent or privileged who are bearing the brunt of impacts. Historically marginalized communities are uniquely vulnerable. Climate risks, and uncritical efforts to mitigate these risks, may also exacerbate existing inequitable social conditions. To promote climate justice and sustainability, climate change adaptation efforts such as NBS must take existing inequities into account and seek to prioritize and engage with communities that are more vulnerable, while also ensuring that these communities enjoy the benefits, or co-benefits, of these interventions.

To understand how NBS can be planned and implemented to address coastal flood risk in the Northeast in a way that prioritizes historically marginalized communities and promotes climate justice, we reviewed scholarly and gray literature on equity and the co-benefits of NBS, conducted interviews with community-based organizations (CBOs) advocating for climate justice or housing in coastal environmental justice communities in the greater Boston region, modeled expected damages for coastal risk and compared different equity-based metrics, measured social vulnerability and disproportionate exposure to these risks, and critically reviewed coastal adaptation recommendations based on the National Coastal Property Model. Finally, we assessed the opportunities and limitations of NBS and integrated our insights into a conceptual framework for understanding how the co-benefits of NBS can be better understood for advancing coastal risk reduction and climate justice.

As the Commonwealth of Massachusetts accelerates its efforts to address environmentally sustainable and socially equitable coastal resilience, this work can help inform those efforts. This report is aimed at engineers, analysts, and coastal zone managers, as well as community advocates, interested in achieving coastal resilience that promotes climate justice.

1.2. Main Findings

- In literature and in practice, NBS encompass a very broad range of interventions, and are often used interchangeably with analogous concepts, such as "green infrastructure." This conceptual flexibility allows for creative solutions under a broad range of circumstances or needs, but it also makes generalizations or lessons more challenging to identify or communicate.
- Guidance and frameworks for planning and implementing NBS are widely available and in broad agreement.

- Social equity constitutes a common concern or at least touchstone in NBS planning literature and guidance. Stakeholder engagement is the most common component of equity minded NBS frameworks. However, the depth of engagement, or what engagement looks like in practice, can vary widely.
- Research and understanding about the efficacy and environmental co-benefits of NBS are relatively robust (albeit complicated), but there is significantly less research or understanding about identifying, measuring, or modeling social co-benefits.
- Research, examples, or understanding of the disbenefits or unintended negative consequences of NBS are rare, although equity minded scholarship and gray literature frequently cite concerns over the potential for "green gentrification."
- Interviews with community-based organizations (CBOs) and planning officials working in coastal environmental justice communities show a common and overriding concern with housing affordability, gentrification, and displacement, but not as a result of green gentrification. In fact, interview participants emphasized the importance of investing in NBS or other green infrastructure in marginalized communities, and they argue that such green investments should not be limited or prevented by concerns about green gentrification.
- There is uneven concern about imminent coastal climate change risks amongst interview participants or the need for significant changes in coastal development. Participants engaged primarily in community development planning or affordable housing advocacy are less concerned about these risks than those engaged directly in climate justice or adaptation advocacy. The former are more likely to perceive that current adaptation efforts and risk mitigation strategies are adequate, while the latter argue that such efforts are inadequate.
- All interview participants agree that coastal development in the greater Boston region, whether for affordable housing or market-rate development, is not limited in any significant way by coastal climate change risks or policies, plans, or projects to adapt to, or mitigate, those risks.
- Most interview participants were aware of one or more completed or planned NBS for climate adaptation in their communities. Some were involved in these projects. However, all interviewees described NBS projects as relatively isolated or property parcel specific, independently determined by developer preferences, and not coordinated by any kind of municipal, regional, or state plans or regulations.
- There is wide agreement from the literature and from interview participants that substantive and deliberative community engagement is essential to advancing effective, equitable, and just climate resiliency. However, interview participants identified poor community engagement practices by government officials and project planners as a familiar and common failing that undermines resiliency projects and perpetuates marginalization of underserved communities. Participants identified a number of practices and lessons for better community engagement.
- Estimates of relative exposure for environmental justice populations in coastal Massachusetts counties, based on the US EPA's social vulnerability methodology, shows that environmental justice populations in some regions of coastal Massachusetts are disproportionately exposed to coastal climate change risk.
- Estimated flood damage to buildings along the Massachusetts coast due to extreme flood events and sea level rise shows that the consequences of coastal property damage are projected to be extreme. By 2070, statewide annual average damages could be more than $1 billion per year. Direct impacts in the Boston Harbor region currently account for more than half of the average annual statewide impact. By 2050, damage to structures in the Boston Harbor region may account for two-thirds of statewide damage.

- The geographic pattern and ranking of coastal damage risks are significantly affected by whether these expected damages are measured based on the total value of property at risk versus metrics based on damages relative to the value of properties within a community, as well as other non-monetary metrics, such as the total population at risk or the number of renters vs property owners. How these potential damages are measured has implications for what areas, and *which communities*, are prioritized.
- Nature-based solutions (NBS) potentially offer a wider range of environmental and social co-benefits in dealing with coastal climate risk compared to traditional engineering approaches that focus on eliminating flood risk by armoring. However, the appropriateness, efficacy, and the potential co-benefits and co-costs of NBS are highly site- and context-specific. NBS are generally understood as being effective at mitigating flood risk, particularly for high frequency, low consequence events, but their effectiveness is often a function of their size and available space to migrate as sea level changes.
- In addition to feasibility, the value of the co-benefits and co-costs of NBS should reflect community needs and priorities, which means that engineers, analysts, and coastal zone managers should seek to improve understanding and communication regarding 1) the efficacy of armoring alternatives in mitigating coastal risks to infrastructure; and 2) the expected co-costs and co-benefits of alternatives.
- Coastal resilience alternatives are not limited to a simple binary choice between traditional armoring solutions or NBS. These approaches can be implemented in combination, or as a portfolio, that achieves risk reduction objectives while supporting the co-benefits prioritized by the affected communities.

Chapter 2. Description of Methodology

To understand how NBS can be planned and implemented to address coastal flood risk in the Northeast in a way that promotes climate justice, we reviewed scholarly and gray literature on equity and the co-benefits of NBS, conducted interviews with community-based organizations (CBOs) and municipal planners advocating for climate justice or housing in coastal environmental justice communities in the greater Boston region, estimated flood damage to buildings along the Massachusetts coast due to extreme flood events and sea level rise, estimated disproportionate exposure to socially vulnerable populations in coastal counties of Massachusetts, evaluated the impacts of different metrics for identifying or prioritizing coastal communities at risk and potentially eligible for NBS, and finally, developed a conceptual framework for understanding the potential co-benefits of NBS.

2.1. Literature Review

We targeted leading scholarly journals, as well as gray literature from NGOs, the federal government, and Massachusetts-based reports on related programs. We employed a broad net search for "nature-based solutions" alone and in various combinations with "benefits", "trade-off", "equity", "justice", and "gentrification" over the last 10 years. We later expanded our search to include literature related to "green infrastructure" as we discovered that the latter is used interchangeably with NBS by some scholars and institutions and offered a wider range of relevant or at least analogous examples. We looked at guidance publications from the US Army Corps of Engineers, and we reviewed planning and action grant reports submitted under the Massachusetts Vulnerability Preparedness (MVP) program. The latter identified reports from over 120 municipalities across Massachusetts (more than 1/3 of all municipalities across the state) that have planned or implemented climate change adaptation projects that incorporate some form of NBS since the program began in 2018. The latter raises interesting questions about how NBS are identified or defined in practice.

Our review of this wide range of literature and reporting reveals several interesting themes and insights into how NBS and their practices are conceptualized, how notions of social equity are conceptualized and operationalized, and how the benefits of NBS might be defined, modeled, or measured.

2.2. Interviews

To better understand the experiences and perceptions of communities regarding climate adaptation, NBS, and social equity concerns, we conducted seven, in-depth interviews with representatives of municipalities, civic associations, community development corporations, and community-based organizations in coastal environmental justice communities[1] in the greater Boston region that focus on climate change adaptation or affordable housing advocacy and development. We conducted semi-structured interviews, in person or via video conference, during the spring of 2023. Participants were briefed on the purpose of the project and provided with a list of question prompts prior to the interviews. Interviews were recorded and transcribed, and transcripts were shared with participants for clarification, correction, amendment, or retraction. Themes from the interviews were identified and synthesized through a process of iterative content analysis. All participants were offered monetary honorariums for

[1] Environmental justice communities or populations are Census Block Groups identified under Massachusetts state law which meet one or more demographic criteria thresholds. https://www.mass.gov/info-details/environmental-justice-populations-in-massachusetts

their time. The interview protocol was reviewed by the Institutional Review Board at Salem State University and approved as Exempt (Exemption Notification - IRB ID: 6127).

2.3. Modeling Expected Damages for Coastal Risk; Using MC-FRM; Other Equity-Based Metrics

Current and future flood depths were derived from the Massachusetts Coast Flood Risk Model (MC-FRM) covering the entire coast of Massachusetts at a 2-meter grid resolution for six extreme flooding events: 20-year, 50-year, 100-year, 200-year, 500-year, and 1,000-year. Flood damage to buildings from these events was estimated using differentiated depth-damage functions by residential, industrial, and commercial categories; estimated property values from readily available sources; and relevant building characteristics for residential, industrial, and commercial structures.

The projections of sea level rise used in the modeling of coastal flood risks are consistent with the approach used in the US Global Change Research Program's 2017 National Climate Assessment and the Global and Regional Sea Level Rise Scenarios developed for use in climate impact assessment (USGCRP 2017, 2018). Under this approach, the USGCRP developed projections of sea level rise for each of four representative scenario groups—Intermediate, Intermediate-High, High, and Extreme. The Commonwealth of Massachusetts has selected the High scenario as the preferred scenario for assessment of vulnerability and flood risk, consistent with an "Unlikely to exceed" (83 percent) probability for a higher greenhouse gas emission scenario when accounting for possible ice sheet instabilities. For the higher emissions alone (without consideration of ice sheet instabilities), the High scenario is consistent with an "extremely unlikely to exceed" (95 percent) probability. The relative sea level rise that Massachusetts residents may see in the future, which we used as input for the Massachusetts Coast Flood Risk model (MC-FRM), reflects both sea-level and land-level changes, as well as other regional factors that can affect the rate of sea level rise. In the northern part of Massachusetts, this scenario corresponds to approximately 15 inches (39 cm) between 2008 and 2030, 30 inches (76 cm) between 2008 and 2050, and 51 inches (131 cm) between 2008 and 2070. Corresponding estimates for the southern part of Massachusetts are slightly higher – 16 inches (42 cm) by 2030, 32 inches (81 cm) by 2050, and 54 inches (136 cm) by 2070.[2]

Economic vulnerability is assessed using a customized variant of the National Coastal Property model, described in Neumann et al. (2021).[3] The model incorporates site- and property class-specific U.S. Army Corps of Engineers and FEMA compiled depth-damage functions, and an inventory of structure value from a database of assessed value. The model incorporates structure value at a 150 m by 150 m grid resolution, which is updated with recent Zillow adjustments at zip code level for current property values. In addition, because property values tend to increase over time, as GDP per capita increases, the model also incorporates a projection of coastal property values consistent with that applied in Neumann et al. (2021).[4]

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[2] The derivation of these estimates relative to 2008 levels and relative to the NAVD88 datum is presented in Appendix B.

[3] Neumann, J. E., Chinowsky, P., Helman, J., Black, M., Fant, C., Strzepek, K., & Martinich, J. 2021. Climate effects on US infrastructure: the economics of adaptation for rail, roads, and coastal development. Climatic Change. https://doi.org/10.1007/s10584-021-03179-w. The National Coastal Property Model described there was run in "no additional adaptation" mode to characterize vulnerability. The model also incorporates reactive and proactive adaptation modes which use benefit-cost "rules" to identify potentially cost-effective adaptation options. See also Lorie, M., Neumann, J. E., Sarofim, M. C., Jones, R., Horton, R. M., Kopp, R. E., Fant, C., Wobus, C., Martinich, J., O'Grady, M., Gentile, L. E. 2020. Modeling coastal flood risk and adaptation response under future climate conditions. Climate Risk Management, 29. Doi:10.1016/j.crm.2020.100233 for additional model documentation.

[4] The current trend is for rapidly increasing structure values in the vulnerable coastal zone, although the rate of property value growth may change in the future in response to climate risks and/or the implementation of adaptation measures. In addition,

The full version of the model considers both episodic flooding from the combined effects of storm surge, tides, and sea level rise; and the possibility of property inundation as a result of gradual sea level rise. To better match the format of the MC-FRM outputs, which themselves incorporate the joint flood risks over time from all three of these components, only the storm surge economic damage component of the model was applied here. Use of the MC-FRM flood risk as inputs to the NCPM has three main advantages over the approach used in Neumann et al. (2021): 1) The MC-FRM results are used by multiple Massachusetts agencies and departments as forecasts for adaptation planning, so our results will be consistent with those resilience planning processes; 2) The approach is consistent with that used in the recent 2022 Massachusetts Climate Assessment,[5] which itself provides risk inputs that the Commonwealth is using in the State Hazard Mitigation and Climate Adaptation Plan, currently under development; and 3) the MC-FRM flood risk modeling provides a higher spatial resolution and more fully integrated flood risk approach than the simplified "modified bathtub" approach built into the NCPM. The MC-FRM is perhaps unique in U.S coastal flood risk modeling in that it fully integrates the multiple baseline period and climate change hazards of sea-level rise, storm surge, tidal variations, and land subsidence – as well as in a few locations, the potential for riverine flooding in coastal estuaries associated with storm events.

There remain several important limitations of this approach. First, increasing sea level rise and storm surge risks over time may also trigger changes in the demographics of the resident population at risk, which could alter the assessment of disproportionality in exposure to coastal flood impacts. In addition, these results exclude the potential impact of changes to the frequency or severity of extra-tropical storms (one category of which is referred to as "Nor'easters" in New England) – consistent with advice to the Commonwealth of a peer review panel of climate science expert and consistent with the current approach in MC-FRM. In addition, the results in this report exclude secondary and indirect effects of damage to structures associated with flood impacts, such as business interruptions or forced migrations.

Additional methodological details are in the cited studies.

2.4. Measuring Social Vulnerability and Disproportionate Exposure (EPA Method)

The approach used here to identify socially vulnerable populations and to estimate disproportionate exposure is based on that used in a recent report on climate change impacts and social vulnerability sponsored by the U.S. Environmental Protection Agency.[6]

Current scientific research shows that climate change will accelerate the rate of sea level rise along much of the U.S. coastline. Discerning the impact of sea level rise on coastal development and ecosystems requires an understanding of how much sea levels might rise, how these changes will manifest on the physical landscape, societal responses to these risks, and the economic implications of these responses.

As noted in prior literature, the impacts of sea level rise will vary by location and depend on a range of biophysical characteristics and socioeconomic factors, including societal response. The primary impacts of sea level rise are physical changes to the environment. These changes, in turn, affect human uses of the coast such as tourism, settlement, shipping, industry, commercial and recreational fishing, agriculture, and wildlife viewing. The most serious physical impacts of sea level rise on coastal lowlands are (1) inundation and displacement of lowlands; (2) increased vulnerability to coastal storm damage and

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increasing degrees of sea level rise and storm surge risks over time may also trigger changes in the demographics of the population at risk, which could alter the assessment of disproportionality in exposure to coastal flood impacts. Our projections do not incorporate those dynamic influences on future coastal property value, which a limited literature suggests may be significant, but which are only incompletely understood at this point.

[5] Available at: https://www.mass.gov/info-details/massachusetts-climate-change-assessment

[6] EPA. 2021. Climate Change and Social Vulnerability in the United States: A Focus on Six Impacts. U.S. Environmental Protection Agency, EPA 430-R-21-003. www.epa.gov/cira/social-vulnerability-report

flooding; (3) coastal erosion; and (4) salinization of surface water and groundwater. The approach provides comprehensive estimates of the areal extent and economic implications of the first two of these effects.

Impacts to coastal properties from sea level rise and storm surge are particularly site-specific. Local characteristics, such as elevation and proximity to tidally influenced waterbodies, can greatly affect damage assessments and, in particular, adaptation decisions and effectiveness. It is often the case that damages from coastal flooding vary on small spatial scales. For this reason, deterministic models of the impacts of coastal flooding on properties, such as the U.S. National Coastal Property Model (NCPM; see Neumann et al. 2015), simulate impacts at near site-level spatial scales.[7] The NCPM is a well-established model, developed over multiple iterations over two decades, that was designed for national-scale analysis of coastal flooding in the contiguous U.S. coastal zone (Neumann et al 2015; Lorie et al. 2020).[8] The model determines inundated areas at the 150m grid resolution for each coastal county along a sea level rise trajectory for two types of coastal flood hazards—permanent inundation from sea level rise and storm surge—and estimates property losses and expected damage. Although the model itself employs a modified bathtub approach to flood risk that ensures a hydraulic connection as sea levels rise, for this application the flood hazard assessment module is replaced with estimates from the MC-FRM. The MC-FRM provides a superior flood risk estimate, which incorporates many more nuanced and precise location-specific flood risk factors than are available from national scale approaches. The NCPM assumes complete loss of structure value once the mean high or higher water level reaches the property, and loss of land value equivalent to a representative inland parcel, thereby implicitly assuming inland transfer of the amenity value of proximity to the coast over time.

It is important to note that the NCPM includes an initiation period that effectively determines existing protection. In order to compare across various adaptation scenarios, it is important for the model to start from a common and stable state. Effectively, this means that the NCPM must use a potentially aggressive, economically optimal adaptation build simulation for existing protection, a likely overestimate of existing protection for all simulations, even one without adaptation. As a result, estimates from the NCPM are likely an underestimate of climate change damages.

To assess the risks of sea level rise and storm surge, a “No Additional Adaptation” scenario was developed where no protective measures are implemented to avoid the impacts of sea level rise and storm surge. As a result, properties incur damages at an increasing rate. This scenario assumes that property owners abandon properties that are inundated by sea level rise and that they incur damages from storm surge flooding. If the damages incurred by storm surge exceed the value of the property, the analysis assumes that the property owner abandons the property. This “No Additional Adaptation” scenario is used here to estimate vulnerability- it is a useful baseline from which we can assess whether additional adaptation actions might be equitably allocated across the cost, or whether the projected funding of adaptation actions might itself increase disproportionality of vulnerability in the future.

The NCPM also simulates the rollout of property protection from both permanent inundation and storm surge using a set of decision rules that are governed by least-cost principles. Within the model, properties can be protected by hard structures like sea walls, which protect from sea level inundation and storm surge up to the 100-year surge height; elevation of structures, which protects from storm surge only; and beach nourishment, which is similar to hard structures but is only effective up to a certain flood depth. Hard structures and nourishment protect not only the properties but are also built to protect properties

[7] Neumann JE, Emanuel K, Ravela S, Ludwig L, Kirshen P, Bosma K and Martinich J. 2015. Joint effects of storm surge and sea-level rise on US Coasts: New economic estimates of impacts, adaptation, and benefits of mitigation policy. *Climatic Change* 129(1–2):337–349. Available: https://doi.org/10.1007/s10584-014-1304-z.

[8] Lorie M, Neumann J, Sarofim M, Jones R, Horton R, Kopp RE, Fant C, Wobus C, Martinich J, O’Grady M. 2020. Modeling Coastal Flood Risk and Adaptation Choices under Future Climate Conditions, *Climate Risk Management*, Vol 29, 100233. https://doi.org/10.1016/j.crm.2020.100233

further inland. The decision rules within the NCPM compare the cost of different adaptation options within each cell to the expected reduction in damages that would result from those adaptation options. This model assumes that armoring and elevation will be implemented for the 100-year flood. The cost-benefit test compares an estimate of discounted avoided damages over the next 30 years with the cost of each adaptation option. This decision rule is based on an estimate of expected annual damages and expected annual benefits of adaptation. The expected annual benefit is the avoided damages given the assumption that adaptation will prevent damages for events up to and including the current 100-year flood. The decision relies on the following:

- **Cost of adaptation** varies across cells and adaptation type. For abandonment, cost is equal to property value. For armoring and elevation, the cost includes capital and present value of maintenance.
- **Expected annual damages over 30 years** (discounted at 3 percent): The calculation is based on current annual damage, not the projected annual damage.
- **Expected annual damages with adaptation in place**: Damages for events larger than the 100-year event.
- **Expected annual benefits of adaptation:** The difference between the expected annual damages without protection and the expected annual damages with protection.

For each adaptation decision, the NCPM looks ahead 30 years, using current expected annual damage as the approximation. The NCPM discounts future expected annual damage to model adaptation decision-making, which has for Federal government sponsored analyses been the 3 percent (real) rate required by Office of Management and Budget's Circular A-4,[9] to obtain a present value of expected damages over 30 years. Expected damages are estimated with and without adaptation – the difference between these two adaptation scenarios is used to estimate a present value of expected benefits of adaptation. The "with adaptation" scenario reflects adaptation effectiveness sufficient to protect to at least the current 100-year return period flood event (and, by extension, also protect for all flood events now and in the future that are less severe than the current 100-year flood event). In its simplest form, the decision rule implements the lowest cost adaptation option if benefits for that option exceeds the cost of protection. This represents a traditional benefit-cost test for optimal risk reduction investment, emulating the protection decision often used by the U.S. Army Corps of Engineers or for flood mitigation assistance to municipal governments (through the Federal Emergency Management Agency, or FEMA). The costs of protection are estimated by site-specific characteristics, such as if the property is situated in the back bay or ocean-facing, which requires additional costs for sea walls to protect from wave action. The model chooses the protection type that is the cheapest for that grid cell.

It is important to note that many adaptation response decisions of this type in the coastal zone are not made with strict cost-benefit decision rules, particularly at the local level. Other factors may include local zoning bylaws, future land use plans, the presence of development-supporting infrastructure, or proximity to sites with high cultural value. However, the analytical framework of the NCPM provides a simple, benefit-cost decision framework that can be consistently applied for regional and national-scale analysis.

2.4.1. Methods for Assessing Social Vulnerability Dimensions

This study further investigates if socially vulnerable communities are disproportionately more likely to live in areas where the highest percentage of property is projected to be inundated due to sea level rise. An important step in this approach is determining the areas that are projected to have the highest impacts. The analysis first delineates the coastal boundary and then determines which areas are projected to be at

[9] Office of Management and Budget. 2003. Executive Office of the President. https://obamawhitehouse.archives.gov/omb/circulars_a004_a-4/

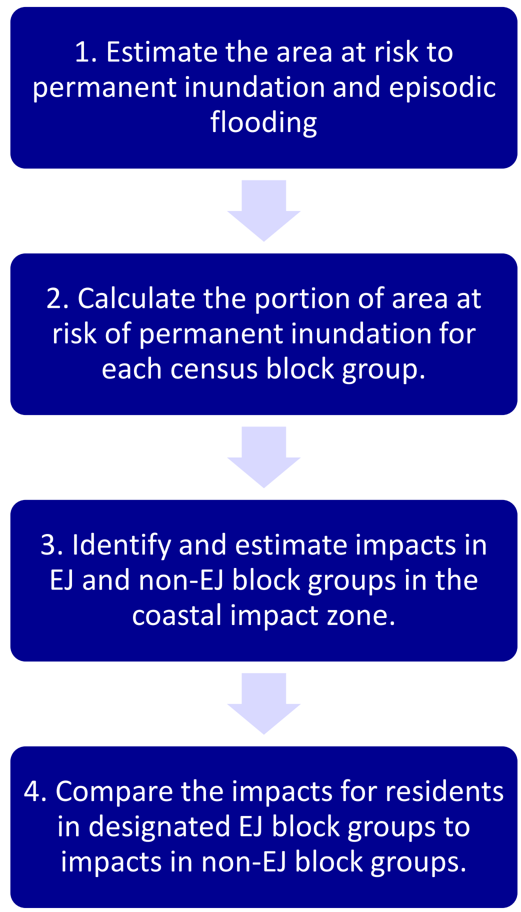
risk of permanent inundation from sea level rise, or at risk of elevated storm surge.[10] The analysis then identifies populations living in Census block groups within these areas.

To explore the risks of permanent inundation on socially vulnerable populations, the approach follows the four steps outlined in Figure 2-1 and described in further detail below.

Step 1: Estimate the area at risk of permanent inundation. The method starts by mapping the Commonwealth's preferred planning and adaptation sea level rise scenario (described in Section 2.3 above). The method also maps the storm surge height portfolio, and tides. These characterizations of coastal hazards are inputs to the MC-FRM, which simulates inundation and episodic flood risk at a 1 m square grid for a base period centered on 2008 and three future eras (2030, 2050, and 2070).

Step 2: Calculate the portion of area at risk of permanent inundation for each Census block group. Using the areas at risk of permanent inundation or areas excluded from protection generated in step 1, the approach aggregates these to the Census block group level (generating proportions of each block group) where data exists describing demographic details of the population that resides there.

Figure 2-1. Four Steps for Assessing Impacts on Socially Vulnerable Coastal Risk-Exposed Populations.



Step 3: Identify impacts in EJ and non-EJ designated Census block groups. The approach does not observe exactly which individuals are both impacted and have an EJ status. Instead, the quantitative evaluation involves comparing the average economic and physical impacts of consequence in EJ population areas to the average consequences in other areas of the Commonwealth. EJ population areas are identified following the EEA's June 2021 Environmental Policy. In that policy, EJ population areas are identified at the Census block group level, where Census block groups typically include between 250 and 550 households. There are approximately 5,000 block groups in the Commonwealth.

The four determinants of social vulnerability included in this analysis are: Low Income, Minority, English Isolation; and combined Minority and Low Income.

Step 4: Compare the average impact to homeowners in the EJ Census block groups to that in non-EJ block groups. These likelihoods are expressed relative to the non-EJ population and are aggregated at the county level. The disproportionality measures are separately calculated for each social vulnerability metric.

2.5. Planning and Implementing NBS (sources of knowledge or insights)

The approach to identifying the populations potentially excluded from protection based on a benefit-cost framework focuses on the financial costs and targeted benefits (i.e., avoided infrastructure damages) of traditional ("gray infrastructure") methods of shoreline armoring. Traditional armoring methods generally rely upon construction of artificial, engineered structures, such as seawalls and breakwaters, which are designed to protect infrastructure from inundation, wave energy, and erosion. Well-designed traditional

[10] The area at risk of storm surge is defined broadly – it is the area potentially flooded by a 500-year event, with 150 cm of global mean sea level rise (i.e., the 500-year floodplain after 150 meters GMSL).

armoring structures can provide complete or near-complete protection to coastal infrastructure from these risks, thus they are widely used, particularly along highly developed coastlines. However, these approaches can adversely affect natural coastal processes (e.g., sediment transport and nearshore hydrodynamics) and destroy or fragment habitats for coastal species. These non-financial costs of traditional armoring methods are difficult to quantify and integrate into a standard benefit-cost framework and, as such, may be discounted or ignored, leading to suboptimal armoring decisions and inequities.

These traditional approaches to coastal resiliency can be viewed as combatting natural forces, defending coastal infrastructure against rising seas and increasingly severe coastal storms. In contrast, as described in more detail in Chapter 3, NBS represent a paradigm shift toward working *with* nature, leveraging the regulating features of natural systems to achieve a desired outcome (e.g., flood risk management) while simultaneously providing a host of additional socioeconomic and environmental co-benefits (e.g., recreation opportunities). In this way, NBS are closely related to the concept of ecosystem services, the notion that nature provides distinct, identifiable benefits to people.[11]

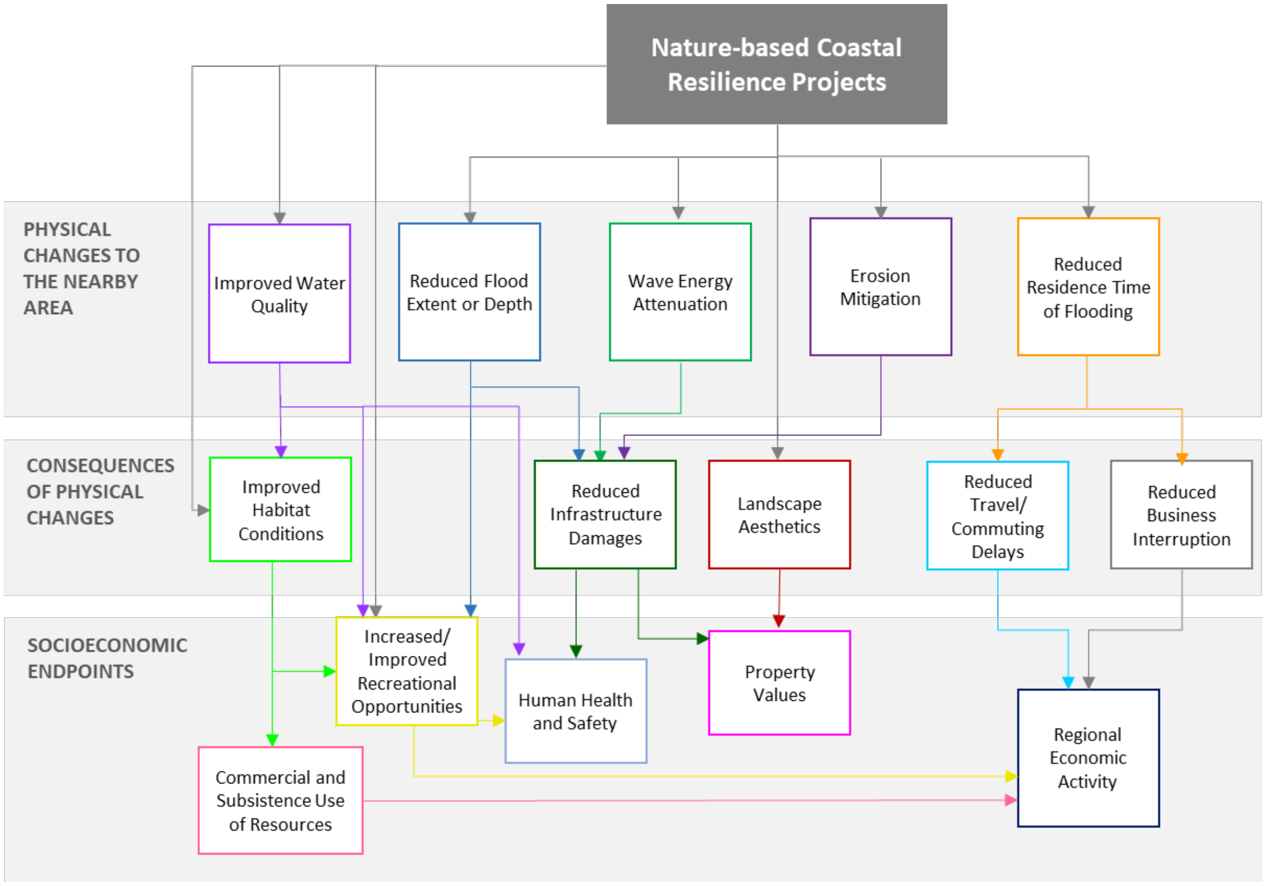
A single, broadly accepted definition or classification system for coastal resilience NBS does not exist. For the purposes of our research and assessment of NBS co-benefits, we focus on the recently published International Guidelines for Natural and Nature-Based Features for Flood Risk Management,[12] which identifies five general categories of relevant NBS: beaches and dunes, coastal wetlands and tidal flats, barrier islands and spits, coral and shellfish reefs, and plant systems (e.g., submerged aquatic vegetation and kelp, living shorelines). We also note that "hybrid solutions" that incorporate elements of both traditional and NBS for armoring are increasingly adopted. Conservation, restoration, and strategic construction of natural features can promote coastal resiliency by attenuating storm surge and wave energy, providing floodwater storage, and preventing shoreline erosion. Effective NBS provide many of the same benefits to society as traditional infrastructure, for example enhanced human health and safety and protection of property values through a reduction in infrastructure damage, and increased economic activity through reductions in travel delays and business closures.

In contrast to traditional infrastructure, however, NBS provide a host of ecological and ecosystem service co-benefits that generate additional value for coastal populations. These include habitat for fish and wildlife, opportunities for outdoor recreation, and enhanced (i.e., more natural) landscape aesthetics, among others. To illuminate potential co-benefits of NBS, we began by developing a simplified conceptual diagram (Figure 2-2) of the pathways through which NBS generate value for society. This diagram is not comprehensive, but highlights categories of co-benefits commonly associated with NBS projects, as confirmed through our project team's experience modeling and quantifying costs, benefits, and tradeoffs associated with coastal armoring alternatives. Ultimately which categories of co-benefits are relevant, and the magnitude of the benefits is highly site-specific and related to the design of the NBS project, as well as the biophysical and socioeconomic context of the site. We use this diagram throughout our research to orient our assessment of planning and implementation for NBS, including evaluating how people, in particular socially vulnerable populations, may benefit from NBS alternatives.

[11] Our research focuses on NBS in the context of coastal resiliency although similar solutions are being applied to address an increasing range of natural hazards (e.g., heat stress, water scarcity).

[12] Bridges, Todd S., Jeffrey K. King, Jonathan D. Simm, Michael W. Beck, Georganna Collins, Quirijn Lodder, and Ram K. Mohan. 2021. "International Guidelines on Natural and Nature-Based Features for Flood Risk Management." U.S. Army Corps of Engineers.

Figure 2-2. Conceptual Diagram of Benefits Flows for NBS



Chapter 3. Findings

3.1. Synthesis of Literature

NBS were first formally defined by the European Commission in 2015 as "actions [that] address environmental, social and economic challenges simultaneously by maximizing the benefits provided by nature (…) inspired by, supported by, or copied from nature".[1] While there are numerous iterations of the NBS definition, the core concept is "the use of nature" to provide solutions to challenges that might otherwise be (or have historically been) addressed with conventional engineering approaches [2]. Examples include protection or restoration of natural streams and rivers to mitigate inland flooding rather than trying to further channelize runoff with concrete drainage systems; creating or restoring nearshore reefs to attenuate the power of waves against the shoreline instead of simply raising concrete seawalls; and restoring or establishing coastal marsh to filter polluted stormwater runoff and reduce the erosive energy of waves on the shoreline.

Another core aspect of NBS is the potential to provide both targeted benefits (e.g., flood reduction, water quality improvement, shoreline protection) and a variety of desirable *co-benefits*. While the concept of co-benefits is typically associated with secondary goals, for NBS the promise of these co-benefits is central to its definition.[3] The most immediate co-benefit is the fact that NBS is premised on the protection or restoration of ecological systems that may otherwise be degraded or absent. Thus, at a minimum, NBS provide both engineering solutions and ecological revitalization, with all the attendant benefits of healthier ecological systems and the services they may provide to both humans and the environment generally. There may be public health and social co-benefits as well, including improved air and water quality, enhanced recreational opportunities from landscape improvements, better access to green space or water bodies, access to local food sources, enhanced economic opportunities, etc. This multi-benefit perspective of NBS has been described as a "paradigm shift"[4] in how communities, governments, conservation organizations, and private developers understand and approach infrastructure, conservation, and climate or hazard adaptation measures.

Academic researchers, NGOs, and governments have embraced NBS as a more sustainable way to address the challenges of a changing climate while meeting other environmental and social needs. In the US, the Federal Emergency Management Agency,[5] the National Oceanic and Atmospheric Administration,[6] and the US Army Corps of Engineers [7] are all leading federal agencies that have adopted

[1] Barbara Sowińska-Świerkosz and Joan García, "What Are Nature-Based Solutions (NBS)? Setting Core Ideas for Concept Clarification," Nature-Based Solutions 2 (December 1, 2022): 100009, https://doi.org/10.1016/j.nbsj.2022.100009.

[2] Sowińska-Świerkosz and García.

[3] Devon M. Jones and Brent Doberstein, "Encouraging Co-Benefits in Climate-Affected Hazard Adaptation: Developing and Testing a Scorecard for Project Design and Evaluation," International Journal of Disaster Risk Reduction 74 (May 1, 2022): 102915, https://doi.org/10.1016/j.ijdrr.2022.102915.

[4] Todd S. Bridges et al., "International Guidelines on Natural and Nature-Based Features for Flood Risk Management" (U.S. Army Corps of Engineers, 2021), 59.

[5] FEMA, "Nature-Based Solutions | FEMA.Gov," accessed February 21, 2023, https://www.fema.gov/emergency-managers/risk-management/nature-based-solutions.

[6] NOAA, "Nature-Based Solutions for Coastal Hazards," accessed February 21, 2023, https://coast.noaa.gov/digitalcoast/training/green.html.

[7] Holly Kuzmitski, "Engineering With Nature Initiative Contributes to White House Roadmap for Accelerating Nat," Engineer Research and Development Center, accessed February 21, 2023, https://www.erdc.usace.army.mil/Media/News-

and actively promote NBS through research, education, and funding. Numerous federal funding programs explicitly allow for, or even encourage, the incorporation of NBS. Federal funding sources for NBS projects include the US Environmental Protection Agency's Nonpoint Source Management Program, the US Housing and Urban Development Community Development Block Grants for disaster recovery or mitigation, the US Federal Emergency Management Agency's (FEMA) Hazard Mitigation Assistance and Public Assistance funds, and the National Oceanic and Atmospheric Administration's (NOAA) Community-Based Restoration Program and National Coastal Resilience Fund.[8]

In Massachusetts, NBS has been institutionalized through the state's Municipal Vulnerability Preparedness (MVP) grant program, which provides support for cities and towns in Massachusetts to identify climate hazards, assess vulnerabilities, and develop action plans to improve resilience to climate change. Municipalities that complete the MVP Planning Grant process become designated as an MVP Community and are eligible for MVP Action Grant funding to implement the priority actions identified through the planning process.[9] The MVP program, which was developed in collaboration with The Nature Conservancy, a leading conservation NGO, lists "employing Nature Based Solutions" as number three on its list of nine core principles that applicants should incorporate into their grant applications.[10] As of early 2023, more than one-third of the municipalities in Massachusetts have successfully applied for this state grant funding, and nearly all of them propose some form of NBS in their planning.

Despite the rapid growth of interest in NBS, however, experience with implementation is still relatively rare, and there are many unanswered questions about how NBS compares to conventional approaches in achieving environmental management or risk reduction objectives,[11] how the performance of NBS should be assessed,[12] and how the benefits and distribution of benefits should be measured.[13]

Stories/Article/3214936/engineering-with-nature-initiative-contributes-to-white-house-roadmap-for-accel/https%3A%2F%2Fwww.erdc.usace.army.mil%2FMedia%2FNews-Stories%2FArticle%2F3214936%2Fengineering-with-nature-initiative-contributes-to-white-house-roadmap-for-accel%2F.

[8] FEMA, "Building Community Resilience with Nature-Based Solutions: A Guide For Local Communities," RiskMAP Increasing Resilience Together (FEMA, June 2021), https://www.fema.gov/emergency-managers/risk-management/nature-based-solutions/planning.

[9] MA Climate Change Clearinghouse, "Municipal Vulnerability Preparedness Program," accessed February 21, 2023, https://resilientma.mass.gov/mvp/index.html.

[10] MA Climate Change Clearinghouse, "Municipal Vulnerability Preparedness (MVP) Program Core Principles" (Commonwealth of Massachusetts, n.d.), https://www.mass.gov/doc/mvp-core-principles/download.

[11] Chausson, Alexandre, Beth Turner, Dan Seddon, Nicole Chabaneix, Cecile A. Girardin, Valerie Kapos, Isabel Key, et al. "Mapping the Effectiveness of Nature-Based Solutions for Climate Change Adaptation." Global Change Biology 26 (2020): 6134–55. https://doi.org/10.1111/gcb.15310.

[12] Kabisch, Nadja, Niki Frantzeskaki, Stephan Pauleit, Sandra Naumann, McKenna Davis, Martina Artmann, Dagmar Haase, et al. "Nature-Based Solutions to Climate Change Mitigation and Adaptation in Urban Areas: Perspectives on Indicators, Knowledge Gaps, Barriers, and Opportunities for Action." Ecology and Society 21, no. 2 (June 1, 2016). https://doi.org/10.5751/ES-08373-210239; Raymond, Christopher M., Niki Frantzeskaki, Nadja Kabisch, Pam Berry, Margaretha Breil, Mihai Razvan Nita, Davide Geneletti, and Carlo Calfapietra. "A Framework for Assessing and Implementing the Co-Benefits of Nature-Based Solutions in Urban Areas." Environmental Science and Policy 77 (2017): 15–24. http://dx.doi.org/10.1016/j.envsci.2017.07.008; Sowińska-Świerkosz, Barbara, and Joan García. "A New Evaluation Framework for Nature-Based Solutions (NBS) Projects Based on the Application of Performance Questions and Indicators Approach." Science of the Total Environment 787, no. 147615 (2021). https://doi.org/10.1016/j.scitotenv.2021.147615.

[13] Narayan, Siddharth, Michael W. Beck, Borja G. Reguero, Iñigo J. Losada, Bregje van Wesenbeeck, Nigel Pontee, James N. Sanchirico, Jane Carter Ingram, Glenn-Marie Lange, and Kelly A. Burks-Copes. "The Effectiveness, Costs and Coastal Protection Benefits of Natural and Nature-Based Defences." PLOS ONE 11, no. 5 (May 2, 2016): e0154735. https://doi.org/10.1371/journal.pone.0154735.

A complementary branch of inquiry also raises questions about the equity or social justice implications of NBS.[14] Over the last decade, a robust body of literature has stimulated critical questions about the potentially regressive social consequences of a broad range of "green infrastructure" projects, including NBS – particularly with regard to disruptive impacts on adjacent property values and accelerated gentrification and displacement of socially vulnerable populations in urban settings.[15] How can NBS contribute to safety and quality of life for historically marginalized and socially vulnerable populations? To what degree does NBS pose equity risks, and how might these risks be mitigated?

Here we present a review of both scholarly and gray literature on Nature Based Solutions (NBS), with emphasis on understanding methodologies for identifying and estimating co-benefits or disbenefits from NBS, especially with regard to vulnerable communities, as well as the social equity dimensions of these projects.

3.1.1. The definition and practice of Nature Based Solutions is variable and not clearly bounded.

NBS is defined quite broadly both in theory and in practice, which complicates our ability to set boundaries on the concept or to identify unique characteristics that carry consistent or similar consequences, including the spatial scale of such projects. The problem of ambiguous or even competing definitions of NBS has been revisited repeatedly by scholars.[16] Most credit the European Commission for offering the first "official" definition of NBS in 2015, and indeed, most references to "Nature Based Solutions" in the peer-reviewed, scholarly literature occur after 2015.[17] Mastler et al.[18] argue that the concept underlying NBS – to (re)integrate nature and its benefits into the city – has a much older lineage, echoing earlier movements for garden cities, greenbelts, and greenways of the late 19th and early 20th centuries. More commonly, scholars observe that NBS is frequently used interchangeably or alongside terms such as "green infrastructure," "blue-green infrastructure," "ecological infrastructure," "engineering

[14] Anguelovski, Isabelle, Anna Livia Brand, Malini Ranganathan, and Derek Hyra. "Decolonizing the Green City: From Environmental Privilege to Emancipatory Green Justice." Environmental Justice 15, no. 1 (2021). https://doi.org/10.1089/env.2021.0014; Haase, Dagmar, Sigrun Kabisch, Annegret Haase, Erik Andersson, Ellen Banzhaf, Francesc Baro, Miriam Brenck, et al. "Greening Cities - To Be Socially Inclusive? About the Alleged Paradox of Society and Ecology in Cities." Habitat International 64 (2017): 41–48. http://dx.doi.org/10.1016/j.habitatint.2017.04.005.

[15] Anguelovski, Isabelle, James J. T. Connolly, Laia Masip, and Hamil Pearsall. "Assessing Green Gentrification in Historically Disenfranchised Neighborhoods: A Longitudinal and Spatial Analysis of Barcelona." Urban Geography 39, no. 3 (March 16, 2018): 458–91. https://doi.org/10.1080/02723638.2017.1349987.; Calderon-Argelich, Amalia, Stefania Benetti, Isabelle Anguelovski, James J.T. Connolly, Johannes Langemeyer, and Francesc Baro. "Tracing and Building up Environmental Justice Considerations in the Urban Ecosystem Service Literature: A Systematic Review." Landscape and Urban Planning 214, no. 104130 (2021). https://doi.org/10.1016/j.landurbplan.2021.104130; Colléony, Agathe, and Assaf Shwartz. "Beyond Assuming Co-Benefits in Nature-Based Solutions: A Human-Centered Approach to Optimize Social and Ecological Outcomes for Advancing Sustainable Urban Planning." Sustainability 11, no. 4924 (2019). http://dx.doi.org/10.3390/su11184924; Cousins, Joshua J. "Justice in Nature-Based Solutions: Research and Pathways." Ecological Economics 180 (February 1, 2021): 106874. https://doi.org/10.1016/j.ecolecon.2020.106874; Rigolon, Alessandro, and Jeremy Nemeth. "'We're Not in the Business of Housing:' Environmental Gentrification and the Nonprofitization of Green Infrastructure Projects." Cities 81 (2018): 71–80. https://doi.org/10.1016/j.cities.2018.03.016.

Shokry, Galia, James J.T. Connolly, and Isabelle Anguelovski. "Understanding Climate Gentrification and Shifting Landscapes of Protection and Vulnerability in Green Resilient Philadelphia." Urban Climate 31, no. 100539 (2020). https://doi.org/10.1016/j.uclim.2019.100539.

[16] Sowińska-Świerkosz and García, "What Are Nature-Based Solutions (NBS)?"

[17] Lei Li et al., "Mapping the Research Landscape of Nature-Based Solutions in Urbanism," Sustainability 13, no. 7 (January 2021): 3876, https://doi.org/10.3390/su13073876.

[18] "A 'Green' Chameleon: Exploring the Many Disciplinary Definitions, Goals, and Forms of 'Green Infrastructure,'" Landscape and Urban Planning 214 (October 1, 2021): 104145, https://doi.org/10.1016/j.landurbplan.2021.104145.

with nature," and others. Escobedo et al.[19] go so far as to describe NBS as only the most recent "metaphor" for the "importance and role of natural and semi-natural ecosystems in cities to improve human well-being in urban regions …" (succeeding other "metaphors" such as green infrastructure, ecosystem services, and urban forestry).

Some scholars argue that conceptual ambiguity surrounding NBS is problematic because it risks oversimplification, potentially creates confusion, hinders measures of progress and improvement, and risks misuse through overuse or overpromising of benefits.[20] As one answer to this problem of ambiguity, the efforts of the International Union for Nature Conservation (IUCN) to draft clearer principles of NBS is frequently referenced.[21] In 2020, the IUCN issued its Global Standard consisting of eight criteria by which to frame NBS actions:

1. address societal challenges;
2. landscape scale of intervention;
3. biodiversity gain;
4. economic viability;
5. governance capability;
6. equitably balance trade-offs;
7. adaptive management; and
8. mainstreamed within an appropriate jurisdictional context.

Similarly, the European Commission has posed a series of questions to "define whether an intervention can or cannot be framed as an NbS":[22]

i. Does it use nature/natural processes?
ii. Does it provide/improve social benefits?
iii. Does it provide/improve economic benefits?
iv. Does it provide/improve environmental benefits? and
v. Does it have a net benefit for biodiversity?

In the US, however, it appears that leading governmental and non-governmental organizations that promote NBS have been less concerned about adopting a uniform definition or erecting clear or hard boundaries around the concept of NBS.[23] This is particularly apparent in the definition and practice of NBS by the Massachusetts MVP program mentioned above.

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[19] "Urban Forests, Ecosystem Services, Green Infrastructure and Nature-Based Solutions: Nexus or Evolving Metaphors?," Urban Forestry & Urban Greening, Green Infrastructures: Nature Based Solutions for sustainable and resilient cities, 37 (January 1, 2019): 4, https://doi.org/10.1016/j.ufug.2018.02.011.

[20] Carsten Nesshöver et al., "The Science, Policy and Practice of Nature-Based Solutions: An Interdisciplinary Perspective," Science of the Total Environment 579 (2017): 1215–27, http://dx.doi.org/10.1016/j.scitotenv.2016.11.106; Emmanuelle Cohen-Shacham et al., "Core Principles for Successfully Implementing and Upscaling Nature-Based Solutions," Environmental Science & Policy 98 (August 2019): 20–29, https://doi.org/10.1016/j.envsci.2019.04.014; Escobedo et al., "Urban Forests, Ecosystem Services, Green Infrastructure and Nature-Based Solutions"; Matsler et al., "A 'Green' Chameleon"; Sowińska-Świerkosz and García, "What Are Nature-Based Solutions (NBS)?"

[21] Hilde Eggermont et al., "Nature-Based Solutions: New Influence for Environmental Management and Research in Europe," GAIA - Ecological Perspectives for Science and Society 24, no. 4 (January 1, 2015): 243–48, https://doi.org/10.14512/gaia.24.4.9; Nesshöver et al., "The Science, Policy and Practice of Nature-Based Solutions: An Interdisciplinary Perspective"; Cohen-Shacham et al., "Core Principles for Successfully Implementing and Upscaling Nature-Based Solutions"; Sowińska-Świerkosz and García, "What Are Nature-Based Solutions (NBS)?"

[22] "FUTURE BRIEF: The Solution Is in Nature," Science for Environment Policy (Luxembourg: European Commission, February 2021), https://knowledge4policy.ec.europa.eu/publication/future-brief-solution-nature_en.

[23] Heather Luedke, "Nature as Resilient Infrastructure – An Overview of Nature-Based Solutions," October 16, 2019, https://www.eesi.org/papers/view/fact-sheet-nature-as-resilient-infrastructure-an-overview-of-nature-based-solutions.

The MVP program defines NBS as "adaptation measures focused on the protection, restoration, and/or management of ecological systems to safeguard public health, provide clean air and water, increase natural hazard resilience, and sequester carbon."[24] A matrix of NBS examples and their benefits on the program's website (https://resilientma.mass.gov/mvp/content.html?toolkit=nature_based) lists three dozen examples of NBS, including green roofs, urban parks/forests, urban gardens, greening transport, wetlands, river restoration, sand dunes, coastal wetlands, sustainable drainage, pervious surfaces, detention basins, rainwater harvesting, geocellular storage, blue roofs, and groundwater recharge, to name a few. Case studies on the same site highlight policy and planning (e.g., zoning ordinances, bylaws, flood planning) and land acquisition (i.e., conservation easements, land conservation) as other forms of NBS. Insofar as coastal NBS are concerned, the MVP identifies a smaller subset of examples: managed realignment, coastal wetlands, sand dunes, and shore and beach.

In order to get a clearer understanding of how NBS has been implemented in practice, we also reviewed planning and action grant reports submitted by over one hundred municipalities under the MVP program through December 2022.[25] We found that MVP projects have been dominated by a few areas of application: stormwater and riverine flood control, reducing nutrient loads from stormwater runoff, and protecting or revitalizing natural ecosystems, such as ponds, wetlands, and rivers. Based on these grant reports and the applicants' framing of their plans or activities, NBS may refer to the materials or methods employed (e.g., naturally occurring ecosystems or landscape features), to the outcomes or goals of a project using any material or method (e.g., stream or wetland restoration, protection of sensitive water bodies), or to any balance or mix of NBS approaches/materials/purposes with conventional engineering approaches (e.g., repairing or improving conventional engineered culverts to reduce flood damage and improve water flow in a stream).

3.1.2. Numerous frameworks offer guidance on conceptualizing, planning, implementing, and evaluating NBS

One of the more prolific subjects in both peer-reviewed and gray literature is the proposal of frameworks to guide understanding, planning, assessment, or implementation of NBS. The abundance of this particular type of literature may reflect the wide variation of NBS conceptualizations, or possibly be a response to that variability as a way of operationalizing particular conceptualizations of NBS.[26] Based on our review, this framework literature can be grouped into two broad categories: guidance on planning or implementation, and methods of assessment or value articulation. Note that these categories are not mutually exclusive, but rather are based on overall thematic emphasis. In general, frameworks grouped into the category of planning and implementation of NBS offer a high-level view of project planning and follow or recommend a common series of steps:

1. identify problem to be addressed by NBS,
2. select or design NBS intervention,
3. implement NBS,
4. monitor and evaluate NBS performance.

All of these planning or implementation frameworks agree that NBS are intended to address a specific environmental or climate-related challenge and create benefits for the natural or non-human environment

[24] "MA Climate Change Clearinghouse," accessed January 24, 2023, https://resilientma.mass.gov/mvp/content.html?toolkit=nature_based.

[25] "Municipal Vulnerability Preparedness Program Action Grant Projects | Mass.Gov," accessed February 25, 2023, https://www.mass.gov/info-details/municipal-vulnerability-preparedness-program-action-grant-projects.

[26] Elisa Calliari, Andrea Staccione, and Jaroslav Mysiak, "An Assessment Framework for Climate-Proof Nature-Based Solutions," Science of The Total Environment 656 (March 2019): 691–700, https://doi.org/10.1016/j.scitotenv.2018.11.341.

and for people or society.[27] There is significant variation amongst these frameworks in terms of their level of abstraction, how each of these steps should be pursued, what criteria or processes should be used to make decisions or assess performance, and how or where non-expert stakeholders should be involved.

Frameworks grouped into the category of methods of assessment or value articulation primarily focus on how to identify relevant benefits and co-benefits of NBS and how to assess their performance or impact.[28] In most cases, scholars or practitioners recommend that "local decisionmakers" or "stakeholders" be involved in helping to identify relevant benefits or co-benefits, or in establishing preferences or "weights" for various benefits or co-benefits.[29] The stakeholder-supported identification of benefits and co-benefits

[27] Christopher M. Raymond et al., "A Framework for Assessing and Implementing the Co-Benefits of Nature-Based Solutions in Urban Areas," Environmental Science and Policy 77 (2017): 15–24, http://dx.doi.org/10.1016/j.envsci.2017.07.008; Judy Bush and Andréanne Doyon, "Building Urban Resilience with Nature-Based Solutions: How Can Urban Planning Contribute?," Cities 95 (December 2019): 102483, https://doi.org/10.1016/j.cities.2019.102483; Calliari, Staccione, and Mysiak, "An Assessment Framework for Climate-Proof Nature-Based Solutions"; Niki Frantzeskaki, "Seven Lessons for Planning Nature-Based Solutions in Cities," Environmental Science & Policy 93 (March 2019): 101–11, https://doi.org/10.1016/j.envsci.2018.12.033; Sara Meerow, "A Green Infrastructure Spatial Planning Model for Evaluating Ecosystem Service Tradeoffs and Synergies across Three Coastal Megacities," Environmental Research Letters 14, no. 12 (December 2019): 125011, https://doi.org/10.1088/1748-9326/ab502c; Christian Albert et al., "Planning Nature-Based Solutions: Principles, Steps, and Insights," Ambio 50, no. 8 (August 2021): 1446–61, https://doi.org/10.1007/s13280-020-01365-1; Barbara Sowińska-Świerkosz and Joan García, "A New Evaluation Framework for Nature-Based Solutions (NBS) Projects Based on the Application of Performance Questions and Indicators Approach," Science of the Total Environment 787, no. 147615 (2021), https://doi.org/10.1016/j.scitotenv.2021.147615; Jones and Doberstein, "Encouraging Co-Benefits in Climate-Affected Hazard Adaptation"; Nadja Kabisch, Niki Frantzeskaki, and Rieke Hansen, "Principles for Urban Nature-Based Solutions," Ambio 51 (2022): 1388–1401, https://doi.org/10.1007/s13280-021-01685-w; Arsum Pathak et al., "Incorporating Nature-Based Solutions Into Community Climate Adaptation Planning" (National Wildlife Federation and EcoAdapt, March 2022); Arsum Pathak et al., "Key Considerations for the Use of Nature-Based Solutions in Climate Services and Adaptation," Sustainability 14, no. 24 (January 2022): 16817, https://doi.org/10.3390/su142416817.

[28] Alida Alves et al., "Assessing the Co-Benefits of Green-Blue-Grey Infrastructure for Sustainable Urban Flood Risk Management," Journal of Environmental Management 239 (June 1, 2019): 244–54, https://doi.org/10.1016/j.jenvman.2019.03.036; Calliari, Staccione, and Mysiak, "An Assessment Framework for Climate-Proof Nature-Based Solutions"; Agathe Colléony and Assaf Shwartz, "Beyond Assuming Co-Benefits in Nature-Based Solutions: A Human-Centered Approach to Optimize Social and Ecological Outcomes for Advancing Sustainable Urban Planning," Sustainability 11, no. 4924 (2019), http://dx.doi.org/10.3390/su11184924; Meerow, "A Green Infrastructure Spatial Planning Model for Evaluating Ecosystem Service Tradeoffs and Synergies across Three Coastal Megacities"; Alessandro Pagano et al., "Engaging Stakeholders in the Assessment of NBS Effectiveness in Flood Risk Reduction: A Participatory System Dynamics Model for Benefits and Co-Benefits Evaluation," Science of The Total Environment 690 (November 2019): 543–55, https://doi.org/10.1016/j.scitotenv.2019.07.059; Watkin et al., "A Framework for Assessing Benefits of Implemented Nature-Based Solutions," Sustainability 11, no. 23 (November 29, 2019): 6788, https://doi.org/10.3390/su11236788; Alida Alves et al., "Exploring Trade-Offs among the Multiple Benefits of Green-Blue-Grey Infrastructure for Urban Flood Mitigation," Science of The Total Environment 703 (February 10, 2020): 134980, https://doi.org/10.1016/j.scitotenv.2019.134980; Adina Dumitru, Niki Frantzeskaki, and Marcus Collier, "Identifying Principles for the Design of Robust Impact Evaluation Frameworks for Nature-Based Solutions in Cities," Environmental Science and Policy 112 (2020): 107–16, https://doi.org/10.1016/j.envsci.2020.05.024; R. Giordano et al., "Enhancing Nature-Based Solutions Acceptance through Stakeholders' Engagement in Co-Benefits Identification and Trade-Offs Analysis," Science of The Total Environment 713 (April 2020): 136552, https://doi.org/10.1016/j.scitotenv.2020.136552; Sowińska-Świerkosz and García, "A New Evaluation Framework for Nature-Based Solutions (NBS) Projects Based on the Application of Performance Questions and Indicators Approach"; Marija Bockarjova et al., "Estimating the Social Value of Nature-Based Solutions in European Cities," Scientific Reports 12, no. 1 (November 18, 2022): 19833, https://doi.org/10.1038/s41598-022-23983-3; Jones and Doberstein, "Encouraging Co-Benefits in Climate-Affected Hazard Adaptation"; Kim Lundgren Associates, Inc., "North Suffolk Social Vulnerability and Equity Assessment: Summary of Findings" (North Suffolk Office of Resilience & Sustainability, June 2022), https://www.dropbox.com/s/uwprkkwqbegz3ig/NSORS_North%20Suffolk%20Social%20Vulnerability%20and%20Equity%20Assessment%20Summary%20of%20Findings_Final.pdf?dl=0; Joy Ommer et al., "Quantifying Co-Benefits and Disbenefits of Nature-Based Solutions Targeting Disaster Risk Reduction," International Journal of Disaster Risk Reduction 75 (June 2022): 102966, https://doi.org/10.1016/j.ijdrr.2022.102966.

[29] Raymond et al., "A Framework for Assessing and Implementing the Co-Benefits of Nature-Based Solutions in Urban Areas"; Alves et al., "Assessing the Co-Benefits of Green-Blue-Grey Infrastructure for Sustainable Urban Flood Risk Management";

and relative values can be used to select the preferred NBS, as well as to assess performance once implemented. Others recommend an expert-driven “scorecard” approach aimed at decisionmakers to help them screen NBS options and their potential benefits and disbenefits before selection or implementation.[30] Assessment of NBS performance, in terms of both benefits and co-benefits, is almost always quantified in some way. The most common approach is to apply monetary values to benefits and co-benefits to make assessment, comparison, and communication with decision makers easier. Monetization of benefits and costs is fundamental to benefit-cost analyses (BCA), one of the most common quantitative approaches for measuring and assessing NBS benefits.[31] Many frameworks for identifying and estimating or measuring the benefits and co-benefits of NBS rely primarily on BCA, although there is wide acknowledgment that such approaches miss important dimensions – how benefits are distributed spatially, to whom benefits accrue, how to account for benefits that cannot be quantified, and structural biases in BCA approaches that may ignore or give inadequate attention to communities with lower property valuations. One exception is recent work by Stroud, Kirshen, and Timmons[32] which proposes an equity weighting method to traditional BCA in estimating co-benefits.

While both scholars and practitioners advocate systematic evaluation of a broad range of benefits and costs for NBS, the actual choices of indicators to be evaluated have been limited. In a systematic review of peer-reviewed literature focusing on impact evaluation or the development of indicators of nature-based solutions, Dumitru et al.[33] found that the direct environmental impacts have been more extensively researched and documented, while social and health-related impacts have been much less so, even though the latter are regularly touted as expected co-benefits. Ommer et al.[34] found similar patterns of bias toward ecological versus socioeconomic indicators in their review of quantitative methods of estimating co-benefits from NBS.

3.1.3. Unintended Consequences

Warnings about the potential for unintended negative consequences of NBS are present in most frameworks and assessments, but scholars have repeatedly noted that there remains a dearth of analysis, empirical documentation, or guidance on identifying, anticipating, or understanding disbenefits, disservices, tradeoffs, or socially regressive or negative impacts, or unintended consequences of NBS.[35]

Pagano et al., “Engaging Stakeholders in the Assessment of NBS Effectiveness in Flood Risk Reduction”; Alves et al., “Exploring Trade-Offs among the Multiple Benefits of Green-Blue-Grey Infrastructure for Urban Flood Mitigation”; Giordano et al., “Enhancing Nature-Based Solutions Acceptance through Stakeholders’ Engagement in Co-Benefits Identification and Trade-Offs Analysis”; Bockarjova et al., “Estimating the Social Value of Nature-Based Solutions in European Cities”; Ommer et al., “Quantifying Co-Benefits and Disbenefits of Nature-Based Solutions Targeting Disaster Risk Reduction.”

[30] Meerow, “A Green Infrastructure Spatial Planning Model for Evaluating Ecosystem Service Tradeoffs and Synergies across Three Coastal Megacities”; Jones and Doberstein, “Encouraging Co-Benefits in Climate-Affected Hazard Adaptation”; Kim Lundgren Associates, Inc., “North Suffolk Social Vulnerability and Equity Assessment: Summary of Findings.”

[31] Alves et al., “Assessing the Co-Benefits of Green-Blue-Grey Infrastructure for Sustainable Urban Flood Risk Management”; Calliari, Staccione, and Mysiak, “An Assessment Framework for Climate-Proof Nature-Based Solutions”; Alves et al., “Exploring Trade-Offs among the Multiple Benefits of Green-Blue-Grey Infrastructure for Urban Flood Mitigation”; Bockarjova et al., “Estimating the Social Value of Nature-Based Solutions in European Cities”; Ommer et al., “Quantifying Co-Benefits and Disbenefits of Nature-Based Solutions Targeting Disaster Risk Reduction”; Hannah M. Stroud, Paul H. Kirshen, and David Timmons, “Monetary Evaluation of Co-Benefits of Nature-Based Flood Risk Reduction Infrastructure to Promote Climate Justice,” Mitigation and Adaptation Strategies for Global Change 28, no. 1 (December 12, 2022): 5, https://doi.org/10.1007/s11027-022-10037-2.

[32] “Monetary Evaluation of Co-Benefits of Nature-Based Flood Risk Reduction Infrastructure to Promote Climate Justice.”

[33] “Identifying Principles for the Design of Robust Impact Evaluation Frameworks for Nature-Based Solutions in Cities.”

[34] “Quantifying Co-Benefits and Disbenefits of Nature-Based Solutions Targeting Disaster Risk Reduction.”

[35] C. M. Shackleton et al., “Unpacking Pandora’s Box: Understanding and Categorising Ecosystem Disservices for Environmental Management and Human Wellbeing,” Ecosystems 19, no. 4 (June 2016): 587–600,

In their systematic review, Ferreira et al.[36] identified only 11 out of 142 articles that considered the risks of "ecosystem disservices." These risks included increases in crime, dirtiness (e.g., leaves or bird droppings), attraction of pests or vermin, limited access for disadvantaged groups, damage to property, allergies from pollen, economic costs for maintenance, spread of invasive plant species, and contamination of soil from chemicals or dirty water. Similarly, Dumitru et al.[37] found that only 5% of articles in their review "(somewhat) consider synergies and tradeoffs." This is consistent with our own analysis. However, one risk of unintended consequences that was uniquely common and frequently mentioned across a broad range of NBS and GI literature was the risk or potential for "green gentrification" – displacement of moderate- or lower-income residents and non-White residents because of rising property values and an influx of more affluent, White residents due to NBS or GI investments.[38] Like other types of disbenefits or undesirable consequences, the framework literature we reviewed offered no clear or practical guidance on how to anticipate, measure, assess, or ameliorate the risk of gentrification that might be created or exacerbated by NBS or GI (although see Bockarjova et al.[39]).

3.1.4. Green Gentrification

References about the risks of green gentrification are ubiquitous across both peer-reviewed and gray literature, but the scholarly literature directly analyzing the patterns or causal mechanisms of green gentrification is mixed. Analyses of green gentrification appear more commonly in reference to the term "green infrastructure" or "urban greening," although NBS may be used interchangeably. The most studied forms of GI or NBS associated with green gentrification have been greenways, such as the High Line in New York City and the Beltline in Atlanta, Georgia, two high profile projects that resulted in increased property values and rent and displaced lower income residents.[40] The effects of parks on adjacent communities have also been commonly studied, although a recent analysis of over two dozen park developments across North America found no consistent association with indicators of gentrification.[41] A study of GI in Philadelphia found a strong correlation between municipal investment and the wealth and race of communities, but the researchers of that study acknowledged that the causal direction was not

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https://doi.org/10.1007/s10021-015-9952-z; Bonnie L. Keeler et al., "Social-Ecological and Technological Factors Moderate the Value of Urban Nature," Nature Sustainability 2, no. 1 (January 2019): 29–38, https://doi.org/10.1038/s41893-018-0202-1; Dumitru, Frantzeskaki, and Collier, "Identifying Principles for the Design of Robust Impact Evaluation Frameworks for Nature-Based Solutions in Cities"; V. Ferreira et al., "Stakeholders' Engagement on Nature-Based Solutions: A Systematic Literature Review," Sustainability (Switzerland) 12, no. 2 (2020), https://doi.org/10.3390/su12020640; Willi Bauer, "Reframing Urban Nature-Based Solutions Through Perspectives of Environmental Justice and Privilege," Urban Planning 8, no. 1 (November 25, 2022), https://doi.org/10.17645/up.v8i1.6018.

[36] "Stakeholders' Engagement on Nature-Based Solutions," 10.

[37] "Identifying Principles for the Design of Robust Impact Evaluation Frameworks for Nature-Based Solutions in Cities."

[38] Isabelle Anguelovski et al., "Decolonizing the Green City: From Environmental Privilege to Emancipatory Green Justice," Environmental Justice 15, no. 1 (2021), https://doi.org/10.1089/env.2021.0014; Bauer, "Reframing Urban Nature-Based Solutions Through Perspectives of Environmental Justice and Privilege"; Melissa García-Lamarca et al., "Urban Green Grabbing: Residential Real Estate Developers Discourse and Practice in Gentrifying Global North Neighborhoods," Geoforum 128 (January 1, 2022): 1–10, https://doi.org/10.1016/j.geoforum.2021.11.016.

[39] "Property Price Effects of Green Interventions in Cities: A Meta-Analysis and Implications for Gentrification," Environmental Science & Policy 112 (October 2020): 293–304, https://doi.org/10.1016/j.envsci.2020.06.024.

[40] Dan Immergluck and Tharunya Balan, "Sustainable for Whom? Green Urban Development, Environmental Gentrification, and the Atlanta Beltline," Urban Geography 39, no. 4 (April 21, 2018): 546–62, https://doi.org/10.1080/02723638.2017.1360041; Kate Derickson, Mira Klein, and Bonnie L. Keeler, "Reflections on Crafting a Policy Toolkit for Equitable Green Infrastructure," Npj Urban Sustainability 1, no. 1 (April 27, 2021): 1–4, https://doi.org/10.1038/s42949-021-00014-0; Jessica Quinton, Lorien Nesbitt, and Daniel Sax, "How Well Do We Know Green Gentrification? A Systematic Review of the Methods," Progress in Human Geography 46, no. 4 (August 2022): 960–87, https://doi.org/10.1177/03091325221104478.

[41] Margarita Triguero-Mas et al., "Exploring Green Gentrification in 28 Global North Cities: The Role of Urban Parks and Other Types of Greenspaces," Environmental Research Letters 17, no. 10 (October 2022): 104035, https://doi.org/10.1088/1748-9326/ac9325.

clear – whether GI led to gentrification or gentrification spurred GI investments or some complex combination of the two.[42] The effects of other forms of GI or NBS have been much less studied.

There is little doubt that gentrification and displacement are real phenomena or that investment and development can contribute to gentrification, but as Quinton, Nesbitt, and Sax[43] point out in their systematic literature review, the research thus far has yet to disentangle non-green gentrification from green gentrification. Sax, Nesbitt, and Quinton[44] suggest that green gentrification may not be "sufficient as a singular explanation" for changes in patterns of development because it inevitably intersects with other political and economic factors. Nevertheless, if investments in GI or NBS may have some role in the potential for green gentrification and displacement, one important question to ask is what mechanisms or approaches can be deployed to prevent or dampen the forces of displacement? Within the context of planning or implementation of GI or NBS, where and when should these interventions take place? Some scholars and practitioners suggest that the most fruitful opportunities for combatting green gentrification are at a municipal or regional governmental policy level, rather than at the individual project planning level.[45] Based on lessons from case studies, such policies need to couple and coordinate greening investment with housing policy for an entire community or region.[46] This coupling might take the form of special zoning overlays that provide planners with the power to control the geography of GI or NBS in order to allocate greening investments more equitably. Similarly, such policies could set higher affordable housing development requirements that are also dispersed and integrated with market-rate development, or institute rent control to protect households most vulnerable to price increases.[47] These proposals require explicit prioritization of social equity and housing by officials as part of municipal or regional agendas for green resilience efforts. It is important to recognize that marginalized communities want the benefits of greener, healthier, and more attractive spaces, while being aware of the complexities and potential threats of such investments.[48]

3.1.5. Incorporating Social Equity or Environmental Justice

Social and environmental justice remain largely peripheral to NBS literature and guidance.[49] This is not surprising given that equity considerations are not generally a part of regional or municipal planning in

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[42] Michael Reibel, Alessandro Rigolon, and Angelica Rocha, "Follow the Money: Do Gentrifying and at-Risk Neighborhoods Attract More Park Spending?," Journal of Urban Affairs 0, no. 0 (March 25, 2021): 1–19, https://doi.org/10.1080/07352166.2021.1886857.

[43] "How Well Do We Know Green Gentrification?"

[44] "Improvement, Not Displacement: A Framework for Urban Green Gentrification Research and Practice," Environmental Science & Policy 137 (November 1, 2022): 373–83, https://doi.org/10.1016/j.envsci.2022.09.013.

[45] García-Lamarca et al., "Urban Green Grabbing"; Sarah Saydun, Interview of climate resilience practitioner on NBS and housing intersections, February 28, 2023.

[46] Alessandro Rigolon and Jeremy Nemeth, "'We're Not in the Business of Housing:' Environmental Gentrification and the Nonprofitization of Green Infrastructure Projects," Cities 81 (2018): 71–80, https://doi.org/10.1016/j.cities.2018.03.016; Melissa Garcia-Lamarca et al., "Urban Green Boosterism and City Affordability: For Whom Is the 'Branded' Green City?," Urban Studies 58, no. 1 (January 1, 2021): 90–112, https://doi.org/10.1177/0042098019885330.

[47] Galia Shokry et al., "'They Didn't See It Coming': Green Resilience Planning and Vulnerability to Future Climate Gentrification," Housing Policy Debate 32, no. 1 (January 2, 2022): 211–45, https://doi.org/10.1080/10511482.2021.1944269.

[48] Mahbubur Meenar, Megan Heckert, and Deepti Adlakha, "'Green Enough Ain't Good Enough:' Public Perceptions and Emotions Related to Green Infrastructure in Environmental Justice Communities," International Journal of Environmental Research and Public Health 19, no. 3 (January 2022): 1448, https://doi.org/10.3390/ijerph19031448.

[49] Joshua J. Cousins, "Justice in Nature-Based Solutions: Research and Pathways," Ecological Economics 180 (February 1, 2021): 106874, https://doi.org/10.1016/j.ecolecon.2020.106874; Bauer, "Reframing Urban Nature-Based Solutions Through Perspectives of Environmental Justice and Privilege"; Zbigniew Jakub Grabowski et al., "How Deep Does Justice Go? Addressing Ecological, Indigenous, and Infrastructural Justice through Nature-Based Solutions in New York City," Environmental Science & Policy 138 (December 1, 2022): 171–81, https://doi.org/10.1016/j.envsci.2022.09.022.

practice.[50] However, scholars and practitioners of GI or NBS regularly acknowledge or explicitly recommend consideration of social equity. Some scholars and organizations offer specific strategies and perspectives on "points of entry" to integrate social equity into the NBS planning or evaluation processes.[51] Haase et al.[52] offer a list of "prerequisites" for socially inclusive development: acknowledgement by all involved of existing spatial and social inequalities, inclusion of a diverse set of participants with different perspectives, acknowledgment and in-depth analyses of trade-offs of greening projects, and a multi-actor governance structure to steer these greening agendas. Eakin et al.[53] identify six points of entry in adaptation-related research "for making justice and politics more visible and tractable": co-production of knowledge with a diverse range of expert and non-expert actors, greater attention to how problems and solutions are framed or defined, explicit decisions about the spatial scale and scope of adaptation, consideration of heterogeneous social values, acknowledging and modeling social and political uncertainty as it might affect project outcomes, and evaluating and building the capacity of stakeholders to meaningfully participate in planning. Based on an examination of the GI planning processes of 19 cities across the US, Hoover et al.[54] offer three recommendations to planners on how to center equity and "avoid perpetuating inequities through the development of green infrastructure": prioritize GI in communities that have a want or need for it and are supportive of GI as a solution, employ methods and criteria that match stated justice goals, and implement such projects alongside policies or regulations that address systemic racism in planning. Similarly, Grabowski, McPhearson, and Pickett[55] examined GI planning processes from 20 US cities and identified several best practices: explicitly define what is meant by equity and justice, confront uneven development and displacement, and meaningfully include communities in the implementation and evaluation of GI plans. Pathak, Glick, et al.[56] argue that inequitable processes or outcomes can be a barrier to successful implementation or adoption. They recommend that equity in NBS can be applied in three ways: recognize the rights and interests of different actors, build on inclusive and effective participation, and ensure equitable distribution of costs and benefits amongst all the relevant actors.

3.1.6. Stakeholder Engagement

Stakeholder engagement is the most commonly acknowledged or recommended element of effective and equitable approaches to NBS. Most researchers have a common notion that NBS projects must involve stakeholder participation. However, the word stakeholder is a very broad term which can be used to refer

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[50] Fushcia-Ann Hoover et al., "Environmental Justice Implications of Siting Criteria in Urban Green Infrastructure Planning," Journal of Environmental Policy & Planning 23, no. 5 (September 3, 2021): 665–82, https://doi.org/10.1080/1523908X.2021.1945916; Zbigniew J. Grabowski, Timon McPhearson, and Steward T. A. Pickett, "Transforming US Urban Green Infrastructure Planning to Address Equity," Landscape and Urban Planning 229 (January 1, 2023): 104591, https://doi.org/10.1016/j.landurbplan.2022.104591.

[51] Dagmar Haase et al., "Greening Cities - To Be Socially Inclusive? About the Alleged Paradox of Society and Ecology in Cities," Habitat International 64 (2017): 41–48, http://dx.doi.org/10.1016/j.habitatint.2017.04.005; Hallie Eakin et al., "Entry Points for Addressing Justice and Politics in Urban Flood Adaptation Decision Making," Current Opinion in Environmental Sustainability 51 (August 1, 2021): 1–6, https://doi.org/10.1016/j.cosust.2021.01.001; Hoover et al., "Environmental Justice Implications of Siting Criteria in Urban Green Infrastructure Planning"; Pathak et al., "Incorporating Nature-Based Solutions Into Community Climate Adaptation Planning"; Pathak et al., "Key Considerations for the Use of Nature-Based Solutions in Climate Services and Adaptation"; Grabowski, McPhearson, and Pickett, "Transforming US Urban Green Infrastructure Planning to Address Equity."

[52] "Greening Cities - To Be Socially Inclusive? About the Alleged Paradox of Society and Ecology in Cities."

[53] "Entry Points for Addressing Justice and Politics in Urban Flood Adaptation Decision Making."

[54] "Environmental Justice Implications of Siting Criteria in Urban Green Infrastructure Planning."

[55] "Transforming US Urban Green Infrastructure Planning to Address Equity."

[56] "Incorporating Nature-Based Solutions Into Community Climate Adaptation Planning."

to a lot of different individuals or entities. The word stakeholder may be used in reference to project planners/designers[57], policy makers[58], residents and businesses[59], and scientists/researchers[60].

Where in the process should the stakeholders be involved?

Most scholars advise that stakeholders should be involved in the planning and designing phase.[61] Others discuss the use of stakeholder participation and the stakeholders' perspectives to aid in assessing the co-benefits of a NBS project.[62] Although most agree that stakeholders should be involved in the planning, designing, and assessment of co-benefits processes, they offer different reasons for including these stakeholders. The most common reason is to gain knowledge from stakeholders (especially locals) and understand their perspectives. By doing this, planners, designers, and/or policy makers can get an idea of the local and cultural context, ensure that everyone is benefiting from the NBS, and identify any challenges that may cause issues with the NBS project. Albert et al.[63] describe numerous challenges that

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[57] Nadja Kabisch et al., "Nature-Based Solutions to Climate Change Mitigation and Adaptation in Urban Areas: Perspectives on Indicators, Knowledge Gaps, Barriers, and Opportunities for Action," Ecology and Society 21, no. 2 (June 1, 2016), https://doi.org/10.5751/ES-08373-210239; Raymond et al., "A Framework for Assessing and Implementing the Co-Benefits of Nature-Based Solutions in Urban Areas"; Giordano et al., "Enhancing Nature-Based Solutions Acceptance through Stakeholders' Engagement in Co-Benefits Identification and Trade-Offs Analysis"; Albert et al., "Planning Nature-Based Solutions"; Veronica Alejandra Neumann and Jochen Hack, "Revealing and Assessing the Costs and Benefits of Nature-Based Solutions within a Real-World Laboratory in Costa Rica," Environmental Impact Assessment Review 93 (March 2022): 106737, https://doi.org/10.1016/j.eiar.2022.106737.

[58] Kabisch et al., "Nature-Based Solutions to Climate Change Mitigation and Adaptation in Urban Areas"; Raymond et al., "A Framework for Assessing and Implementing the Co-Benefits of Nature-Based Solutions in Urban Areas"; Frantzeskaki, "Seven Lessons for Planning Nature-Based Solutions in Cities"; Albert et al., "Planning Nature-Based Solutions"; Neumann and Hack, "Revealing and Assessing the Costs and Benefits of Nature-Based Solutions within a Real-World Laboratory in Costa Rica."

[59] Kabisch et al., "Nature-Based Solutions to Climate Change Mitigation and Adaptation in Urban Areas"; Raymond et al., "A Framework for Assessing and Implementing the Co-Benefits of Nature-Based Solutions in Urban Areas"; Cohen-Shacham et al., "Core Principles for Successfully Implementing and Upscaling Nature-Based Solutions"; Frantzeskaki, "Seven Lessons for Planning Nature-Based Solutions in Cities"; Giordano et al., "Enhancing Nature-Based Solutions Acceptance through Stakeholders' Engagement in Co-Benefits Identification and Trade-Offs Analysis"; Albert et al., "Planning Nature-Based Solutions"; Sowińska-Świerkosz and García, "A New Evaluation Framework for Nature-Based Solutions (NBS) Projects Based on the Application of Performance Questions and Indicators Approach"; Kabisch, Frantzeskaki, and Hansen, "Principles for Urban Nature-Based Solutions"; Neumann and Hack, "Revealing and Assessing the Costs and Benefits of Nature-Based Solutions within a Real-World Laboratory in Costa Rica."

[60] Kabisch et al., "Nature-Based Solutions to Climate Change Mitigation and Adaptation in Urban Areas"; Frantzeskaki, "Seven Lessons for Planning Nature-Based Solutions in Cities"; Sowińska-Świerkosz and García, "A New Evaluation Framework for Nature-Based Solutions (NBS) Projects Based on the Application of Performance Questions and Indicators Approach"; Neumann and Hack, "Revealing and Assessing the Costs and Benefits of Nature-Based Solutions within a Real-World Laboratory in Costa Rica."

[61] Kabisch et al., "Nature-Based Solutions to Climate Change Mitigation and Adaptation in Urban Areas"; Nesshöver et al., "The Science, Policy and Practice of Nature-Based Solutions: An Interdisciplinary Perspective"; Raymond et al., "A Framework for Assessing and Implementing the Co-Benefits of Nature-Based Solutions in Urban Areas"; Bush and Doyon, "Building Urban Resilience with Nature-Based Solutions"; Calliari, Staccione, and Mysiak, "An Assessment Framework for Climate-Proof Nature-Based Solutions"; Frantzeskaki, "Seven Lessons for Planning Nature-Based Solutions in Cities"; Albert et al., "Planning Nature-Based Solutions"; Sowińska-Świerkosz and García, "A New Evaluation Framework for Nature-Based Solutions (NBS) Projects Based on the Application of Performance Questions and Indicators Approach"; Clifton Cottrell, "Avoiding a New Era in Biopiracy: Including Indigenous and Local Knowledge in Nature-Based Solutions to Climate Change," Environmental Science & Policy 135 (September 2022): 162–68, https://doi.org/10.1016/j.envsci.2022.05.003; Kabisch, Frantzeskaki, and Hansen, "Principles for Urban Nature-Based Solutions"; Neumann and Hack, "Revealing and Assessing the Costs and Benefits of Nature-Based Solutions within a Real-World Laboratory in Costa Rica."

[62] Raymond et al., "A Framework for Assessing and Implementing the Co-Benefits of Nature-Based Solutions in Urban Areas"; Pagano et al., "Engaging Stakeholders in the Assessment of NBS Effectiveness in Flood Risk Reduction"; Giordano et al., "Enhancing Nature-Based Solutions Acceptance through Stakeholders' Engagement in Co-Benefits Identification and Trade-Offs Analysis"; Neumann and Hack, "Revealing and Assessing the Costs and Benefits of Nature-Based Solutions within a Real-World Laboratory in Costa Rica."

[63] "Planning Nature-Based Solutions."

may arise in NBS projects such as issues with local laws, societal dimensions, irreversible ecological damage, and human-nature relationships such as ecosystem service distribution. Having this local knowledge and an idea of the cultural context allows planners and designers to incorporate an inclusive design that, "considers all dimensions of socio-environmental justice."[64] However, community engagement may not just be about improving the NBS project. Kiss et al.[65] found that stakeholder participation may not necessarily enhance the environmental and ecological sustainability outcomes of an NBS. They did, however, find that it provides some socially sustainable outcomes by cultivating a sense of belonging, social learning, and increasing motivation within the engaged community for protecting the environment. Stakeholders may be involved in the planning, designing, and assessment of co-benefit processes through interviews, workshops, surveys/questionnaires, and group exercises.[66] Scholarship on NBS and community engagement offers guidance on who the stakeholders are, why it is important for them to be involved, and how to involve them in the NBS project, however, most do not discuss exactly what the outcomes are as a result of involving community stakeholders in an NBS project.

Stakeholder Involvement Post NBS Implementation

Although most researchers advise involving stakeholders throughout the NBS planning and design process, only a few discuss any role after implementation. Raymond et al.[67] argue that stakeholders need to be a part of the entire lifespan of the NBS in order to communicate the co-benefits. Others[68] advise having stakeholders involved in the management and evaluation of the NBS project which is usually done after the NBS has been implemented. If the planners, designers, and policy makers used stakeholder participation to make sure that the NBS is equitably beneficial to the community, then stakeholder involvement should continue after the NBS has been implemented. This will allow them to understand how the NBS is working and to assess whether or not the NBS is indeed providing the benefits/co-benefits they assessed before implementation and ensure that the NBS is not negatively impacting the community. Ferreira et al.[69] note that of the few NBS articles focusing on stakeholder engagement, fewer have looked at the perceived risks from community involvement in NBS, or conversely, "how NBS are perceived as contributing to reduce social injustice."

3.1.7. Discussion

Our review of scholarly and gray literature on Nature Based Solutions (NBS) shows that NBS encompass a very wide range of interventions. The term is used interchangeably with Green Infrastructure (GI) and similar terms referring to the "use of nature" in place of, or alongside, conventional engineering approaches to address environmental needs or challenges. Although NBS have been widely adopted by scholars and practitioners to address climate change risks, the literature and guidance on how to equitably plan and implement such projects is uneven. Most scholarship and guidance recommend that social equity be taken into account, but there is less specific guidance on how to do this in practice, or examples of how

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[64] Kabisch, Frantzeskaki, and Hansen, "Principles for Urban Nature-Based Solutions."

[65] "Citizen Participation in the Governance of Nature-Based Solutions," Environmental Policy and Governance 32, no. 3 (2022): 247–72, https://doi.org/10.1002/eet.1987.

[66] Pagano et al., "Engaging Stakeholders in the Assessment of NBS Effectiveness in Flood Risk Reduction"; Giordano et al., "Enhancing Nature-Based Solutions Acceptance through Stakeholders' Engagement in Co-Benefits Identification and Trade-Offs Analysis"; Albert et al., "Planning Nature-Based Solutions"; Sowińska-Świerkosz and García, "A New Evaluation Framework for Nature-Based Solutions (NBS) Projects Based on the Application of Performance Questions and Indicators Approach"; Neumann and Hack, "Revealing and Assessing the Costs and Benefits of Nature-Based Solutions within a Real-World Laboratory in Costa Rica."

[67] "A Framework for Assessing and Implementing the Co-Benefits of Nature-Based Solutions in Urban Areas."

[68] Sowińska-Świerkosz and García, "A New Evaluation Framework for Nature-Based Solutions (NBS) Projects Based on the Application of Performance Questions and Indicators Approach"; Cottrell, "Avoiding a New Era in Biopiracy."

[69] "Stakeholders' Engagement on Nature-Based Solutions."

this can be done. Methods to estimate the benefits of NBS are dominated by monetary metrics of environmental or ecological services or outcomes, while metrics of social or equity-related outcomes are much less common. A minority of scholars warn about potential negative social equity outcomes, tradeoffs, or disservices of NBS. The most common concern is the potential for "green gentrification." However, the literature on "green gentrification" is not yet able to disentangle "green gentrification" from "non-green" gentrification. Moreover, scholars argue that interventions to mitigate gentrification or displacement likely require wider engagement with the political and economic context of communities than is typical of NBS or GI projects. One area of common agreement is the importance of stakeholder engagement for planning, implementing, and measuring the effectiveness of NBS. There is considerably more guidance on stakeholder engagement, as well as examples. However, the word "stakeholder" is not often defined, and as with other social outcomes, there is less guidance on how to measure the effectiveness of such engagement.

3.2. Synthesis of Interviews

This section provides a synthesis of interviews conducted with representatives of community-based organizations (CBOs), community development corporations (CDCs), and municipal or regional planners from coastal communities with environmental justice populations in the greater Boston region. The aim of these interviews was to understand community perceptions and experiences of NBS and coastal resilience projects more generally. Responses and quotes have been anonymized as much as possible to protect participants' privacy.

3.2.1. Limited understanding of, or experiences with, Nature Based Solutions in coastal urban communities

Most participants are aware of NBS conceptually, though few have direct experience or involvement with these projects. Similar to the literature on NBS, most participants made little distinction between NBS, green infrastructure (GI), and analogous concepts. Participants relate to the concept of coastal NBS primarily through experience with inland "green infrastructure" projects, such as parks, pervious paving, street trees, rain gardens, or similar unconventional engineering efforts to deal with stormwater and urban flooding. Although all participants represented coastal communities, some participants were not aware of completed or ongoing coastal NBS projects within or immediately adjacent to their communities.

3.2.2. Support for NBS but with concerns for their relevance, prioritization, and sustainability

Participants generally support investments in NBS or GI within their communities, although most expressed one or more concerns about its relevance to other pressing community issues, who will benefit from these projects, their effectiveness in addressing longer term flooding risks, and the capacity or willingness of the government to invest adequately in these solutions or to maintain them.

The value of NBS is apparent both from public incentives and from experience with previous GI projects. Participants are aware that NBS are being promoted by various state policies and that there are financial incentives to encourage their use. There is also recognition that NBS can be effective solutions with co-benefits. One participant recalled earlier initiatives by their city to mitigate stormwater runoff through community awareness campaigns led by CBOs and "engineered nature" projects, such as tree planting, pervious paving, and rain gardens. The environmental impacts of these efforts were marginal, in part because they were implemented in an ad hoc way and on a very small scale relative to the pace of conventional development. The main benefits were educational.

> "But to, to actually get people thinking about how you want the water to go into the ground, and get people thinking more about greenspaces and the benefits they provide, both for you personally, but then for the neighborhood as well, making connections,

> because a lot of these projects were done in collaboration with informal neighborhood groups, so building social capital and connecting to people, so there was a lot of positives."

Based on experience with GI, there is concern about municipalities' capacity to maintain or invest in NBS. Several participants noted that innovative GI projects often require maintenance tasks or routines that are more labor intensive, or which require unfamiliar maintenance regimes that may also complicate budgeting and lines of responsibility.

> "So you put in that little bioswale instead of the sidewalk. Now instead of a sidewalk sweeper just going down the sidewalk and cleaning it, you actually have to have somebody go by and pick the trash out of the daylilies, and things that are growing in that bioswale, or whatever vegetation, you know, water philic, hydrophilic vegetation you've got in your bioswale. It's gonna get the same candy wrappers and lottery tickets, and everything. It'll blow in there, and you can't just sweep it. You gotta like break it, or you gotta reach in and grab it. And so ... for these tree pits, you have to have regular maintenance of them. And it's not just like the [public works department] opens up the storm drain and just puts the bucket down and just pulls out all the shit that's been accumulating. They actually have to go in and open up these things, and it's a much more involved process to sort of maintain the functions of some of these interventions. You have to vacuum permeable asphalt, you know, to make sure that the pores remain open, so you have to run a vacuum over it. … All of that sort of stuff becomes more complicated."

> "[I]f cities want to be serious about actually using green infrastructure to mitigate climate risks, they're going to need to figure out how to maintain green infrastructure, but it's not there yet."

There is also concern that such interventions not only challenge municipal organization and budgets in general, but that there is a lack of appreciation for the unequal capacity of communities to sustain these interventions. Two separate participants related the same story of a failed rain garden at a public housing development in a historically marginalized community. The rain garden was originally installed on the grounds of the public housing project by the City with resident input. However, there was no apparent commitment or coordination about who would maintain the rain garden. There was an assumption that residents would maintain it, but no effort was put into engaging residents after it was installed. There was no consideration of the mobility of the residents, or the fact that as renters they might have less incentive to maintain land that they do not own. Without dedicated maintenance, the rain garden eventually filled with debris and became more of a nuisance than a help for mitigating flooding. Similar concerns about capacity were raised regarding the temporary, grant-based funding for many NBS or GI projects. How would longer term costs be handled by communities with less resources?

Although there is general agreement on the value and need for NBS in addressing climate resiliency, participants are skeptical of governmental capacity or political will to implement such interventions on the scale needed, to push back against the economic pressure to develop any available real estate, or to capture adequate physical space within the constraints of largely built-out urban communities. Experience to date has shown NBS or GI interventions to be happening on a small, "piecemeal" scale that environmentally focused CBOs argue is inadequate to meet the magnitude of the risks presented by climate change.

> "… some of the interventions that are needed are not compatible with the scale at which the city really does its planning and the scale at which the city operates, which is parcel-by-parcel, and we're talking like 2,000 square feet, or something like that. You need acres for these coastal interventions to work."

> "I guess my only question with some of the coastal resilience ideas, ... I honestly can see a lot of value with an area like New Orleans, you know, Louisiana. I'm not sure. Boston is so built out."

> "… it just blows my mind that people just, you know, they keep talking about having a living shoreline in front of our development, and we're gonna put up a berm. Like that's the solution."

The relevance of NBS to historically marginalized communities is contingent on their ability to provide tangible, material benefits directly to these underserved communities, and to support community priorities that are more immediate and pressing, such as housing affordability and access.

> "I think the big thing that comes up for us as lot is like who has access to these spaces. Where are they in relationship to various neighborhoods? Where is the emphasis put on reinvestment in thinking about, is it being done to clear the way for more gentrification and more folks coming in from outside of [the City], or is it being done to reinvest in the communities that have been disinvested in?"

> "Our main focus is housing and climate justice, as well, but I think it's like, before you can reinvest it in parks, you need to think about ... the neighborhood holistically rather than like how can we fix up these greenspaces. It's just that the housing issue is so acute for folks that nothing else can take precedence over that…"

3.2.3. Gentrification is a top concern, but not necessarily green gentrification

In contrast to the literature on NBS and GI, participants in marginalized communities uniformly rejected the idea that green gentrification is a relevant concern.

Although participants intuitively understand the logic behind the idea of green gentrification, none see NBS or analogous 'greening' activities as being primary, or even significant, drivers of rising housing costs and resulting displacement of lower income residents. Rather they point to larger, macroeconomic, and regional trends that have evolved over years preceding these projects.

> "… the biggest thing with housing, you know, is just the pace of development, the pace of speculative development."

> "When we talk about green displacement, green gentrification, it's just gentrification."

> "[People say] 'If you put in this thing to prevent flooding then, you know, it's going to displace the poor people who live here.' Well, if you put in the park, or if you put in new pavement or a bike lane, that's also going to result in, in displacement. So, you could have transit-oriented displacement. You could have green infrastructure displacement. It doesn't really matter. Green gentrification is just gentrification. The market has absorbed some of these sustainability goals and is using those to market the units they're selling. … So the gentrification occurs, and whether or not it's green gentrification just has to do with what the latest investments are in the neighborhood that sort of sweeten the deal for gentrifiers."

Some participants noted that they have no practical way of knowing the degree to which any particular project contributes to gentrification.

Whether or not NBS or other greening investments contribute to gentrification, there is a clear message that marginalized communities want these investments and the amenities that they bring, which is consistent with the findings by Meenar, Heckert, and Adlakha.[70] This perspective was voiced in different ways by all participants. These green investments are recognized as essential infrastructure that must be a part of the equitable development of all communities, especially those that have experienced underinvestment.

> "… the folks who are part of our organization, the members, you know, really do care about these things, really do care about access to good quality natural spaces, connection to the natural world. … It's like we have communities that have been disinvested in infrastructurally for years, and years and years, both in terms of the housing, but also in terms of the sewer systems and the roads and the sidewalks and all of these things that are relevant in relation to climate and climate resiliency, I think that people are conscious of, and care about, and are thinking about."

> "… I guess our approach is to try to build as much of the, is to try to make sure that there's as much affordable housing as possible and that what's built is as high quality as possible. So I don't know exactly how that plays to gentrification, but I'd rather see a new building built with sort of green infrastructure than a new building that's built and kind of ignores the problem, and it maybe won't even be around long-term because it's ignoring the problem …"

> "We hear from the community every time we have a community meeting, like 'we want more open space. We want more trees.' Like it doesn't seem like a solution would be to say, 'well, we're just not gonna improve these areas.' People want it, but, 'No, sorry. That might contribute to gentrification.' But of course, that's always the tension, I think, with any sort of project like this with that. It certainly does make the area more desirable and potentially more expensive, and it's also something we hear from the community that they can improve on."

Marginalized communities want investment that brings sustainability benefits, and which proactively addresses pressing economic and social problems of displacement and ongoing marginalization.

> "… anything else that happens in the city has to be seen through that lens, and we have to think about will that help – I think it's a less a thing of like we only need things that won't make that worse. I think it's a thing of we need projects that will directly think about mitigating that and making it better, and I think that's a tricky thing because that's not always the purpose of these types of [NBS or GI] projects."

> "… are these projects designed through an equity lens and then implemented through an equity lens that's not just in name, but actually in practice? Then, I think there's a lot of like really great opportunity because I think we need to address climate resiliency. We need to, you know, address the climate crisis, and we also need to address the system inequity, you know, in the city, and we can't separate one from the other."

3.2.4. Development in flood prone areas is unconstrained by policies or projects around flood risk

Contrary to the interviewers' expectations, participants uniformly agreed that private development along the coastline, or in other flood prone areas, continues unabated and with little to no disruption by governmental policies, regulations, or flood mitigation projects. This agreement is striking because there is also significant variation in how participants individually perceive these flood risks. While

[70] Meenar, Mahbubur, Megan Heckert, and Deepti Adlakha. 2022. "'Green Enough Ain't Good Enough:' Public Perceptions and Emotions Related to Green Infrastructure in Environmental Justice Communities." *International Journal of Environmental Research and Public Health* 19 (3): 1448. https://doi.org/10.3390/ijerph19031448.

environmentally focused CBOs see climate-related flood risk as an existential threat to their communities that is being improperly managed, housing-focused CBOs and municipalities see the risk as largely under control and manageable.

For participants engaged directly in affordable housing development, the largest threat is not from flooding, but rather from competition against commercial developers for scarce, developable land and control over the trajectory of community development.

> "Now, the city's plan is to allow development on all of these [coastal] sites. … But their plan is that when developers come in, you build the giant wall, and then we'll let you build as many units as you want, and that's not acceptable. We want them to build a lot, but we want some control over the affordability, and over the heights and density of the properties."

Participants engaged directly in affordable housing development described ongoing developments or plans for development in areas that are subject to some level of flood risk. They are cognizant of these risks and describe little difficulty in addressing these risks to comply with applicable laws and regulations. In fact, they note that compliance with existing regulations covering development in flood prone areas is significantly less onerous than other regulations, such as those requiring public access or general environmental review.

> "… we have two projects where the parcels were either partially or fully in the flood zone, and so we needed to get an order of conditions, and do a MEPA filing, and apply for a Chapter 91 license, and by far, the thing that required the most time and thought and, I don't know, just attention, was the Chapter 91 license. And that's not to say that public access to waterways isn't important because it absolutely is, but you know, we could kinda propose what we wanted in terms of resiliency, and it felt like we went above and beyond, I think what would have been regulatory required of us that didn't seem super onerous and, in some ways, I wonder if that's like a little backwards."

> "Our experience has been that, that we need to do the thinking around, at least from a storm water perspective, we need to be thinking around resiliency because there's not necessarily a regulatory framework that's challenging us there. There, there are requirements, but they're not as onerous as some other requirements."

Participants engaged directly in housing development describe wide latitude in how they can address flood risks, with relatively little guidance or specific requirements from regulations. Instead, they take their cues on flood risk, and appropriate mitigation of those risks, primarily from the recommendations of private architects and engineers, as well as their own sense of long-term responsibility for their residents. They describe a variety of approaches to mitigate flood risk, which varies from property to property: berms to "remove" a property from the flood zone (to comply with FEMA), grading and elevating sites, elevating buildings to allow water to pass beneath, and creating floodable open space. One participant contrasted their approach to the private developer practice of placing garages on the first floor to minimize the impact of periodic flooding, which is equally acceptable from a regulatory perspective, but likely less acceptable for a surprised tenant.

3.2.5. Poor community engagement practices undermine resiliency projects and perpetuate marginalization of underserved communities

While the outcomes of a given project are important to communities, participants observe that the processes of decision making and engagement are the most common failings. These community engagement failings are not just frustrating, they undermine the effectiveness of projects to meet community needs, and they contribute to cynicism and apathy, making future community engagement even more difficult.

Historically marginalized communities are further marginalized by exclusionary processes or structures of communication and participation. Municipal officials and other decision makers need to employ appropriate modes of communication, and trusted liaisons, in order to effectively communicate with these communities and to solicit their input. Favoring one mode of communication over another because of its convenience for decision makers (e.g., web-based surveys vs in-person meetings), or failing to monitor who has participated and who has not participated in community feedback, can result in biased participation and data gathering that excludes certain groups of residents.

Two participants representing different communities told remarkably similar stories about how municipal officials used practices of community engagement that effectively excluded the most marginalized members of their communities and their needs. In one case, the City was holding community meetings over the course of several years to decide how to renovate a park for better flood mitigation. Members of a historically underrepresented neighborhood in the City attended these meetings faithfully to ensure that their preferred option was kept on the table. However, in a meeting where officials chose to eliminate the neighborhood's preferred option (and which the members of the underrepresented neighborhood were unusually absent because of an unexplained breakdown in email notifications), City officials opted to prioritize the results of an online poll of residents for a different option. The participant confronted City officials about the failure in proper notification about the vote, but City officials held that decision was binding. A subsequent report of City deliberations acknowledged that residents who attended the meetings in person were more favorable to the neighborhood's preferred option, but that residents who voted in an online poll were not. The city opted to favor the results of the online poll over in-person attendance without further justification.

> "So it takes a while to gain the trust of, of the residents, and then when you finally do gain enough trust to get them to participate and get involved, and then you go and do that. Mm, it makes it tougher for other, others who are well-intentioned and trying to do good things in the neighborhood to get them involved. So this is something that I'm kind of battling with."

A second participant related a similar story in another community. That City received a sizeable federal grant and sought community input on how to use the funds. Rather than attempting to convene community meetings or to coordinate with CBOs, the City launched an online survey to solicit feedback. The CBOs did not realize the significance of the survey initially but scrambled to organize residents and encourage participation. Many residents did not understand the significance of the City's email solicitations, or were skeptical about the value of participating. The CBOs communicated directly with City officials to express their concerns and to advocate for specific priorities for the most marginalized residents, particularly around the need for housing affordability assistance. But officials gave the electronic survey more importance, ultimately deciding to spend most of the money on park renovations.

> "… a lot of it was based off of saying, well, the survey was the survey, and like using it as this like weird absolute truth where it's really only this fraction of the population who even filled it out … it just didn't feel like a, it was like a community-engaged process, but not in a way that the voice of the community was put into practice …"

In subsequent opportunities to allocate more funding, multiple CBOs were able to coordinate their efforts and convince the City to allocate money toward housing assistance, but the amount still paled in comparison to that spent on green infrastructure. More importantly, the experience of the process provoked resentment.

Project proponents need to take the time to understand the needs and unique contexts of the communities that they reach out to, and the ways in which project benefits may, or may not, flow to underrepresented community members. One common issue is a disconnect in understanding about how to engage or understand the situation of renters versus property owners, and residents with varying levels of connection to a locality. One participant described efforts by their city to promote resiliency in an underserved neighborhood. City officials and the participant's CBO struggled to generate interest or participation, which the participant attributes to the lack of immediate relevancy to the context of community concerns. The neighborhood consists mostly of renters who do not often feel like they have a vested interest in the neighborhood, nor do they feel comfortable or empowered to ask the landlord to make changes that would benefit renters (e.g., more energy efficient appliances, better insulation to reduce heating/cooling costs). At the same time, many landlords or property owners do not live in the neighborhood and aren't involved in the neighborhood other than collecting rent and checking on their property or tenants. The City ultimately produced a report on resiliency for the community with recommendations, but there was little effort to communicate the recommendations to neighborhood residents. Equally problematic, most of the recommendations in the final report were geared toward property owners, so it was unclear how renters could pursue or benefit from these recommendations.

> "… folks need to investigate who their audience is, or who the stakeholders are - who they're going to expect to interview or try to get input from, and then take it from there. It's gonna take time, and, and hopefully, they plan way ahead of time so that they can dedicate the time necessary to learn who the players are, get to know who they are, where they are, earn their trust, to then be able to work with them."

Project proponents and officials need to be transparent, honest, and realistic about the real benefits or costs of a given project for the community. Overpromising of potential outcomes or benefits of past projects has left some community members wary of the value of participation or the degree to which input will actually result in promised benefits. One participant recounted how a conservation organization worked with a regional university to plan significant improvements of a neglected local park within the community. The engagement process generated significant enthusiasm for this community that was sorely lacking in recreational space. The project organizers convened public meetings to solicit community participation in design of the park. Unfortunately, later testing revealed soil contamination, which required expensive remediation that consumed a large part of the budget. The resulting park fell far short of community hopes, but more importantly, contributed to a sense of futility in the value of participating for this already marginalized community.

> "And then the equipment that was expected for the, you know, young children to be able to play with, ended up being, you know, a soft landing spot and, and a little twirly thing. … and so you've invested all that time and energy in meetings and that's your final project. Now, people aren't gonna understand, 'oh, they found toxins in there. They have to use the money for that.' No, what they're gonna go back to is 'I spent three hours on four occasions each time listening and looking at designs and picking out and giving my input, and this is what I get.'"

Historically marginalized communities are willing to make the time to engage in public decision making when there is a relevant material benefit to the community, and the community's participation can actually influence the process and outcome. Project proponents must recognize that community participation is not a costless activity, and that community members' time and attention is just as valuable and as scarce as their own. Participation is not its own reward. Participation by underrepresented communities as a symbolic form of representation is offensive and exhausting. Participation needs to be taken seriously and be part of a reciprocal relationship of trust.

> "… there's this element of like everybody wants that representation at the table but then, like that has to go two ways, and like there's been so many times that people have just been like, 'yeah, we'd love to consult you on this.' You know, 'we'd love to like, you know, have you give input or fill out this survey, or come to this meeting space,' and then we don't see any of the results, or we're not like a part of the actual like concrete implementation of things in a way that feels meaningful to folks, so, yeah."

> "… people are just so tired of being involved in name and … being involved superficially. There's such a fatigue with that, and being involved in things that don't really quite matter to them because they're being, because the whole process is already set up in such a way."

For participants primarily engaged in affordable housing advocacy or development, the value of participating in GI or NBS projects for the community is not always clear. One participant noted that his CBO has been repeatedly invited to meetings on a proposal to develop a coastal park in an underutilized section of the City, but they are not inclined to participate because the relevance to their underserved community has not been made clear.

> "… it doesn't feel, like I was saying, sort of directly linked enough to reinvestment in working class communities or intersections of housing and climate. ... I see the emails from various folks being like, 'we have a input session on this,' or 'do you want it,' and like we could insert ourselves there, but it just doesn't feel worth the time and energy, not because it's not important, but because it's just, there's only so much we can do."

3.3. Expected Annual Losses Based on the Massachusetts Coastal Flood Risk Model (MC-FRM)

Assessing the current and future coastal flood risks to the Massachusetts coast, as well as understanding the risks to the residences and lives of sub-populations of concern, requires a clear understanding of the current and future vulnerabilities in the coastal zone. Future vulnerabilities are defined by the evolution of climate change through the 21st century, in particular the combination of sea-level rise and episodic storm surge – with the latter worsening over time as the pattern, frequency, and severity of coastal storms (particularly hurricanes) is affected by changes in climate and sea-surface temperature.

We use as our starting point the risks to coastal infrastructure of all types, and then explore the insights gained and potential pitfalls of alternative metrics aimed at understanding the vulnerability of populations of concern. Ultimately, this provides a foundation for considering the benefits of action to reduce those vulnerabilities, through nature-based solutions, more traditional "hard" infrastructure, or a combination of both. This section focuses on establishing a foundation for the current and future vulnerability of coastal infrastructure.

As noted in the Methods section above, the results presented here reflect analysis of MC-FRM flood risk data and the application of methods from Neumann et al. (2021)[71] to estimate flood damages. These methods closely follow those applied in the 2022 Massachusetts Climate Assessment (Commonwealth of Massachusetts, 2022). The relative sea level rise projections developed for the Commonwealth of Massachusetts, and used as input into the MC-FRM, use a probabilistic approach, closely following the methodology developed by Kopp et al. (2014), with the ice mass model outputs presented by DeConto and Pollard (2016).[72]

A few key insights emerged from the Climate Assessment analyses, as follows:

[71] Neumann, J. E., Chinowsky, P., Helman, J., Black, M., Fant, C., Strzepek, K., & Martinich, J. 2021. Climate effects on US infrastructure: the economics of adaptation for rail, roads, and coastal development. Climatic Change. https://doi.org/10.1007/s10584-021-03179-w

[72] Kopp, R.E., Horton, R.M., Little, C.M., Mitrovica, J.X., Oppenheimer, M., Rasmussen, D.J., Strauss, B.H., and Tebaldi, C. 2014. Probabilistic 21st and 22nd century sea-level projections at a global network of tide-gauge sites. Earth's Future, 2, 383–406, doi:10.1002/2014EF000239;DeConto, R. M., and Pollard, D. 2016. Contribution of Antarctica to past and future sea-level rise. Nature, 531(7596), 591–597.

- Overall, the consequences of coastal property damage from increased coastal flooding were projected to be extreme (the highest category for Magnitude of Consequence used in the assessment) due to widespread and substantial potential for damage to coastal structures.[73]
- The results indicated that current statewide annual average expected damages to coastal structures are about $185 million, based on the Commonwealth's coastal risk assessment for a base period of 1999-2017 – note that we can expect that damages in any one year could be more or less than this average over the full period.[74]
- Damages were projected to almost double by 2030 as a result of changes in sea level and storm surge activity, and almost double again, to over $600 million per year, by 2050. By 2070, statewide annual average damages could be more than $1 billion per year.[75]
- These estimates are the direct damages to structures and include damage to the contents of those structures. To provide context, the structure value alone within the floodplain of the current 100-year return period coastal storm is just under $55 billion, of which about $40 billion is residential, $12 billion is industrial, and $2.5 billion is commercial.
- The direct impacts in the Boston Harbor region (mostly Suffolk County, but also including some nearby municipalities in adjacent counties) show currently the region accounts for about 55 percent of the average annual statewide impact. However, projections show damages from coastal flooding could grow faster in the Boston Harbor region than in other areas of the state due to projected local sea level rise and the existing development footprint. By 2050 structures in the Boston Harbor region would account for almost 2/3 of statewide damages.

Figure 3-1 below provides a spatial representation of the results from the Climate Assessment. The figure displays the percentage of properties by census block group with a minimum of five percent Average Expected Damage (AED) forecast for the year 2070. Properties with a five percent AED are projected to experience annual damage equal to five percent of their total value, on average, by the year 2070. For example, a five percent annual average impact corresponds to damages of $10,000 for a structure valued at $200,000, and $100,000 for a structure valued at $2 million. As an annual average, this level of AED is large in magnitude, especially considering this average annual value could be larger in years with high storm activity. The map shows that census block groups with higher prevalence of severe damage to

[73] Magnitude of Consequence is one of the three pillars of risk ranking used, the other two being Disproportionality of Exposure and Climate Adaptation Gap. Magnitude of Consequence is a risk rating score designed to answer the question: How large of a climate effect do we expect from this impact? Consequence scores are built from an evidence base of quantified physical impacts (e.g., modeled projections of acres of marsh lost, number of buildings flooded); quantified economic impacts, including changes in expenses or revenues and welfare measures (e.g., delay cost, health risk); and qualitative measures of the impacts of climate change, specified for each sector. Magnitude of consequence scores are classified on a five-point scale, ranging from Extreme – the largest and most impactful outcomes—to Insignificant.

[74] The base period, centered on 2008, incorporates the actual sea level observations from 1999-2017. In this way, MC-FRM includes the actual observed sea level rise conditions that have occurred at each of three NOAA tide-gauge stations between 2000 and 2008, and also uses the relative sea level rise projections (all of which are referenced to mean-sea level, NAVD88).

[75] The SLR scenarios employed for this report follow those used by the Climate Assessment, which in turn are consistent with those selected by the Commonwealth of Massachusetts has selected as the preferred scenario for assessment of vulnerability and flood risk. This scenario is consistent with the following probabilities from Kopp et al. (2017):

- Unlikely to exceed (83%) under RCP8.5 when accounting for possible ice sheet instabilities;
- Extremely unlikely to exceed (95%) under RCP4.5 when accounting for possible ice sheet instabilities.

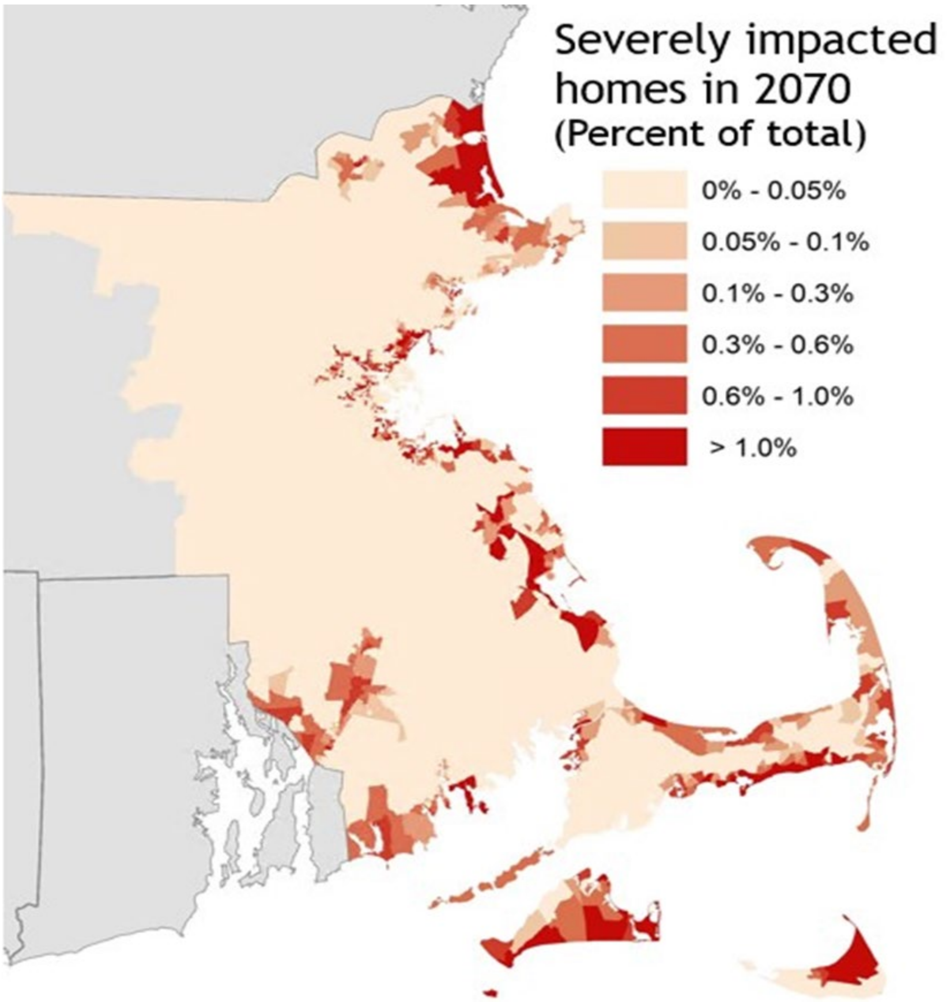
See Appendix B of the Climate Assessment and Kopp, R. E., DeConto, R. M., Bader, D. A., Hay, C. C., Horton, R. M., Kulp, S., Oppenheimer, M., Pollard, D., & Strauss, B. H. 2017. Evolving Understanding of Antarctic Ice-Sheet Physics and Ambiguity in Probabilistic Sea-Level Projections, Earth's Future,5,1217–1233, https://doi.org/10.1002/2017EF000663, for more details.

structures are distributed across nearly the entire length of the Commonwealth coast and islands, and not concentrated in any one location.

Although potentially severely impacted structures are prevalent throughout the Massachusetts coast, because the Climate Assessment notes the importance of the Boston Harbor region of the Commonwealth in terms of total damages, and because Massachusetts Environmental Justice populations are most prevalent in this region, much of the remainder of this section focuses on Suffolk County and surrounding areas. Those are the areas where it is most likely that coastal resilience and hazard mitigation steps such as NBS might be undertaken, and also where benefits of NBS might accrue to EJ populations.

Figure 3-1. Percent of Building Value Impacted by Coastal Flooding by 2070

The proportion of buildings in a census block group with 5 percent (of total value) or higher expected annual damage by 2070 as a result of the combined effect of sea level rise, tides, and episodic storm surge combined. Building scope includes residential structures, spatial scope includes the full area of all NOAA-designated coastal counties. Note that the estimated Annual Economic Damage (AED) threshold of 5 percent also averages a range of severe and less severe events and their probabilities, and individual events could have much larger impacts.



Source: Reprinted from Figure A15, 2022 Massachusetts Climate Assessment, using methods from Neumann et al. (2021)

3.3.1. Significance of Ratios vs. Absolute Values

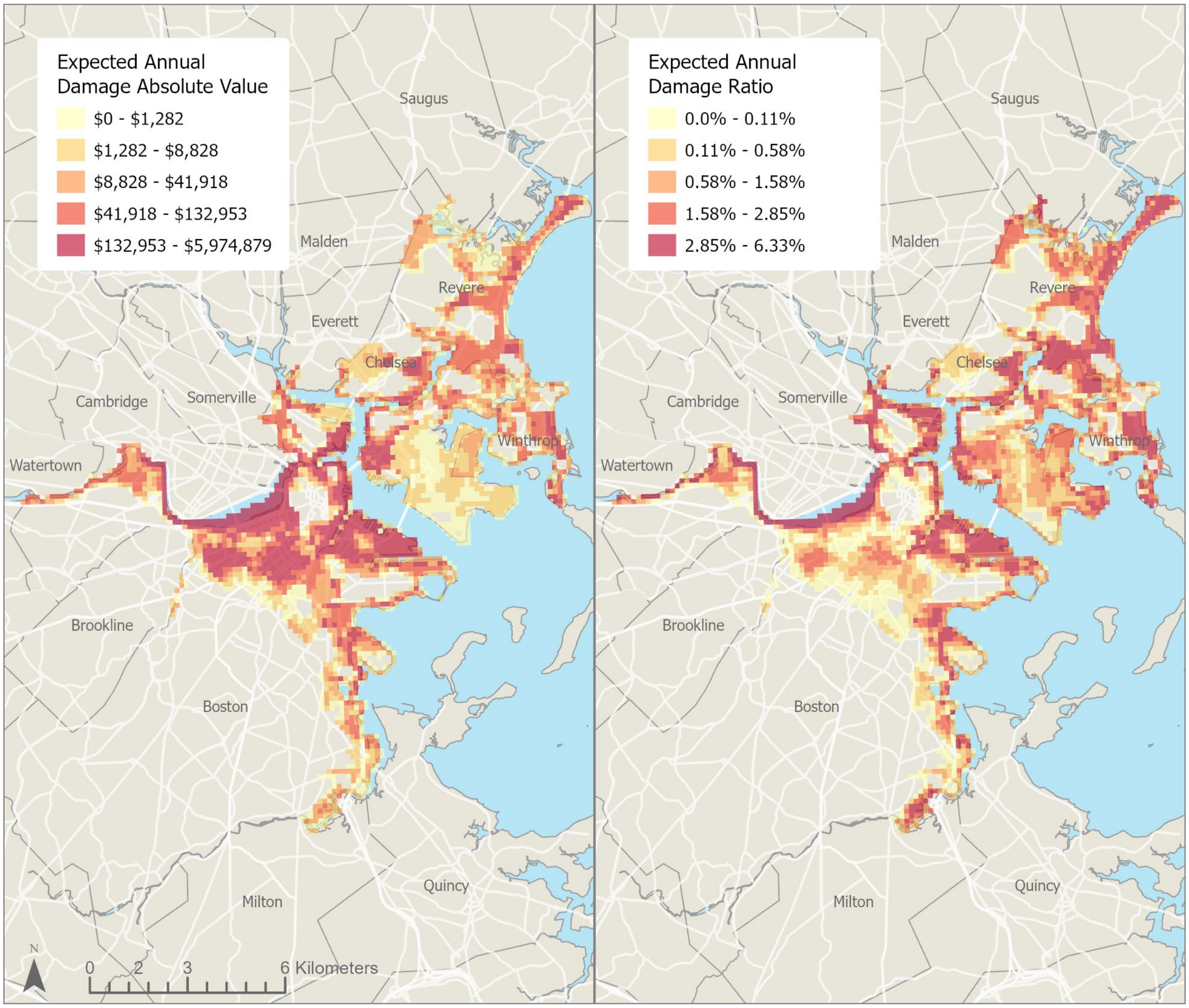
As briefly noted above, Magnitude of Consequence is one of the three pillars of risk ranking used in the Massachusetts Climate Assessment, the other two being Disproportionality of Exposure (an assessment of the distribution of impact among EJ populations) and Climate Adaptation Gap. Magnitude of Consequence is a risk rating score designed to answer the question: "How large of a climate effect do we expect from this impact?" In the Climate Assessment, absolute damages were used to rank Magnitude of Consequence, but a different measure, relative damages, were used to assess the potential for Disproportionality of Exposure. The use of absolute damages is appropriate for a cross-impact comparison, but the use of relative damages implicitly controls for wealth, at least in part. For example, $10,000 of storm-induced damage is an absolute measure, regardless of who bears the impact of that damage – but $10,000 is only 0.5% of a $2 million structure and is 5% of a $200,000 structure. The structure value serves as a proxy for the wealth of the owner (or renter) who might reside in that structure. The ability to absorb that damage, without forced displacement from the residence, is highly correlated with the available means and wealth of the structure's owner. In effect, low-income individuals are more likely to be adversely affected as they have fewer financial resources to protect against and support recovery from these hazards.[76] Therefore, the use of relative damages better captures potential impacts of concern to low-income, lower wealth populations of concern.

Figure 3-2 below provides an illustration of the difference between impacts measured on an absolute (Panel A) versus a relative scale (Panel B), with a focus on Suffolk County. In both panels, impacts are measured at a consistent 150 meter grid spatial scale, and the five gradations of color are expressed as ranked quintiles of grid cells, with equal numbers of grid cells in each of the five gradations. Panel A shows a pattern of "hotspots" of absolute damage that largely follows the most economically valuable structure values of the Massachusetts coast that are also vulnerable to coastal damage, such as the Back Bay and South End neighborhoods of Boston. However, these areas of high coastal value are also less likely to meet criteria for designation as EJ block groups. Panel B, using the relative "damage ratio" method, shows a somewhat different pattern of high damage concern, which controls for structure value. For example, parts of East Boston and Revere are in high quintiles of damage in Panel B compared to Panel A. The areas of Panel B in red also have a higher probability of including EJ block groups. Both methods nonetheless focus on areas with the greatest vulnerability to coastal flooding, usually characterized by proximity to the shoreline and low elevation. Because of the high amenity value of proximity to the shoreline, structure (as well as land) value is often closely correlated with shoreline proximity, and structure value commonly drops off as proximity to the amenity value and the high-risk potential of the shoreline diminishes.

[76] Howell J, Elliott JR. 2019. Damages done: the longitudinal impacts of natural hazards on wealth inequality in the United States. *Soc. Probl.* 66:448–467. https://doi.org/ 10.1093/socpro/spy016.

Figure 3-2. Differential Impact of Coastal Hazards in 2050 Using Absolute Damages Versus Relative Damages (Damage Ratio)

Panel A: Absolute Damages | Panel B: Relative Damages



Commonly, a benefit-cost analysis (BCA) of coastal adaptation measures makes use of absolute measures of value. In other words, the benefit of a protection structure is characterized by the efficacy of that measure in preventing absolute damages to structures. Vulnerability analyses also might rely on absolute values of damage. A shortcoming of that approach is that, when looked at in spatial terms, with an eye toward prioritizing adaptation action or NBS deployment, a focus on absolute values skews toward more valuable properties and likely implies that adaptation measures would disproportionately benefit higher income populations. This result has been found in some analyses of the incidence of "exclusion from adaptation" for EJ populations if adaptation decisions are made that rely on traditional benefit-cost analyses.[77]

3.3.2. Incorporating Other Equity Metrics

While relative value metrics are preferred over absolute value metrics for EJ focused risk and adaptation analyses, where possible, other metrics can also have value and should be explored to ensure that benefits of adaptation better target EJ populations. One option is to consider more directly impacts on residential renters – residential renters are more likely to also be members of EJ communities, compared to owners. Estimation of coastal hazard impacts to renters is more difficult than estimating impacts to all classes of structures, but some metrics can be explored at large scale and may be helpful in targeting benefits of adaptation for EJ populations.

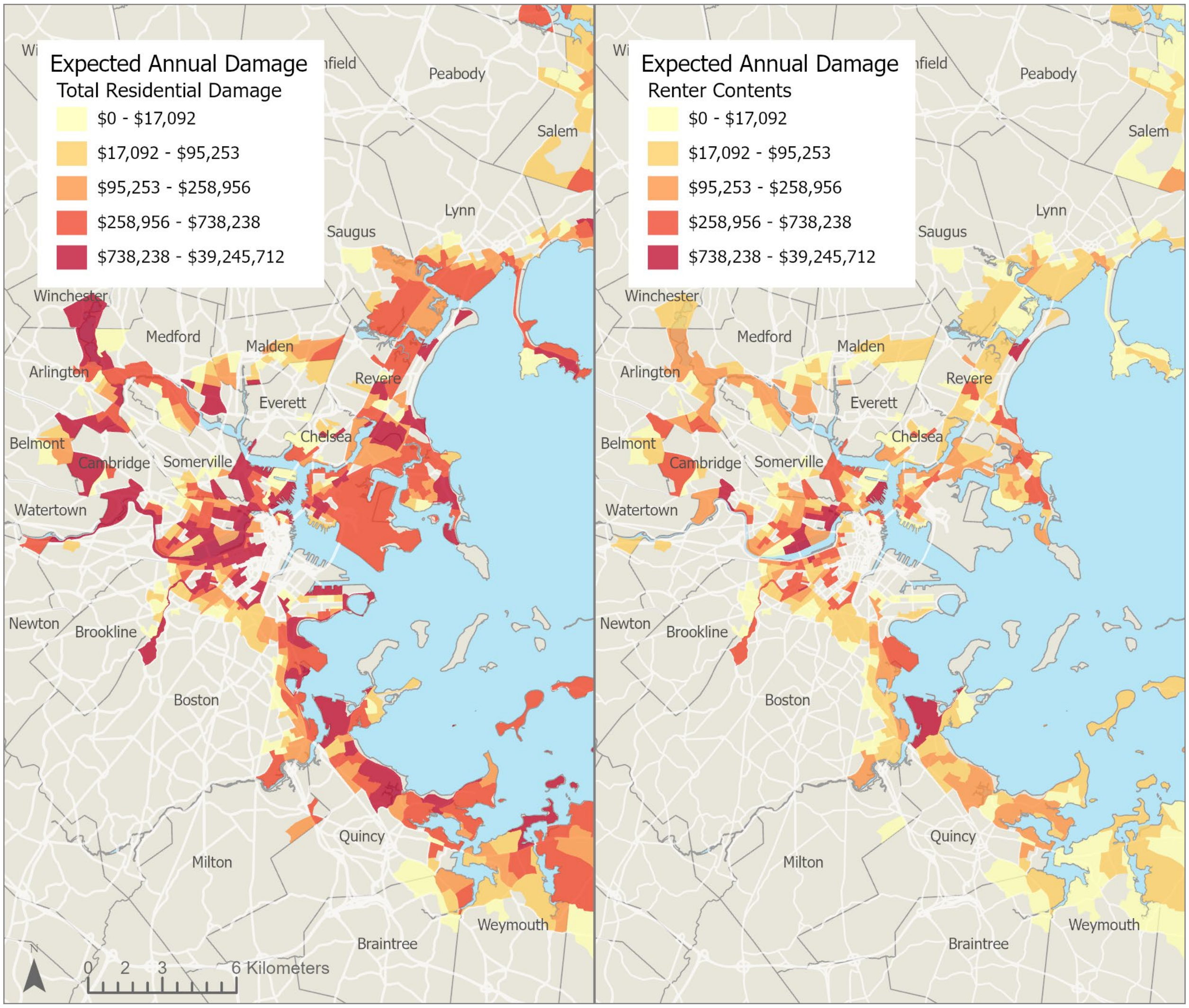
Figure 3-3 below illustrates the application of a readily estimated metric of impact, focused on damages to residential renters' "structure contents" which may be vulnerable to coastal flooding. Contents typically includes furnishings, apparel, appliances, and other personal property which may be inside a structure during a flood event. The geographic focus of Figure 3-3 is Suffolk County, but other nearby areas of the coast are also shown at the edges of the map. Panel A shows total EAD for all residential structures in 2050 – this measure includes damages to both the structure itself and its contents, and also includes structures (and their contents) which are both owner-occupied and rented. Panel B focuses only on the contents component of flood damage, and adjusts damages for the percentage of residents who are renters versus owners, using ACS data. The spatial unit of analysis for Figure 3-3 is census block group, and the quintile legend used in Panel A is used consistently in Panel B to facilitate comparison of the two metrics.

The pattern of damages for renter contents differs substantially from that for total residential damages. The hotspots for total residential damages are widespread across the region, but the hotspots for renter contents damages are focused in smaller subsets of area such as parts of Quincy, Somerville, Revere, and Allston.

[77] Martinich J, Neumann J, Ludwig L, and Jantarasami L. 2013. Risks of sea level rise to disadvantaged communities in the United States. *Mitig. Adapt. Strateg. Glob Change* 18:169–185, DOI 10.1007/s11027-011-9356-0; EPA. 2021. Climate Change and Social Vulnerability in the United States: A Focus on Six Impacts. U.S. Environmental Protection Agency, EPA 430-R-21-003.

Figure 3-3. Absolute Total Damages and Renter Contents Damages in 2050

Panel A: Total Residential Damages Panel B: Renter Contents Damages



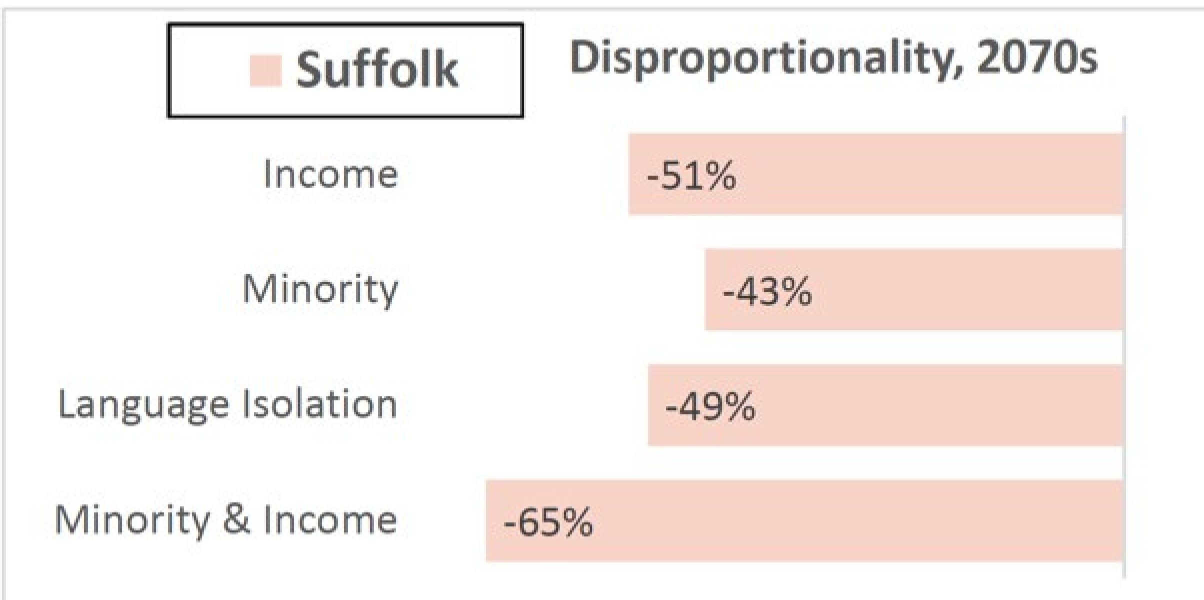
Data such as that applied in Figure 3-3 could be used to better target benefits of coastal protection to EJ populations. Such data can also be used to develop strategic plans for outreach to renters and, in particular, EJ communities within the rental population, to increase awareness of these benefits – as has been recently demonstrated in Mass Save's Massachusetts Strategic Renters Plan.[78]

[78] See for example, Mass Save 2022, Massachusetts Strategic Renters Plan, submitted September 22, 2022, available at https://ma-eeac.org/wp-content/uploads/Final-MA-Strategic-Renters-Plan-9-15-22-.pdf . The plan is focused on identifying barriers for renters to participate in Mass Save energy efficiency programs, some of which are specific to renters and some of which are specific to EJ populations. While focused on a different topic, strategic planning of this sort could also be applied in coastal resilience planning and could include similar targeting of EJ populations.

3.4. Social Vulnerability and Disproportionate Exposure Across the Massachusetts Coastline

The Massachusetts Climate Assessment included analysis of the potential for disproportionate exposure to coastal hazard damage using the same damage data described previously in this section, and the official Commonwealth of Massachusetts EJ block group designations.[79] For that analysis, the results were calculated statewide, and for multi-municipality regions, most of which constituted multiple counties. There were three coastal regions (Boston Harbor; North and South Shores; and Cape, Islands, and South Coast), and a fourth region with a small portion of tidally influenced areas near Taunton in what was called the "Eastern Inland" region. The disproportionality of exposure analysis largely found that coastal hazards primarily affect non-EJ populations, even when using a relative impact measure such as the damage ratio described above. Our knowledge of specific EJ concerns in the coastal area suggested that a more granular analysis, at county scale, could be beneficial. Table 3-1 reports the results of that analysis for Suffolk County – which reveals that even at county scale, EJ populations are not disproportionately affected by coastal flood hazards (the negative values in Table 3-1 indicate that EJ populations are less than proportionately affected). Put another way – our analysis shows that EJ populations are under-represented in the areas most vulnerable to coastal flooding, relative to their share of the overall population at county scale. This result is good news for EJ populations, but it does not mean that EJ populations as a whole are safe from this risk.

Table 3-1: Disproportionality of Exposure Measure for Suffolk County, Coastal Flood Risk



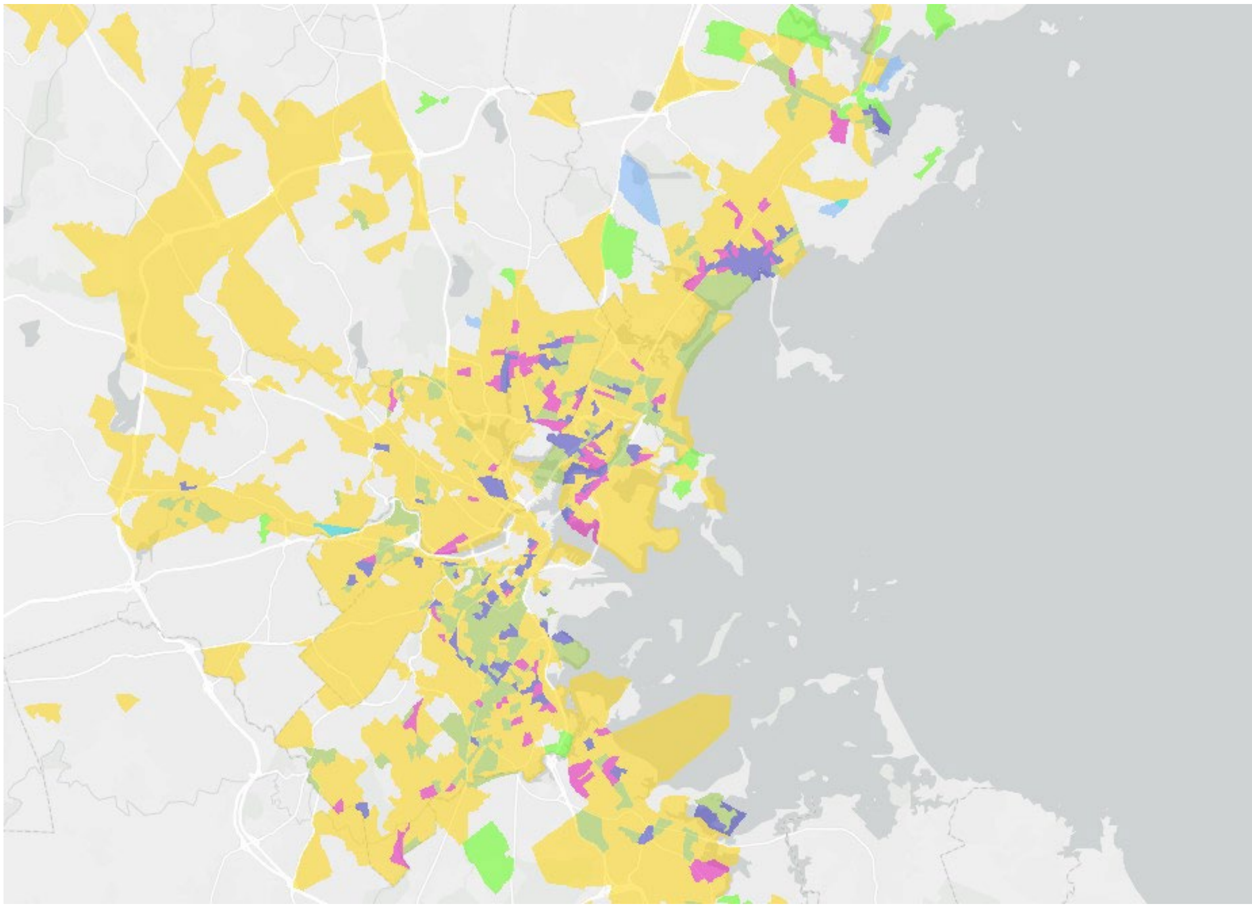
To provide a more flexible, customizable and spatially scalable means for assessing the combination of coastal risk and EJ population residency, we developed a GIS tool which overlays multiple measures of coastal risks, from both SLR and storms or both in combination, and at current and future time periods. The full scope of the tool is described in a data tool delivered separately from this report, but Figure 3-4 below provides a set of sample screenshots from the tool, focused on the Suffolk County area. Panel A

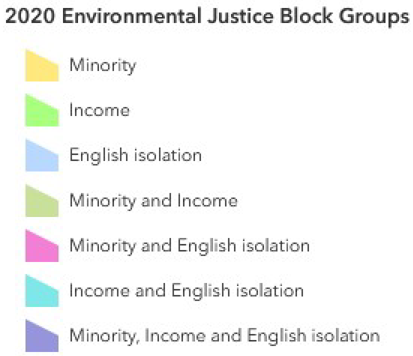
[79] "Massachusetts Climate Change Assessment." 2022. Commonwealth of Massachusetts. https://www.mass.gov/info-details/massachusetts-climate-change-assessment.

displays the block groups which qualify in each of the four EJ designation categories, as well three additional "combination" categories (i.e., block groups which meet the criterion for EJ designation for multiple categories). Panel A shows the high prevalence of EJ block groups in the Suffolk County/Boston Harbor area. Panel B shows the EJ block groups overlaid with a map of the projected 2050 1 percent annual change coastal flood risk (sometimes called the 100-year return period coastal floodplain). As shown in Panel B, many of the areas of projected coastal flood risk lie outside of EJ block groups, providing additional insight for the results in Table 3-1 above, but there are certainly exceptions that represent areas of both high coastal flood risk within EJ block groups. Alternative risk overlays are available for multiple annual change storm floodplains, for multiple sea-level rise levels, and for multiple years along the Commonwealth's preferred SLR scenario for adaptation planning. We encourage coastal planners to make use of the tool to better understand where NBS or other resilience investments might be targeted for maximum impact on EJ population risks.

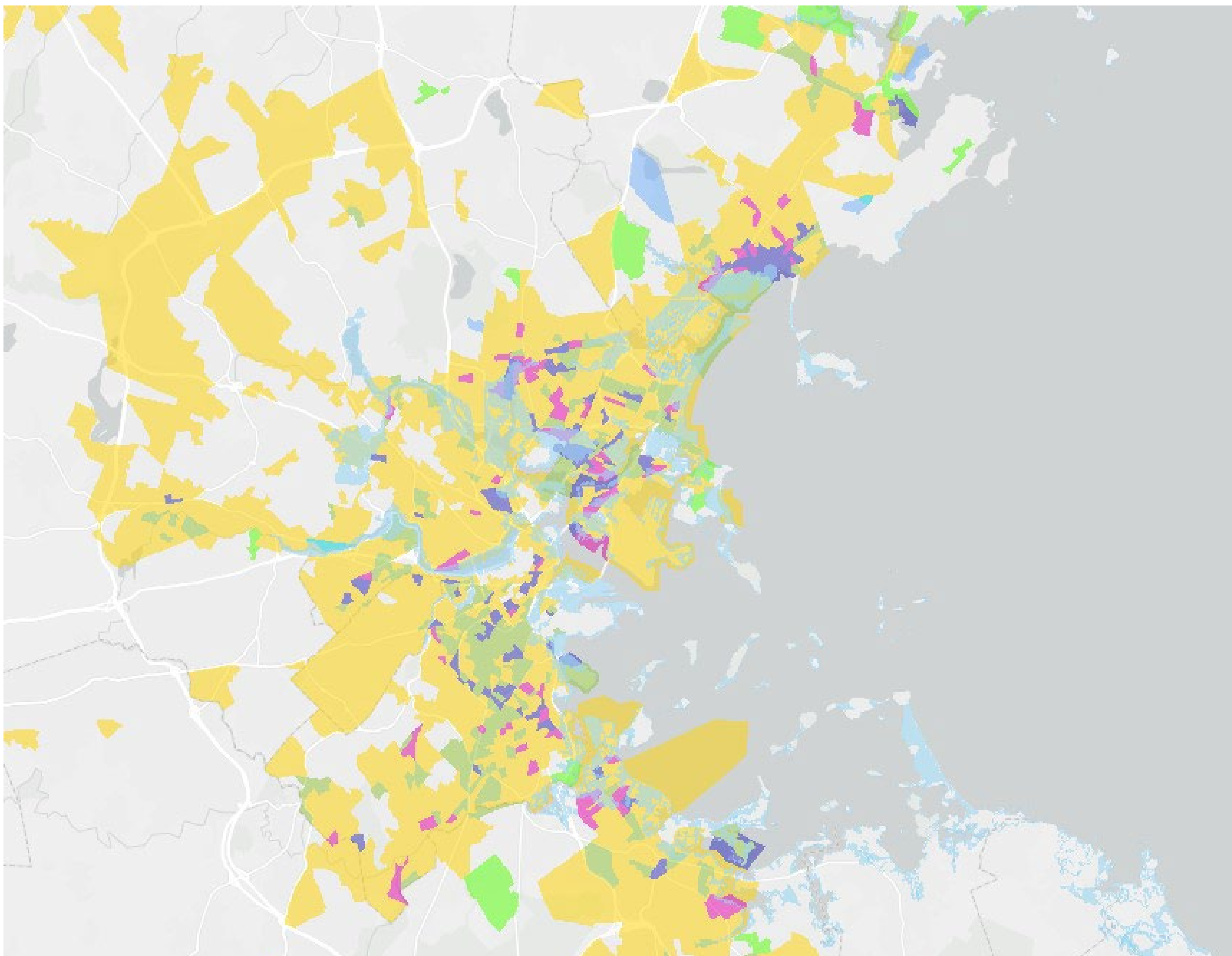
Figure 3-4. Sample Overlays of EJ Designated Block Groups and Flood Risk Zone in the Suffolk County/Boston Harbor Area

Panel A: Massachusetts EEA EJ Block Groups





Panel B: Block Groups Overlaid with the 2050 1 percent annual chance (100-year return period) coastal flood (in light blue)



3.5. Coastal Adaptation Recommendations Based on Benefit-Cost Analysis: Conventions, Shortcomings, and Missing Elements

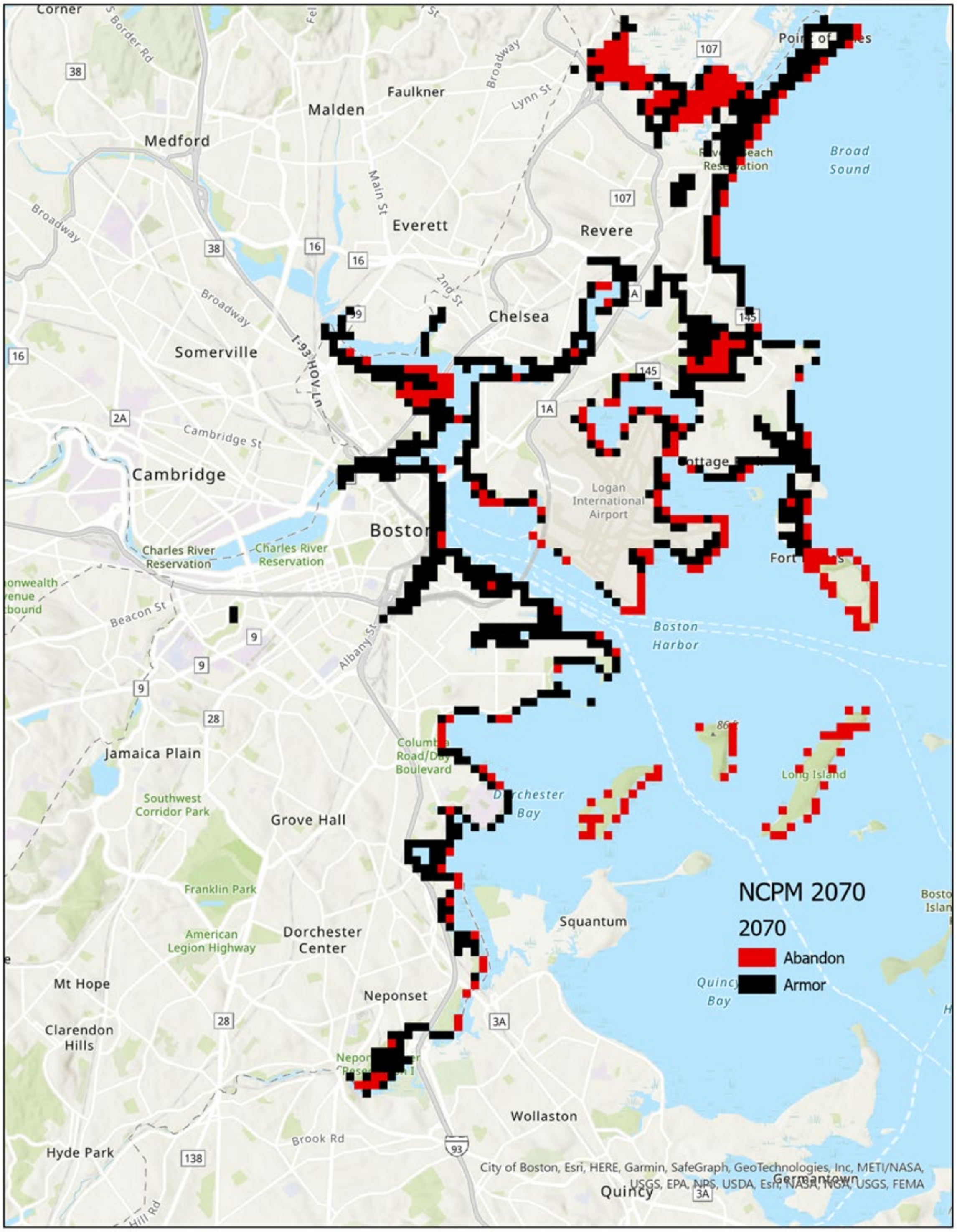
Decisions to invest in coastal resilience are complex, involving detailed engineering, environmental impact, and economic and financing analyses prior to initiation of any project. Some simplifying assumptions are necessary to conduct supporting analyses such as the quantification of economic benefits and project costs, as part of project benefit-cost analyses. Many funding agencies require a benefit-cost analysis, while also acknowledging that BCA can omit certain difficult-to-quantify benefits and costs (such as the environmental, recreational, and societal benefits of NBS in Figure 2-2 above; and the environmental costs of engineered seawalls and hard structure projection infrastructure). In addition, the efficacy of NBS investments in reducing flood risk may be untested or highly uncertain, complicating the estimation of the benefits of NBS in many locations. Available information nonetheless suggests that NBS may be most effective in reducing impacts of the low severity, high frequency storms (e.g., the 5 to 10 percent annual chance flood risk, or 10-to-20-year return period storms), and less effective for lower frequency, higher severity storms and flood events (e.g., the 1 percent chance or 100-year return period event). In this section, we explore these difficult questions around how to best target coastal adaptation using benefit-cost analysis or other tools and data developed for this project.

The previously described National Coastal Property Model (NCPM) simulates flood damages resulting from sea level rise and storm surge along the contiguous U.S. coastline (Neumann et al. 2021). The model also projects where local-level investments targeted at a limited set of adaptation measures might be adopted if flood risk benefits exceed the measure installation costs over a 30-year period. The options for adaptation investment or risk response are as follows:

- **Abandon** – based on a benefit-cost ratio test, least cost decision, protection is too costly, and the inhabitants retreat further inland
- **Armor** – again based on a benefit-cost ratio test, the cell is protected with grey infrastructure (e.g., a sea wall)
- **Elevation** – similar to armoring, the cell is protected but it is less expensive to elevate the structure to avoid storm surge damage than to armor – elevation is often implemented either as an interim measure or in areas where the coastal risk is for episodic flooding from infrequent storms rather than permanent inundation from gradual sea-level rise
- **Nourish** – beach nourishment can be implemented to provide flood protection, up to a limit of 1ft of flood water depth above current sea level. Beach cells always nourish.

Figure 3-5 below provides the results of a sample run of the NCPM armor-abandon decisions, by NCPM 150 m grid cell, using the Commonwealth's preferred adaptation planning sea level rise scenario for 2070, and using the MC-FRM derived expected annual damage data. The results show that by 2070, a large portion of the Boston Harbor region coastline might be sufficiently threatened by coastal hazards to justify armoring. This is not meant to imply that other solutions, such as NBS, might instead or also be justified, only that currently available information suggests that there would or could be considerable economic incentive to install flood risk protection across large sections of the coastline. In some areas, this economic pressure for hard structure armoring is already evident as a result of current coastal flood risks.

Figure 3-5. Sample Results for Adaptation Strategies from National Coastal Property Model



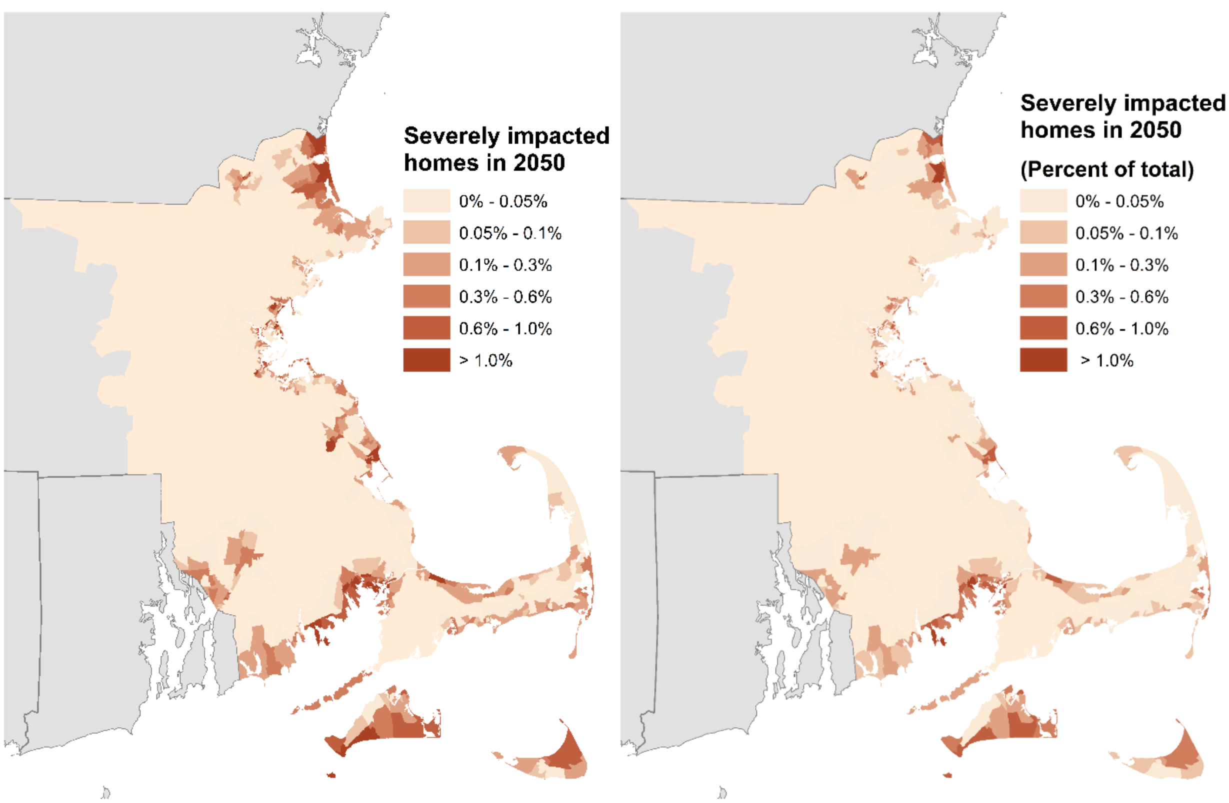
The NCPM type of benefit-cost analysis tool has important limitations, however. It does not address the non-flood protection benefits, or the co-costs and co-benefits. By focusing on the flood benefits, and in that category, the absolute flood benefits, it might also be skewing a focus on flood protection toward the currently most valuable properties, which could further exacerbate inequity in the coastal zone. In addition, this BCA framework does not provide a priority focus on the threatened EJ population. The framework can draw insights on who benefits from these projects but is often not applied for that purpose.[80]

To add additional insights that may be relevant to the value of pursuing NBS type solutions, as opposed to traditional armoring, we generated a new set of risk and vulnerability data which may be useful to planners. Figure 3-6 provides a side-by-side comparison of the prevalence of severely impacted residences in 2050 for the full range of storm probabilities and severities (Panel A) and for an alternative risk scenario where a hypothetical NBS installation prevents damage for all high frequency, low severity flood events up to the 3.3 percent annual chance flood event (the 30-year return period storm). As a comparison of Panel A and Panel B shows, a hypothetical NBS installation could substantially reduce storm damages across large expanses of the Massachusetts coastline, especially along tidally influenced river banks on the South and North Shores; along the northern shore of Cape Ann; along the Nantucket Sound shore of Cape Cod; and in some locations in the Boston Harbor region. While this is only an illustrative scenario, and does not consider site-suitability for NBS or project-specific flood mitigation effectiveness data, the illustration does suggest there is potential for substantial flood risk protection benefits for the stylized scenario considered here.

Figure 3-6. Illustrative Potential Benefits of NBS for Coastal Flood Risk Reduction

Panel A: Risks for all probabilities and severities

Panel B: Risks excluding high frequency, low severity storms



[80] Martinich J, Neumann J, Ludwig L, and Jantarasami L. 2013. Risks of sea level rise to disadvantaged communities in the United States. *Mitig. Adapt. Strateg. Glob Change* 18:169–185, DOI 10.1007/s11027-011-9356-0.

3.6. Considerations for Planning and Implementing NBS

Coastal zone stakeholders have options for reducing risks associated with SLR and coastal storms, including a variety of traditional infrastructure and NBS alternatives. Our literature review and interviews highlighted the importance of community engagement to work toward informed, equitable decisions regarding coastal resilience planning. However, communities require information on environmental, social, and economic tradeoffs across feasible resilience alternatives to contribute meaningfully to such community engagement efforts. Engineers, analysts, and coastal zone managers should seek to improve understanding and communication regarding 1) the efficacy of armoring alternatives in mitigating coastal risks to infrastructure; and 2) the expected co-costs and co-benefits of alternatives.

3.6.1. NBS Efficacy in Mitigating Coastal Storm Damages to Infrastructure

Whereas traditional armoring alternatives are designed to largely eliminate risks of coastal storms on property and infrastructure, the question of efficacy of NBS with respect to this objective is more complicated. Our project team's experience modeling benefits of specific NBS projects indicates that these projects can influence coastal processes by reducing flooding, mitigating wave energy, reducing erosion, and reducing the residence time of flood waters (see the conceptual diagram in Figure 2-2). Whether and to what degree these changes reduce damages to coastal properties and infrastructure is highly site-specific.

Generally, NBS are considered effective tools for mitigating flood risk.[81] However, limits and nuances exist to their applicability and effectiveness. First, options for NBS may be constrained by available space. The ability of coastal wetlands to attenuate wave energy, for example, depends on the size of the wetland. In addition, their ability to be self-sustaining in the face of sea level rise requires undeveloped space for landward migration. Similar logic follows for beaches, with the additional requirement of sediment budget availability to achieve sustainability. Options for NBS may therefore be limited along areas of the coast that are already highly developed without significant costs to relocate existing infrastructure.

It is well known that hard infrastructure (e.g., seawalls) deflects wave energy to adjacent areas to varying degrees depending on design characteristics.[82] Similar concerns may exist for certain NBS (e.g., reefs), whereby the NBS attenuates wave energy in some coastal areas by displacing it to others. In other words, while the net flood risk management benefits may be positive, it is possible that localized areas may be negatively affected.

Finally, performance of NBS over long time periods is not well understood.[83] For example, knowledge gaps exist surrounding the evolution of NBS over time as they interact with other natural features and

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[81] See, for example: Moller, I., Kudella, M., Rupprect, F., Spencer, T., Paul, M., van Wesenbeeck, B.K., Wolders, G., Jenson, K., Bouma, T.J., Miranda-LKange, M., and S. Schimmels. 2014. "Wave Attenuation over Coastal Salt Marshes under Storm Surge Conditions." *Nature Geoscience. 7;* Morris, R.L., Konlechner, T.M., Ghisalberti, M. and S.E. Swearer. 2018. "From Grey to Green: Efficacy of Eco-engineering Solutions for Nature-based Coastal Defence." *Global Change Biology*. 24; Leonardi, N., Carnacina, I., Donatelli, C., Ganju, N., Plater, A., Schuerch, M., and S. Timmerman. 2017. "Dynamic Interactions between Coastal Storms and Salt Marshes: A Review." *Geomorphology*. 301; Chausson, A., Turner, B., Seddon, D., Chabaneix, N., Girardin, C.A.J., Kapos, V., Key, I., Roe, D., Smith, A., Woroniecki, S. and N. Seddon. 2020. "Mapping the Effectiveness of Nature-based Solutions for Climate Change Adaptation." *Global Change Biology*. 26(11); Fairchild, T., Bennett, W., Smith, G., Day, B., Skov, M., Möller, I., Beaumont, N., Karunarathna, H., and J. Griffin. 2021. "Coastal Wetlands Mitigate Storm Flooding and Associated Costs in Estuaries." *Environmental Research Letters*. 16(7).

[82] Plant, N.G., and and G.B. Griggs. 1992. "Interactions between Nearshore Processes and Beach Morphology near a Seawall." *Journal of Coastal Research.* 8(1).

[83] Piercy, C.D., Altman, S., Swannack, T.M., Carillo, C.C., Russ, E.R., and J.H. Winkelman. 2021. "Expert Elicitation Workshop for Planning Wetland and Reef Natural and Nature-based Features Futures." *Report Number ERDC SR-21-4*. Vicksburg, MS: US Army Engineer Research and Development Center.

processes, and how any changes might affect NBS performance. Research suggests that isolated NBS are effective at smaller, localized scales but that a broader network strategy of NBS may be required for mitigating risks at the scale of traditional armoring.[84] Some NBS are most effective against smaller storm and flood events,[85] but may be destroyed by a single severe storm. Of course, similar concerns exist for hard infrastructure, especially if designed and prior to current understanding of climate change impacts on sea level rise and storm frequency and intensity. One final nuance between NBS and hard infrastructure is that certain NBS (e.g., reefs and vegetation) may be vulnerable to destruction at first but grow more resilient as they become established over time.

Modeling or at least qualitative comparisons of the efficacy of project alternatives is an important first step for project planning.

3.6.2. NBS Co-benefits and Identifying Community Priorities

As described in this report and depicted in Figure 2-2, beyond reducing risks of coastal storms on infrastructure and socioeconomic resources, NBS are generally designed to provide ecological and ecosystem service co-benefits that additionally benefit people and communities. However, the types and magnitudes of ecosystem service co-benefits vary significantly by NBS project design and location. Planners and analysts should consider developing an analysis or project-specific conceptual diagram to explore the likely co-benefits of project alternatives. Stakeholder engagement may then focus on identifying the co-benefits most highly valued by the community. It may be that socially vulnerable communities have different and specific relationships with coastal resources that influence their priorities. For example, particular populations may hold cultural value or have economic ties to harvesting wild resources (fish, plants) in coastal areas. NBS may be designed to improve conditions for these natural resources or avoid the adverse effects that traditional armoring may introduce. As another example, some community groups may prefer expanding conservation land while others may prefer adding nature-based recreational resources.

As previously noted, some NBS projects are most effective against smaller flood events associated with more frequently occurring storm events. As smaller flood events generally generate less damage than more significant storm events, coastal resilience planning and policy is often focused on the larger storm events. This focus on larger storm events may underestimate the benefits of NBS.[86] To the extent that socially vulnerable populations reside in areas subject to smaller, more frequent storm events, policy and planning focused on the large storm events may overlook the risks to these populations, and the potential benefits of NBS.

Finally, resilience alternatives need not be limited to single traditional or NBS solutions. Given differences in efficacy of methods, and potentially competing priorities of stakeholders regarding co-benefits, addressing equity in coastal resilience should consider a portfolio approach. A portfolio of projects can be designed to best achieve the targeted risk reductions while achieving high-priority co-benefits in line with community priorities and include options for mitigating unintended adverse outcomes.

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[84] Ferreira, Carla S.S., Sandra Mourato, Milica Kasaniun-Grubin, Antonio J.D. Ferreira, Georgia Destouni, and Zahra Kalantari. 2020. "Effectiveness of Nature-based Solutions in Mitigating Flood Hazard in a Mediterranean Peri-Urban Catchment." *Water* 12: 2893.

[85] Lallemant, David, Perrine Hamel, Mariano Balbi, Tian Ning Lim, Rafael Schmitt, and Shelly Win. 2021. "Nature-based Soloutions for Flood Risk Reduction: A Probabilistic Modeling Framework." *One Earth* 4: 1310-1321.

[86] Lallemant, David, Perrine Hamel, Mariano Balbi, Tian Ning Lim, Rafael Schmitt, and Shelly Win. 2021. "Nature-based Soloutions for Flood Risk Reduction: A Probabilistic Modeling Framework." *One Earth* 4: 1310-1321.

Chapter 4. Recommendations

4.1. Incorporating Equity-Minded Metrics (e.g., ratios, SVI, disproportionality measures)

Prioritize vulnerable communities as a matter of policy – recognize key causes of vulnerability beyond primary coastal risk, such as economic and political marginalization, residential segregation, and gentrification (which might be exacerbated by climate gentrification).

Use relative rather than absolute measures of damage or risk. How impacts are measured, as absolute damages versus relative damages, affects the geographic pattern of prioritization and more importantly, which communities are prioritized. Metrics of absolute damages emphasize areas with higher property valuations, while deemphasizing areas of lower property valuation. The latter are more likely to represent socially vulnerable populations with less capacity to absorb these impacts. By contrast, relative metrics of damage, which control for differences in property valuations, are more likely to draw attention to the risks faced by more socially vulnerable communities.

Evaluate existing data which more accurately targets communities of concern (e.g., renters rather than owners; critical community/cultural resources and gathering places; state- or federally designated environmental justice populations), and on a site-specific basis collect and develop new data wherever possible which more accurately characterizes risks to people and places of importance to these communities. Site-specific characterizations of vulnerable populations or infrastructure should be informed by direct community engagement and not be based solely on secondary datasets.

Recognize that coastal risks and risk mitigation may be "farther down the list" than other more immediate concerns, such as food or housing security, or economic displacement. Risks that are not contemporary but instead are more likely to manifest with largest magnitude in the future, as a result of climate change, should be addressed as a potential "threat multiplier" for existing pressures, rather than the primary challenge.

4.2. Best Practices in Community Engagement

Engage as early as possible in project planning and allocate sufficient time and resources to engage with the community; common project timelines leave insufficient opportunities for engagement. Meeting twice for a couple of hours is inadequate. Follow-up on project results and community perceptions of outcomes should be a basic part of the community engagement process.

Modes of communication (i.e., language, accessibility of language, applicability to renters vs property owners) need to take into account community preferences or characteristics. Email does not work for some communities with little access to computers or the Internet, or who simply do not use email.

Design proposals need to be honest and realistic to avoid creating inflated expectations and disappointment. Promises should not be made lightly, lest they perpetuate cynicism, resentment, or simply indifference.

Learn and think carefully about the needs and context of different community stakeholders: renters, absentee landlords, institutional vs individual property owners, as well as language, education level, power or efficacy in engaging with authorities or landlords (including community histories of conflict or marginalization)

Conduct community engagement in an accountable way that looks closely at who is participating and who is not. Disaggregate demographic characteristics of community input to ensure that the voices heard are representative of the community. Do not just rely on who shows up. Surveys that only capture some voices in the community are not legitimate representations.

Partner with existing institutional community members and their networks – community based organizations (CBOs), community development corporations (CDCs), other government entities with a regular presence, faith institutions, schools – to do outreach, communication, and engagement.

The value of participation for the community must be very clear from the community perspective. Asking for community input is not costless and the opportunity for community engagement is not itself a benefit. There must be concrete benefits that come from participation. And there must be meaningful impact or control of implementation. Why is participation relevant to the community? Why should they be there? Will their input actually have influence? How?

4.3. Place-Specific Planning

The ecological and ecosystem service co-benefits are what sets NBS apart from traditional armoring methods. However, the specific types and magnitudes of co-benefits of a given NBS vary by project (dependent upon the nature, scale, and specific design of the NBS) and site. Planners and analysts should develop an analysis or project-specific conceptual diagram (e.g., Figure 2-2) to explore the likely co-benefits of project alternatives. Stakeholder engagement may then focus on identifying the relevant co-benefits most highly valued by the community.

With respect to coastal flood risk, some NBS are most effective in mitigating the risks of smaller, more frequent storm events. Resilience planning should capture risks to populations residing in areas experiencing these lower-consequence but high-frequency flood events, including evaluating the effectiveness of NBS. Figure 3-6 above provides an illustration of the type of data which might be used for identifying the intersection of EJ neighborhood locations and areas where reduction of the risks that NBS can mitigate may be substantial, but Figure 3-6 should only be used as an initial screening analysis. More site-specific analyses could provide a much better representation of "who benefits" from NBS flood risk reduction, and ought to be pursued as part of broader NBS related strategic planning.

For some NBS, the risk reduction benefits are localized as compared with traditional armoring approaches. However, NBS can provide ecosystem services of value to communities and socially vulnerable populations. Addressing equity in coastal resilience should consider a portfolio approach for resilience alternatives. A portfolio of projects in a region can be designed to best achieve the targeted risk reductions while achieving high-priority co-benefits and include options for mitigating unintended adverse outcomes.

4.4. Areas for Further Investigation

Additional effort is needed to better measure and/or model NBS social co-benefits and disbenefits, such as those identified in Figure 2-2. Currently there are substantial challenges in quantifying the non-flood risk mitigation benefits of NBS, although conceptually they are well established. Primary research may be required to develop a stronger basis for quantifying these benefits. In particular, Massachusetts-specific research on these non-flood risk mitigation benefits could provide a stronger justification for deploying NBS in a broader set of site-specific contexts.

Coastal adaptation recommendations based on BCA need to be revised to incorporate a wider range of benefits of NBS. These benefits are not captured in most BCA due to a lack of data or modeling guidance. For example, the National Coastal Property Model, and BCA in general, have important limitations for NBS and for EJ focused modeling of benefits and costs. It does not address the non-flood protection benefits, or the co-costs and co-benefits, of various flood mitigation choices. By focusing on the flood benefits, and in that category, the absolute flood benefits, it might also be skewing a focus on flood protection toward the currently most valuable properties, which could further exacerbate inequity in the coastal zone. It does not provide a priority focus on environmental justice or other socially vulnerable populations. In addition to calculating the aggregate benefits of these projects, it should identify *who* benefits from these projects (e.g., renters vs property owners, adjacent neighborhoods vs the region, local businesses vs regional businesses).

The efficacy of NBS in mitigating flood risk varies by project and cannot be generalized across diverse projects or geographies. Individual NBS projects appear to be most effective for the low severity, high frequency end of the damage exceedance curve; however, landscape-level planning of multiple projects within a watershed may increase these benefits. In some instances, hybrid NBS and hard structure alternatives might provide the best results both for the overall population and for socially vulnerable populations specifically.

There is the possibility that NBS, like traditional coastal flood risk measures may be displacing risk to other locations. While the net flood risk management benefits may be positive, it is possible that localized areas may be negatively affected. Care should be taken to evaluate whether and what populations may be adversely affected by a resilience project. Additionally, the performance of NBS over long time periods is not well understood. NBS is relatively new, and additional research on the expected life cycle, maintenance requirements, and overall efficacy of NBS to provide flood risk and non-flood risk benefits is needed.

Finally, it appears that the Commonwealth Coastal Zone Management team and the broader state government are currently at an important stage in designing a strategy for coastal resilience. The risk assessment and priority-setting established through the Massachusetts Climate Assessment has directly informed adaptation and resilience planning in 2023 State Hazard Mitigation and Climate Adaptation Plan,[1] which in turn has called for development of a Resilient Coasts Strategic Plan. The Resilient Coasts plan is an opportunity to incorporate hazard, damage estimation, EJ, and NBS effectiveness data and concepts in statewide planning and implementation, and to continue the conversation with stakeholders such as CBOs to raise awareness of both the imminent coastal risks and the possible solutions available to provide broad and lasting benefits. We remain hopeful that the information and data generated for this report may prove useful in both the planning and rapid implementation of NBS and other coastal resilience solutions under consideration for the Commonwealth.

To cite this report:

Luna, Marcos, Jim Neumann, Rebecca Smalley, Maura Flight, and Charles Fant. 2024. "From Analysis to Action: Strategies for Promoting Climate Justice when Implementing Nature-based Solutions to Coastal Risk." Stone Living Lab.

[1] "ResilientMass Plan: 2023 Massachusetts State Hazard Mitigation and Climate Adaptation Plan." 2023. Commonwealth of Massachusetts. https://www.mass.gov/info-details/2023-resilientmass-plan.

Appendix A. Interview Prompts

From Analysis to Action: Strategies for Promoting Climate Justice when Implementing Nature-based Solutions to Coastal Risk Interview Questions

Please note that questions may be altered depending on the flow of the conversation

1. Before we begin, can you please tell me whether you have received a description of the project and a disclosure statement describing your rights as a participant in this research project, and that you understand these rights?
2. Please describe your organization and your role in the organization
3. Are you familiar with Nature Based Solutions or green infrastructure projects aimed at climate adaptation or flood risk mitigation?
4. Are NBS projects a part of your development or planning or conversations?
5. What do you think of Nature Based Solutions or green infrastructure projects? How do they, or might they, affect housing or other vulnerable populations in your community?
6. Do you think that NBS or similar kinds of projects positively or negatively impact community stability or the ability of current residents to remain in the neighborhood? Please explain.
7. How can these projects be planned or implemented in a way that benefits vulnerable residents, especially with regard to housing? What should developers and public officials be thinking about?
8. In general, what are the big risks for community stability, especially for housing?
9. Are climate change risks or adaptation part of your planning or development?
10. To your knowledge, does your city's climate plans incorporate housing in climate resilience efforts?
11. Are you invited and do you participate in discussions about coastal resilience strategies by the city or the state? If so, who else is in the room when you're there?
12. In general, what are the existing strategies that you use, or recommend, to combat gentrification or to foster community stability?
13. To your understanding, how might climate adaptation/resilience development efforts help or hinder these efforts against gentrification or displacement? Do these projects represent opportunities for the community?
14. What are your recommendations for preferred modes of communication and community engagement with government officials and developers on NBS, green infrastructure, or other climate adaptation strategies that could influence community development and stability?
15. What questions, information, or other resources would you or your organization need to better understand or engage with NBS, green infrastructure, or other climate adaptation strategies or policies that could influence community development and stability?
16. Are you interested in learning more about this research project and/or reviewing results and recommendations that we produce?

Definition of terminology

Nature Based Solution: Interventions to reduce environmental risks, such as coastal flooding, by restoring and/or mimicking nature or natural processes – such as coastal wetland restoration projects, constructed dunes, or waterfront parks that can withstand periodic flooding – instead of, or maybe in addition to, conventional engineering approaches like concrete seawalls or breakwaters.

Green Infrastructure: Projects that combine gray infrastructure (i.e., traditional engineering structures) with nature-based solutions to create hybrid systems that improve resilience to climate impacts, while also often resulting in environmental, economic, and social co-benefits. Generally, green infrastructure is a built or engineered solution such as a green roof or bioswale.

Climate adaptation: Climate change adaptation or climate adaptation means taking action to prepare for and adjust to both the current and projected impacts of climate change.