



Building Resilience of Urban Ecosystems and Communities to Sea-Level Rise: Jamaica Bay, New York City

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Abstract

Climate change-induced sea-level rise (SLR) and coastal flooding pose serious threats to low-lying urban coastal regions. Densely populated cities with fragile

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urban ecosystems face the brunt of rising sea levels and other coastal disasters. Building urban climate change resilience to SLR reduces vulnerability and enhances the urban ecosystem and the community's potential to maintain both social and ecological functions to adapt to the rising sea levels. Jamaica Bay in New York City provides an example of social and ecological interactions in an urban area that address challenges of SLR. It offers an opportunity to study different approaches that communities adopt to build resilience, while placing ecosystems at the center of adaptation initiatives. COREDAR- (a capacity building tool) based SLR and flood risk information assortment and GIS-based SLR and flood risk assessments were carried out. The findings of the study in this chapter (1) describe the potential areas and population that are at risk to the predicted impacts of SLR in the Jamaica Bay region and (2) present empirical case studies on climate resilience efforts taken by a range of stakeholders from city governments, research and academic institutions, civil society, to others from the Jamaica Bay region. The chapter illustrates different approaches to integrate adaptation efforts in the social and ecological systems to improve adaptation to SLR in urban communities.

Keywords

Urban climate change · Sea-level rise · Ecosystems · Communities · Resilience · Adaptation · Jamaica Bay · New York City

Introduction

Global sea levels have risen throughout the twentieth century. These rises will almost certainly accelerate through the twenty-first century and beyond because of global climate change, but their magnitude remains uncertain (Nicholls and Cazenave 2010). The Fifth Assessment Report (AR5) of Intergovernmental Panel on Climate Change (IPCC) has projected sea-level rise (SLR) for all four Representative Concentration Pathways (RCPs), based on CMIP5 climate projections. Global mean SLR for 2081–2100 relative to 1986–2005 will likely be in the range of 0.26–0.55 m for RCP2.6, 0.32–0.63 m for RCP4.5, 0.33–0.63 m for RCP6.0, and 0.45–0.82 m for RCP8.5 (Church et al. 2013; IPCC 2013; Ramachandran et al. 2017). However, the effects of climate change (SLR) on coasts are not uniform, but vary considerably from region to region and over a range of temporal scales (Nicholls et al. 2007). The most serious physical impacts of SLR are as follows: (1) coastal erosion, (2) inundation and displacement of wetlands and lowlands (in particular, coastal wetlands including salt marshes are projected to be negatively affected by SLR especially where they are constrained on their landward side, or starved of sediment) (Breitmeier et al. 2009), (3) increased coastal storm flooding and damage, (4) increased salinity of estuaries and aquifers (Barth and Titus 1984; Marfai and King 2008), etc.

Cities are home to over half of the world's people and are at the forefront of the climate change issue. Importantly, the rising sea levels lead to increased inundation of low-lying areas and put global cities and urban coastal communities at greater risk

(Khan 2017). For coastal cities, enhanced SLR and storm surges affect inhabitants and essential infrastructure, property, and ecosystems (Rosenzweig et al. 2011). According to the United Nations, coastal flooding affects ten million people each year, a number expected to increase exponentially due to climate change. IPCC (2013) states that about 65% of the world's cities with populations of over five million are located in the LECZ (low elevation coastal zone). SLR is not uniform across regions; some communities in places such as subsiding deltas are highly vulnerable (IPCC 2007). A study by the Organisation for Economic Co-operation and Development (OECD 2007) found that the populations of Mumbai, Guangzhou, Shanghai, Miami, Ho Chi Minh City, Kolkata, New York City, Osaka-Kobe, Alexandria, and New Orleans will be most exposed to surge-induced flooding in the event of SLR.

One of the possible measures to address the challenges of SLR at the city level is by building resilience of urban ecosystems and communities as an adaptation strategy. "Resilience" can be defined as the capacity of social, economic, and environmental systems to cope with a hazardous event, trend, or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation (IPCC 2014). To understand resilience we need to understand how physical, ecological, and social systems interact (Branco and Waldman 2016). Socio-ecological resilience theory understands systems as constantly changing in nonlinear ways; it is therefore a highly relevant approach for dealing with future climate uncertainties (Rodin 2014; Tyler and Moench 2012). Nevertheless, urban resilience refers to the ability of an urban system and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity (Meerow et al. 2016). The literature on resilience in complex adaptive systems emphasizes the integration of social agents and institutions along with biophysical elements as components of socio-ecological systems (Folke 2006; Folke et al. 2002; Gunderson and Holling 2002; Tyler and Moench 2012). Institutions for collective action and governance can also be designed to strengthen resilience by supporting ecosystem restoration and sustainability (Adger et al. 2005; Folke et al. 2005; Ostrom 1990; Tompkins and Adger 2004; Tyler and Moench 2012).

There is broad consensus that (1) cities must become resilient to a wider range of shocks and stresses and become better prepared to address climate change and (2) efforts to foster climate change resilience must be bundled with efforts to promote urban development and sustainability (Leichenko 2011). The starting point in managing risks and building long-term resilience is for a city to understand its exposure and sensitivity to a given set of impacts and develop responsive policies and investments that address these vulnerabilities (The World Bank 2011). To the extent that low elevation coastal populations are at risk from SLR stronger storms and other seaward hazards induced by climate change, it is important to assess the size of these populations and how they are distributed (McGranahan et al. 2007) and

how the ecological system, present in the midst of social system, is impacted by rising sea levels in the urban context. Thus, building resilience and adapting to climate change is increasingly a high priority for cities. At the same time, cities are well positioned to propose and implement thoughtful development policies to address climate change and promote resilience.

In this context, this chapter focuses on SLR impacts in the low elevation coastal zones of urban areas with a question of how coastal cities can be transformed into systems in the changing climate that are more resilient and adaptive to the rising sea levels. Jamaica Bay in New York City is our focus for ideas about global coastal resilience to changing climate, and it has been taken to assess the impacts of SLR and explore various strategies taken to build socio-ecological resilience in the bay area.

Jamaica Bay, New York City

Jamaica Bay is a tidal lagoon on the south shore of western Long Island, New York, bounded by residential areas of Brooklyn, Queens, and Rockaway Beach and John F. Kennedy (JFK) International Airport (Brand et al. 2018). The geographical coordinates of Jamaica Bay are 41° N, 74° W (Fig. 1a). The Jamaica Bay unit is the largest of the three administrative units (Jamaica Bay, Sandy Hook, and Staten Island) and is one of the largest expanses of open space in the region, consisting of over 19,000 acres of land, bay, and ocean waters within two boroughs of New York, i.e., Brooklyn and Queens (US Department of Interior 2013). Jamaica Bay Wildlife Refuge (JBWR) is located at the center of the bay area and has been protected since 1972 as part of the Jamaica Bay Unit of Gateway National Recreation Area (GNRA) administered by the National Park Service (Tanacredi and Badger 1995; Hartig et al. 2002). Social science literature about Jamaica Bay has used various scales to define study areas. The various boundaries represent specific agency boundaries, realistic or imagined ecosystem boundaries, or boundaries drawn because of particular scientific expertise (Allred et al. 2016). The bay area units surrounding the Jamaica Bay Wildlife Refuge including (1) Seagate, Coney Island; (2) Brighton Beach; (3) Sheepshead Bay, Gerritsen Beach, and Manhattan Beach; (4) Georgetown, Marine Park, Bergen, and Mill Basin; (5) Canarsie; (6) Far Rockaway, Bayswater; (7) Hammels, Arverne, and Edgemere; and (8) Breezy Point, Belle Harbor, Rockaway Park, and Broad Channel are demarcated for this study (Fig. 1b).

The bay is shallow with numerous salt marsh islands and tidal mudflats that vary in extent with the lunar cycle (Black 1981; Burger 1981; Brand et al. 2018). Water depths in the bay average 16 ft with depths up to 40 ft in the deepest portions of the dredged channels and basins. Some of the islands in the bay have upland communities including open field, shrub thicket, developing woodlands, and beach grass dune (DOS 1992). It is also designated as a Significant Coastal Fish and Wildlife Habitat by the New York State Department of State (NYC-DEP 2016). The bay estuary contains diverse wetland ecosystems and 330 different wildlife species (Van Hooreweghe 2012). It's a critical stopover area along the Eastern Flyway migration route and is one of the best bird-watching locations in

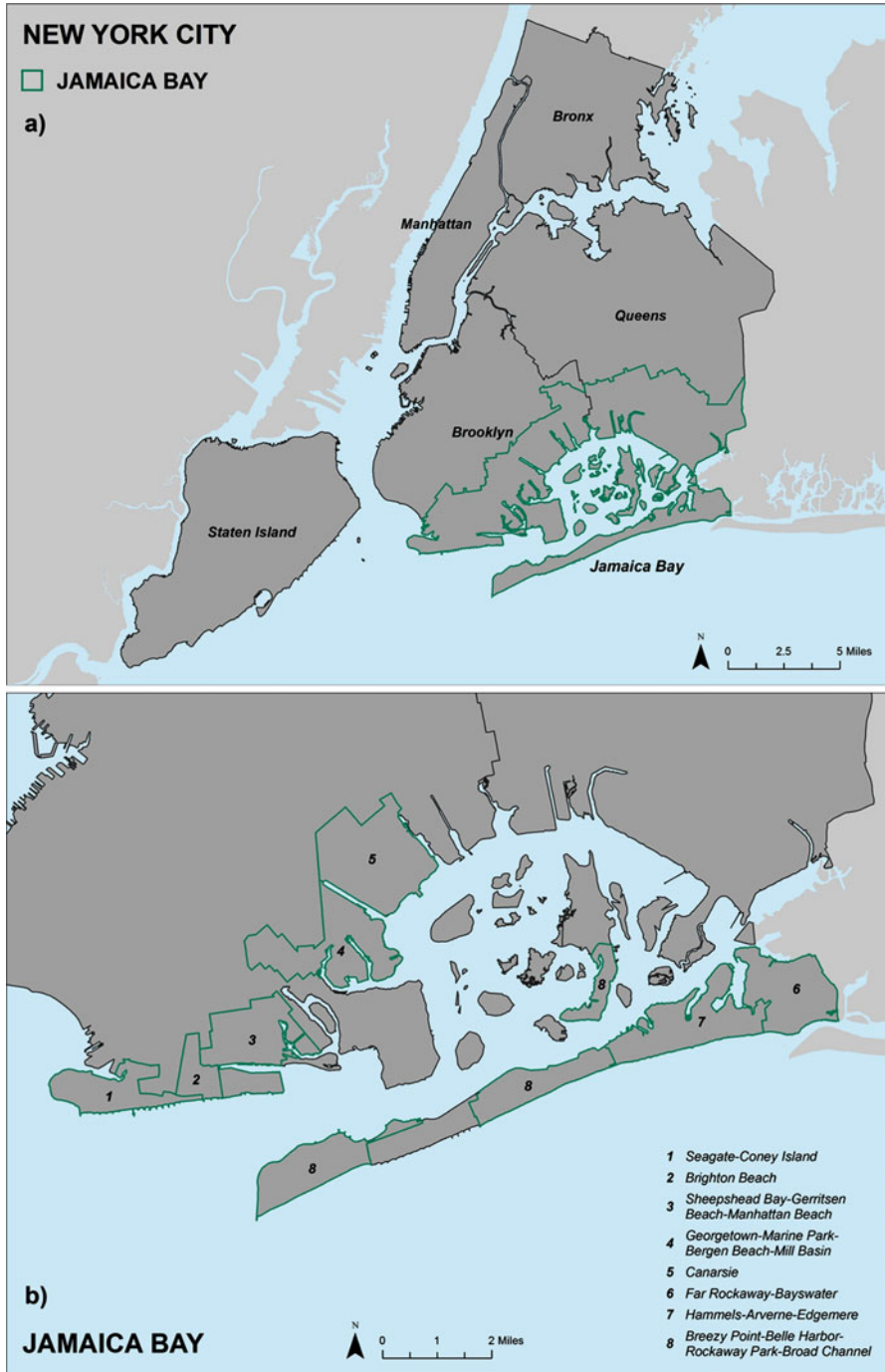


Fig. 1 (a) Boundary of New York City (NYC); (b) study area of Jamaica Bay region, NYC (Source: CIESIN, The Earth Institute, Columbia University, NY)

the Western Hemisphere (National Park Service 2004). On the other hand, the bay is embedded within a heavily urbanized region with extremely high population densities. According to 2016 US Census Bureau estimates, there were 2,629,150 people residing in Brooklyn and 2,333,054 in Queens as part of 8537, 673 people residing in New York City (NYC Department of City Planning 2018). As a result of human activity and development, the ecologically rich habitat of Jamaica Bay has changed considerably (NYC-DEP 2016). In terms of total area, the urban environment is the dominant feature of the modern-day landscape. In the last century, urban expansion has resulted in the filling of tidal salt marsh and freshwater wetlands, loss of all freshwater riparian habitat areas, and the loss of upland grassland, shrub land, and forest habitat (NYC-DEP 2007). Salt marshes covered an estimated 6550 ha in 1900 (Englebright 1975). By 1970, only around 1620 ha of salt marshes remained. Although protected since 1972, the remaining tidal wetlands within the boundaries of Gateway National Recreation Area were still shrinking in part due to ongoing SLR and other factors (Gorntiz et al. 2002). In October of 2012, Hurricane Sandy inflicted significant damage and loss of life in the Jamaica Bay region (ERG 2016). Despite profound alterations to the bay, it is still one of the largest areas of open space within New York City, a significant natural area within one of the nation's most populous urban centers (Waldman 2008).

Methodological Approach to Address Sea-Level Rise and Floods at Jamaica Bay

COREDAR-Based Sea-Level Rise and Flood Risk Information Assortment

COREDAR (Communicating Risk of sea-level rise and Engaging stakehOlders in framing community-based Adaptation stRategies), a capacity building tool for SLR risk communication and urban community-based adaptation, has been used in this study (Khan et al. 2015; UNAI 2016; State of the Planet 2016). The tool is based on the framework that was developed following the IPCC Fifth Assessment Report, Working Group I Report on Climate Change 2013: The Physical Science Basis; Working Group II Report on Climate Change 2014: Impacts, Adaptation and Vulnerability; Climate Change 2014: Synthesis Report with an emphasize on SLR and urban CBA (Khan 2017). The tool helps to gather holistic information on SLR risk communication and urban CBA in a systematic stepwise approach with information ranging from (1) climate and the profile of the urban coastal city, (2) past sea-level trends, (3) future SLR projections, (4) predicted SLR impacts, (5) predicted SLR vulnerabilities, (6) SLR risk information communication, (7) framing SLR and urban CBA strategies, and (8) mainstreaming SLR adaptation policies. In this study, this tool has been used to collect various information of SLR with relevance to the Jamaica Bay region of New York City. Each step offers a checklist for scientific and research communities (SLR science); local communities, NGOs, and private and

public partners (SLR and society); and policy-planners and decision-makers (SLR policy) to involve and contribute to the SLR and urban CBA decision-making process (Khan 2017).

GIS-Based Sea-Level Rise and Flood Risk Analysis

This section describes the processes and data used to produce estimates of flooded area and population at risk for the 100- and 500-year floodplains in the years 2020 and 2050. (1) **Data source:** In this study, data such as (a) Neighborhood Tabulation Areas, Department of City Planning (2013); (b) 2010 Census Blocks Department of City Planning (2013); (c) SLR maps of 2020 and 2050, 100–500-year floodplain, Mayor’s Office of Long-Term Planning and Sustainability (2013); and (d) 2010 Census Summary File 1, US Census Bureau (2011) are used. (2) **Flood scenario extent preparation:** Flood scenario extent feature classes were first projected to a local NYC coordinate system (NAD 1983 StatePlane New York/Long Island FIPS 3104 ft), and then each flood extent was dissolved into a single feature class. For cartographic purposes the extents were clipped to the census block boundaries from the NYC Department of City Planning. (3) **Census block boundary preparation:** The 2010 census population was downloaded in ASCII format from Summary File 1 of the US Census. It was then converted into text format and joined to the census block boundaries using a common identifier (a concatenation of state, county, tract, and block geoids). Next the area in square meters was calculated for each census block using the Calculate Field tool in ArcGIS. Subsequently, each census block was assigned to a neighborhood defined by the Neighborhood Tabulation Areas feature class from the NYC Department of City Planning. This was accomplished by (a) converting the census blocks to points, (b) using the Spatial Join tool in ArcGIS to assign a neighborhood name to all census block points contained within each neighborhood boundary, and (c) joining the neighborhood names back to the census block boundaries using a common identifier. (4) **Analysis:** Estimating the population at risk and flooded area in each of the four flood scenarios was a multi-step process. The census block boundaries were clipped to each flood extent to delineate flooded areas. The flooded area (square meters) of each census block within the flood extent was determined using the Calculate Field tool in ArcGIS. Next, the population within the flooded area of the census block was calculated using the formula below. This calculation relies on the assumption that the population in a census block is evenly distributed (Doxsey-Whitfield et al. 2015), and therefore the proportion of population at risk would be equal to the proportion of flooded area:

$$P_{\text{atrisk}} = P_{\text{total}} * \frac{A_{\text{flooded}}}{A_{\text{total}}}$$

where P is population and A is area. Finally the neighborhood names along with borough name were used to summarize the flooded area and population at risk for each flood scenario. The schematic representation of the methodology adopted in this study is outlined below (Fig. 2).

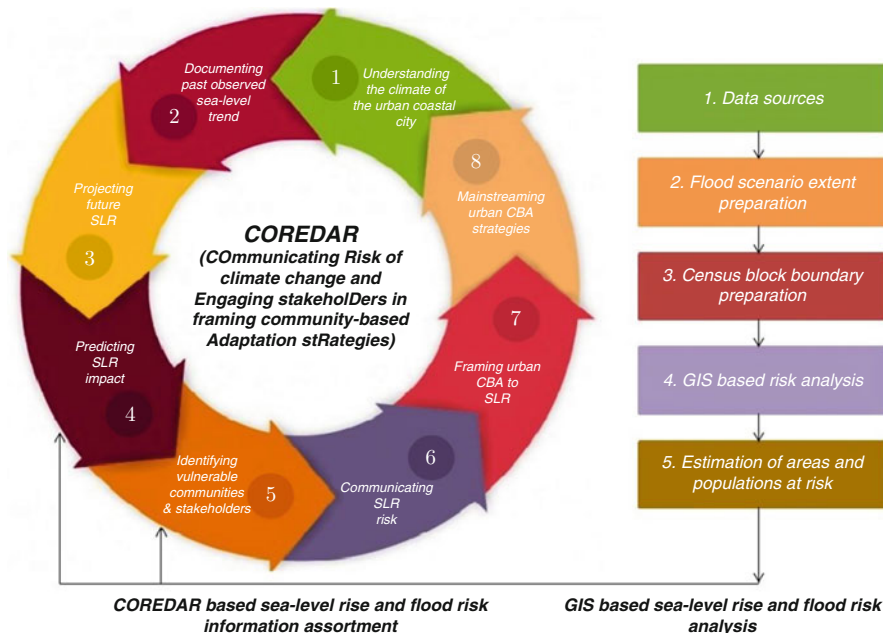


Fig. 2 Schematic representation of the methodological approach adopted (Source: Khan 2017 and CIESIN, The Earth Institute, Columbia University, NYC, NY)

Predicted Impact of Sea-Level Rise and Floods at Jamaica Bay

The rate of local SLR in New York City is around 2.84 mm/year with a 95% confidence interval of ± 0.09 mm/year based on monthly mean sea-level data from 1856 to 2016 which is equivalent to a change of 0.93 ft in 100 years, based on the tide gauge data from Battery Park in Manhattan (NOAA 2018). The New York City Panel on Climate Change (NPCC2) has projected SLR in four time slices as the 2020s, 2050s, 2080s, and 2100 for NYC. Based on 24 GCMs and RCPs, NPCC has estimated SLR for NYC as 10 in. (0.25 m) in the 2020s, 30 in. (0.76 m) in the 2050s, 58 in. (1.47 m) in the 2080s, and 75 in. (1.91 m) by 2100 under the high estimate (Horton et al. 2015; Gornitz et al. 2017). These estimated increases in sea level could accelerate the loss of wetlands and uplands from wave-driven erosion and flooding. Warming associated with climate change also is predicted to increase the frequency and severity of major storms and hurricanes. These storms, in conjunction with high sea levels, have the capacity to cause extensive change to the present morphology of Jamaica Bay, including the Rockaway barrier system and inlet (Waldman 2008). Using the static approach, the NPCC2 created specific map products such as GIS shape files of the future 100-year flood extent for the 2020s, 2050s, 2080s, and 2100 based on FEMA's Preliminary FIRMs. These estimates illustrate that Queens is the

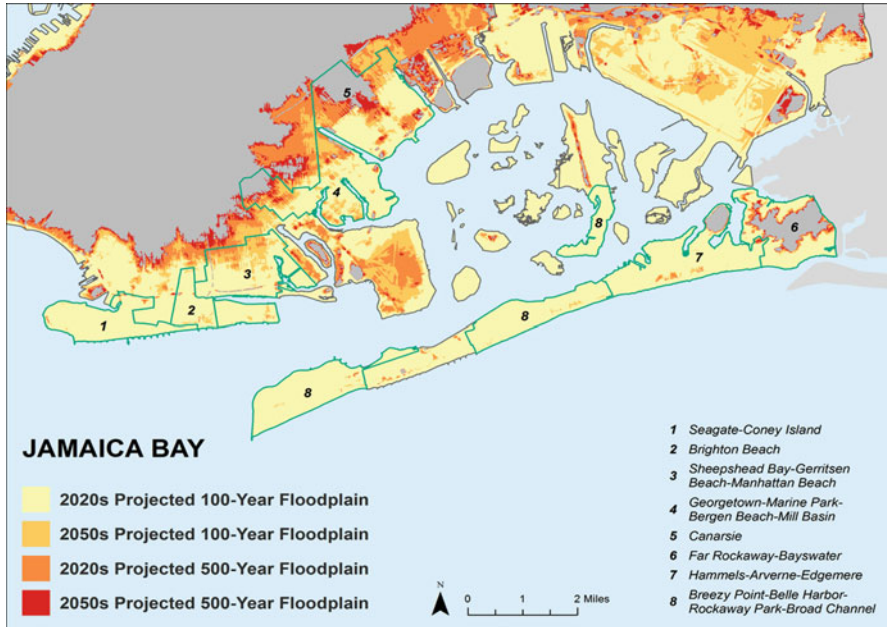


Fig. 3 Predicted areas at risks of Jamaica Bay region to 100- and 500-year floods of the 2020s and 2050s (Source: CIESIN, The Earth Institute, Columbia University, NY)

borough with the most affected land area, followed by Brooklyn, Staten Island, the Bronx, and Manhattan (Patrick et al. 2015). For example, large portions of land subject to flooding in Queens are part of the Gateway National Recreation Area, including the uninhabited intertidal salt marshes of the Jamaica Bay Wildlife Refuge and the parks of Fort Tilden, Breezy Point Tip, and Jacob Riis.

Rather than adopting the NPCC2 approach, in this study, the map products (Fig. 3) of predicted impact of SLR specific to the neighborhoods of Jamaica Bay region are created for SLR projections such as 10 in. (0.25 m) and 30 in. (0.76 m) of the future 100-year and 500-year floods of 2020 and 2050. Breezy Point, Belle Harbor, Rockaway Park, and Broad Channel; Sheepshead Bay, Gerritsen Beach, and Manhattan Beach; and Hammels, Arverne, and Edgemere are three neighborhoods of Jamaica Bay that are at high risk when compared to Far Rockaway, Bayswater, and Brighton Beach and other regions (in terms of acres of areas) to 100-year and 500-year floods of the 2020s and 2050s (Table 1). Likewise, map products (Fig. 4) are created for populations of Jamaica Bay region at risk to future 100-year and 500-year floods of the 2020s and 2050s. Population at Sheepshead Bay, Gerritsen Beach, and Manhattan Beach and Canarsie and Hammels, Arverne, and Edgemere are at high risk when compared to Breezy Point, Belle Harbor, Rockaway Park, and Broad Channel and Far Rockaway, Bayswater, and other regions (in terms of population) to 100-year and 500-year floods of the 2020s and 2050s (Table 2). As a whole, the Sheepshead Bay, Gerritsen Beach, and Manhattan Beach and Hammels,

Table 1 Estimation of areas at risks in Jamaica Bay region to 100- and 500-year floods of the 2020s and 2050s

S.No	Name of the neighborhood of Jamaica Bay	Total area (acres)	100-year flood (acres of area at risk of flooding)		500-year flood (acres of area at risk of flooding)	
			2020	2050	2020	2050
1.	Seagate, Coney Island	889	871	879	888	888
2.	Brighton Beach	394	368	389	393	393
3.	Sheepshead Bay, Gerritsen Beach, Manhattan Beach	1454	1093	1327	1430	1433
4.	Georgetown, Marine Park, Bergen Beach, Mill Basin	1592	891	1202	1370	1434
5.	Canarsie	1883	762	1045	1364	1507
6.	Far Rockaway, Bayswater	1248	614	679	769	829
7.	Hammels, Arverne, Edgemere	1421	1267	1294	1321	1326
8.	Breezy Point, Belle Harbor, Rockaway Park, Broad Channel	2283	2255	2279	2283	2283

Arverne, and Edgemere neighborhoods of Jamaica Bay are at high risk (both in terms of areas and population) when compared to the Far Rockaway, Bayswater, neighborhood and other regions of Jamaica Bay (both in terms of areas and population) to 100-year and 500-year floods of the 2020s and 2050s.

Case Studies on Socio-ecological Resilience to Sea-Level Rise and Floods at Jamaica Bay

Hurricane Sandy has brought public attention to the climate hazards of the New York area. It demonstrated the system's vulnerability to a whole host of weather-related threats, ranging from storm surge and SLR to heavy downpours – threats that are expected to worsen as the climate changes (Plan NYC 2013). It was a wake-up call for studying hurricane effects on the resilience and stability of coastal wetlands along the Atlantic coast, especially coastal areas along the northeast Atlantic seaboard where a dense human population resides. Over the last decade, there has been an active debate on the best ways to protect areas such as Jamaica Bay from storms. Hurricane Sandy only highlighted the need to provide better information. There have been a number of initiatives taken by various stakeholders of New York City in general and Jamaica Bay in particular, and one such example is the NYC Special Initiative for Rebuilding and Resiliency (SIRR). However, given the effect of accelerating SLR and the possibility of more intense hurricanes due to projected climate change (Wang et al. 2017), it is necessary to build the socio-ecological resilience of the Jamaica Bay region. One possible approach involves building sea walls (or flood walls) and other “gray” structures that will work to stop storm surge and strong waves caused by coastal storms. This is often referred to as “shoreline armoring.” A second

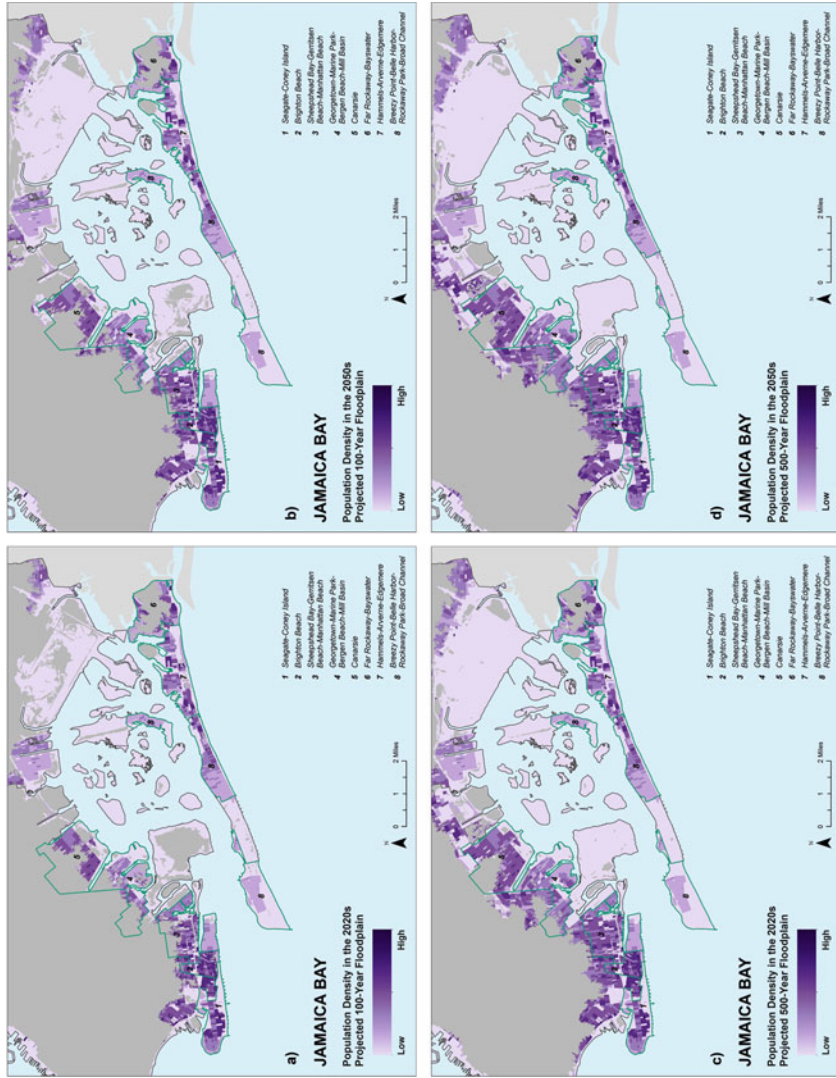


Fig. 4 Predicted population densities at risks of Jamaica Bay region to 100- and 500-year floods of the 2020s and 2050s (Source: CIESIN, The Earth Institute, Columbia University, NY)

Table 2 Estimation of population densities at risks in Jamaica Bay region to 100- and 500-year floods of the 2020s and 2050s

S.No	Name of the neighborhood of Jamaica Bay	Total population	100-year flood (population at risk)		500-year flood (population at risk)	
			2020	2050	2020	2050
1.	Seagate, Coney Island	31,965	31,819	31,868	31,963	31,965
2.	Brighton Beach	35,547	32,768	35,182	35,547	35,547
3.	Sheepshead Bay, Gerritsen Beach, Manhattan Beach	64,518	43,779	57,724	64,094	64,155
4.	Georgetown, Marine Park, Bergen Beach, Mill Basin	45,231	17,806	28,862	35,216	37,720
5.	Canarsie	83,693	33,412	46,204	64,314	70,744
6.	Far Rockaway, Bayswater	50,058	23,454	25,799	28,961	31,161
7.	Hammels, Arverne, Edgemere	36,885	34,933	36,061	36,651	36,885
8.	Breezy Point, Belle Harbor, Rockaway Park, Broad Channel	28,018	27,251	28,009	28,018	28,018

approach is to build “green” infrastructure such as dunes and marshes that will also protect coastal areas and provide habitat as well as recreational opportunities. The “green” approaches are sometimes referred to as “living shorelines” (ERG 2016). A National Oceanic and Atmospheric Administration (NOAA) Coastal Ocean Climate Application program award evaluated the potential impacts of a living shoreline approach on Jamaica Bay (Orton et al. 2017). The results of this work are available in an online interactive mapping application and accompanying technical report at <http://adaptmap.info/>. On the other hand, local communities in Jamaica Bay have identified a number of projects to increase their resiliency to coastal storms. Resilience planning engages decision-makers and vulnerable population in managing climate change and in implementing specific activities that can build understanding on how to respond (ADB 2014). The communities of Jamaica Bay with partner agencies and organizations are charting a path to urban coastal resilience that others around the country can build on (Fitzpatrick 2014). The case studies presented in this chapter stemmed out of the larger impetus to study the effects and impacts of Hurricane Sandy, focusing on coastal SLR and related themes of adaptation, mitigation, and resilience. However, these case studies do not reflect on the newer analyses and findings of the predicted impact of sea-level rise and floods at Jamaica Bay described in this chapter.

Adaptation to Coastal Flooding in New York City Neighborhoods

Adaptation to coastal flooding due to storms is a high priority for city governments on the densely populated northeastern coast of the United States (The City of New York 2011). The concern increased sharply after Hurricane Sandy. New York City has been at the forefront of engaging with climate scientists to understand the

city's vulnerability to climate risks in general and to coastal flooding in particular and to develop adaptation strategies. Initial efforts to address the increasing coastal flood risk were primarily focused on engineered solutions (The City of New York 2013). More recently, the city has engaged in efforts to improve adaptation of residential communities.

This case study complements the efforts to improve adaptation at the neighborhood level by documenting the recovery from Hurricane Sandy in two coastal neighborhoods in New York City, which were most devastated by the storm. The study demonstrates sources of vulnerability that need to be addressed as well as factors that facilitated the recovery, which illustrate how adaptation can be improved. This study focuses on the Rockaways neighborhoods of the Jamaica Bay region. This neighborhood bore the brunt of Hurricane Sandy, experiencing similar intensities of impacts, and is still recovering from the storm. This case study adopted a mixed method approach, combining evidence from in-depth interviews of community leaders, people involved in the recovery, and residents with data from surveys of residents in the two neighborhoods.

The evidence suggests that low- and middle-income homeowners are least recovered from Hurricane Sandy and most vulnerable to future coastal flooding. This evidence is contrary to the common assumption in the literature on social vulnerability that low-income populations are most vulnerable to climate risks, and it illustrates the importance of documenting vulnerabilities that are specific to each climate risk and context in order to inform policy decisions (Madajewicz and Coirolo 2018). The main loss caused by the storm, whose cost was borne by residents of the affected areas, was damage to people's homes. Rebuilding was the component of recovery for which there was least assistance available. Fifty-two percent of the homeowners who responded to the surveys had flood insurance. Eighty-seven percent sustained flood damage. Insurance did not cover the full cost of damages for almost anyone. Low- to middle-income homeowners spent on average \$30,000 on the recovery out of their own pockets, over and above any money recovered from insurance or from other assistance. For the homeowner at the 25th percentile of the income distribution, which is \$42,500 in the survey sample, the amount was 71% of their gross annual income. Higher income homeowners spent a similar amount, \$28,000, which is about 32% of gross annual household income for the homeowner with median annual household income. Renters, who are in the same income range as the low- to middle-income homeowners, spent on average \$3400 out of their own pockets. Low- to middle-income homeowners received on average \$9000 in financial assistance and \$24,000 in insurance payments, while wealthier homeowners received on average \$19,000 in financial assistance and \$21,000 in insurance payments. Renters received \$3700 on average in financial assistance. After these expenditures, low- and middle-income homeowners are far less resilient to future storms than they were before Sandy.

Limited access to several types of information and knowledge was a major source of vulnerability in coastal neighborhoods after Hurricane Sandy. Poor understanding of storm warnings resulted in residents remaining in their homes. Recovery was slower where distribution of information about treating mold and about sources of

assistance was limited. Widespread lack of awareness about future flood risk and how homeowners can reduce damage from future flooding contributed to prevalent rebuilding that retained the same risks, which affected homes before Hurricane Sandy. For example, 80% of survey respondents had to replace their boilers and/or hot water heaters after the storm. Yet only 17% raised any of their electric utilities and the heights to which these utilities were raised were not informed by estimates of future flood risk. Progress on adaptation requires improved understanding at the local, neighborhood level of future flood risk, storm warnings, and actions that residents can take to adapt, in order to inform the resident's decisions about the costs they want to incur to reduce their expected future damages from coastal flooding and whether or not they want to relocate.

Neighborhoods that had stronger community organizations recovered more quickly and completely. Social networks as well as volunteers, community groups, and nonprofit, non-governmental organizations (NGOs) had the presence on the ground that enabled them to collect precise information about who needed what and where and to address those needs quickly. Community organizations were the principal sources of help with rebuilding homes. The rebuilding work ground to a halt when many homes still needed assistance because the NGOs depleted their funding. Public/private partnerships could enhance the capacity of local and volunteer networks and organizations to deliver well-targeted assistance that would improve adaptation to future storms. Partnerships could combine local information and capacity to meet needs rapidly, which are the strengths of the community organizations, and the resources and technical expertise of the public sector (Madajewicz and Coirolo 2018).

Building Community Resilience Capacity in Jamaica Bay

When Hurricane Sandy lashed into New York, most New York City residents thought they were well prepared to weather the hurricane and its after-effects. The negative consequences of the storm disproportionately impacted its most vulnerable residents: the working poor living in immigrant enclaves, those individuals without access to private transportation, public housing residents, and others who were already living in challenging circumstances before the storm eventuated. In 2014, approximately 18 months after the event, researchers from the Institute for Sustainable Cities (ISC) at Hunter College, with support from the Science and Resilience Institute at Jamaica Bay, and the Rockefeller Foundation undertook a qualitative study in several neighborhoods in and around Jamaica Bay to understand how individuals in neighborhoods and communities were navigating the recovery.

The ISC study used qualitative and ethnographic field research methods to connect with these vulnerable populations. The data collection was organized in two levels; a team of graduate students compiled a database of over 400 direct service providers and community-based organizations working in the Jamaica Bay area. This was no small challenge, when considering the reality that Jamaica Bay itself extends 31 square miles and the population in the greater Jamaica Bay watershed approximates about one million

people. The service providers shared their localized and specialized knowledge about the geographical and the social context of different neighborhoods and communities. The research team selected eight neighborhood areas including Gerritsen Beach, Canarsie, Idlewild, Broad Channel, Far Rockaway, Rockaway Park, Arverne, and Breezy Point to conduct focused interviews with residents, engaging them to reflect on their post-Sandy experiences.

In encapsulating the lived experiences of vulnerable populations, the research study was started to document how a singular event such as Hurricane Sandy served as a disruptive event that negatively impacted long-term resilience. The picture of community resilience that gathered after synthesizing interviews with residents, service providers, and professional experts is a complex and sometimes a counter-intuitive narrative. For some individuals and in some neighborhoods, resilience was a state of mind in part, because of an indomitable individual spirit, coupled with a neighborhood that was already connected and engaged. In these resilient neighborhoods like Broad Channel or Breezy Point, residents spoke English, had stable jobs, and owned their homes. They had lived in Jamaica Bay long enough to understand the risks that came with living on the coast, like the effect that tides have on SLR. A mixture of stoicism and a determination to rebuild and stay in a place indicated to the researchers that the benefits of staying in that neighborhood far outweighed perceived “temporary” inconveniences created by the storm.

At the same time, in some neighborhoods like Canarsie, newer New Yorkers who had moved there because of low rents in full/partial basement apartments were displaced for several months. The absence of stable and affordable housing options made renters vulnerable as soon as their places of residence were damaged. The research reaffirmed what became widely known – that both private and public supplies of housing were affected as a result of the storm; the research further elucidated the disproportionate burden borne by renters. It also documented that the instability in housing access created additional problems for vulnerable populations. However, one of the more important findings of the ethnographic work was the absence of key informants who were scattered because of the housing and transportation challenges. This is one of the main challenges researchers encountered in understanding community resilience practices in the low-income neighborhoods around Jamaica Bay (Ramasubramanian et al. 2016a).

In documenting the lived experiences of everyday people, the research team recognized that community (or neighborhood) resilience relies heavily on preserving affordable housing stock in safe and usable condition after a natural disaster. Likewise, maintaining effective public transportation networks after disaster events is an important cornerstone of community resilience because it provides access to jobs and much needed income support. Housing, transportation, and jobs then are the cornerstones of community resilience. The post-Sandy research in Jamaica Bay also educated the research team in recognizing the value of micro-neighborhood research. It was a preliminary step in understanding how to integrate the lived experiences of individuals and groups to make recommendations to state and non-state actors that would enhance community resilience. In this context, community resilience includes the experiences of individuals and groups and takes into the

account the natural environment, the built environment, and the network of civil society and government organizations that provide infrastructural and resource support for that community.

Importantly, the field work resulted in two broad categories of recommendations: one related to education and the second related to engagement. (a) Educating the general public about the issues related to climate change and consequent impact propensity for more frequent and more powerful storms, rising sea levels, numerous flooding events, and so on is critical to creating community resilience in coastal neighborhoods. This education should be available to young people as well as older adults and include both long-term residents and newcomers to the area. (b) The theme of engagement captures the complexity and the challenges of promoting community resilience. The research team recommends that community resilience activities become incorporated as part of a larger neighborhood-based development strategy that emphasizes opportunities for people in the community to come together for vocational education, job training, or learning about ways to revitalize their neighborhoods through civic action. The need for a physical location to host these types of engagement activities that was accessible to neighborhood residents was also recognized (Ramasubramanian et al. 2016b).

In conclusion, the ISC qualitative research about Jamaica Bay communities, approximately 18 months after Hurricane Sandy made landfall, revealed that community resilience among poor communities was present, although fragile and in need of external inputs of resources and expertise. Additional research is needed to investigate the ways in which such support can be effectively delivered to these communities.

Conclusion

Accelerated SLR is a major long-term outcome of climate change leading to increased inundation of low-lying areas which will subject global cities and urban coastal communities to greater risk (Khan 2017). It plays havoc with coastal cities, submerging some areas, and making others far more vulnerable to storm surges, or adversely impacting key infrastructure (Rosenzweig et al. 2011). Building resilience and adapting to climate change threats like SLR are increasingly high priorities for urban coastal cities (Romero Lankao and Dodman 2011; Khan 2017). The starting point in managing risks and building long-term resilience is for a city to understand its exposure and sensitivity to a given set of impacts and develop responsive strategies (The World Bank 2011). Building socio-ecological resilience is one of the significant ways to address SLR as an adaptation strategy. Social and ecological resilience to climate change are inextricably linked and should be considered as integrated socio-ecological systems (Wasterman et al. 2012). Thus, building socio-ecological resilience of densely populated urban coastal regions warrants urgent attention, and cities can take major steps toward building urban climate resilience to SLR. However, there is no single action that will make a city resilient to climate change (SLR). Resilience is instead achieved through a number of actions, building upon each other over time. These actions would be enhanced and progressed as

peoples and institutions learn from past experiences and apply it to future decisions (ADB 2014). Furthermore, building resilience requires not only robust decision-making by those in positions of formal authority but also a strong web of institutional and social relationships that can provide a safety net for vulnerable populations (The World Bank 2011). Jamaica Bay in New York City is a paradigmatic example of environmental vulnerability, particularly given future SLR (Seavitt 2015). Nevertheless, the New York metropolitan region is a classic example of a complex socio-ecological system (Cadenasso et al. 2007; McPhearson et al. 2014). In particular, Jamaica Bay is an ultimate socio-ecological system that exhibits interactions to physical and ecological systems and human or social systems (Binder et al. 2013; Allred et al. 2016). It has the potential to be transformed as an ecological, infrastructural, and community asset – an anchor of the region’s resiliency (Seavitt 2015). The bay provides an incredible opportunity for exploring the performance of nature-based features, particularly salt marshes, maritime forests, and dunes. The bay is a dynamic ecological entity – a sandy, shifting terrain geologically capable of functioning resiliently during and after disturbance events (Seavitt 2015). In this study, COREDAR- (a capacity building tool) based SLR and flood risk information assortment using GIS-based SLR and flood risk assessments of the Jamaica Bay region of New York City (1) provide important information about neighborhood areas and population of Jamaica Bay region that are at risk for SLR projections such as 10 in. and 30 in. of the future 100-year and 500-year floods of the 2020s and 2050s and (2) offer experiences and lessons learned from case studies emphasizing the interaction of socio-ecological systems as a powerful mechanism to enhance resilience since they bring together stakeholders from different sectors, build on their strengths, and craft capacity that would not otherwise exist (Thunder Bay 2015). However, generating and sharing knowledge is critical to build resilience of ecosystems and communities to SLR. As outlined in this chapter, the information gleaned and the case studies highlighted with Jamaica Bay could help spur coastal cities to build resilience of urban ecosystems and communities to SLR. Importantly, it provides access to new information and creates the opportunity to reflect, learn, and act. Thus, the fate of Jamaica Bay serves as a wake-up call to build socio-ecological resilience of other coastal wetlands facing the intertwined effects of SLR and human-induced stresses (Hartig and Gorntiz 2001).

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