National Park Service
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Natural Resource Stewardship and Science

Visionmaker Jamaica Bay

Analysis of community-generated adaptation strategies to enhance resilient ecosystems in and around Jamaica Bay, post-Hurricane Sandy

Natural Resource Report NPS/NCBN/NRR—2019/1925



ON THE COVER

A screenshot of Visionmaker Jamaica Bay depicting a vision of Mill Basin, Brooklyn, New York City.
Image credit: Eric Sanderson.

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Analysis of community-generated adaptation strategies to enhance resilient ecosystems in and around Jamaica Bay, post-Hurricane Sandy

Natural Resource Report NPS/NCBN/NRR—2019/1925

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Executive Summary

To support efforts to make Jamaica Bay more resilient and to enhance ecosystem management in part of the Gateway National Recreation Area, this project developed a free, online tool called Visionmaker Jamaica Bay (https://visionmaker.us/nyc/jamaicabay/) that enables anyone to develop, evaluate and share their own ideas for the future of Jamaica Bay and its watershed in New York City. Launched on June 30, 2015 as part of this project, Visionmaker Jamaica Bay includes several advances specific to ecosystem management for urban coastal areas, including elements that treat climate resiliency, evaluate ecosystem responses to adaptation and restoration strategies, and identify sources of vulnerability. We added new ecosystem relevant to management of the Jamaica Bay Wildlife Refuge, added new metrics of the economic costs and benefits associated with landscape change, introduced new calculations that better estimate species richness and provide estimates of species composition depending on user visions, and implemented a new raster tiling scheme to improve processing times and avoid crashes.

Drawing on a wide array of data about the natural and built environment of New York City, Visionmaker Jamaica Bay provides a set of choices/parameters to develop and share visions of resilience as defined by different users. Visions include representations of the ecosystem geography of Jamaica Bay or some subset of the area; choices about lifestyle parameters; and a selection of a climate scenario to be evaluated. Visionmaker then returns a set of model results about the effects of the user's vision on the area's hydrology, carbon emissions and sequestration, biodiversity, and population. Through this project we also added new metrics of the costs to change ecosystems from one type to another. These options and the suite of model results allows users to broadly explore what resilience means to them on their own terms. Our general definition of resilience captures two aspects of system dynamics: "1. able to bounce back after change or adversity; and 2. capable of preparing for, responding to and recovering from difficult conditions" (NYC 2013). Visionmaker is a tool to help managers, educators, community activists, and local residents create and share visions at different scales, and with different foci, but in the same framework, enabling comparision and discussion.

To investigate how different communities of practice envision Jamaica Bay's resilience, we conducted 12 workshops in cooperation with the new Science Resilience Institute at Jamaica Bay and location institutions. We targeted land managers, researchers, K-12 educators, environmental NGO-members, and Community Board members. While these workshops only yielded 63 visions from 82 users, over the project period 12,326 visions were created city-wide. We analyzed who, how and why users were using Visionmaker Jamaica Bay in our workshops and examined user visions of adaptation to sea level rise and climate change.

We learned that participants tended to focus on ecological aspects of resilience above all else. Most users favored increasing resilience through enhancing salt marsh and green infrastructure while, for the most part, keeping the built city landscape of streets and buildings intact. While there were some small differences between communities of practice on governance, social, and social-ecological attitudes, results reveal little variation between groups from before and after using the tool. Our

sample size was small however. Participants identified several educational and planning applications for Visionmaker. Our results, which must be interpreted carefully given the sample size, suggests that resilience was a relatively static term amongst our participants, defined within a fairly narrow set of bounds. In contrast, advances with the tool have opened up opportunities for a wide range of actors to engage in new practices that may help support innovative resilience thinking and create future Visionmakers around Jamaica Bay. We published about our work in books and journal articles and spoke about our work in forums in New York City and nationally.

The next steps with Visionmaker are to expand its use in and around Jamaica Bay. The National Park Service should use Visionmaker to evaluate and share its visions of the future of its properties, especially given sea level rise. Communities around Jamaica Bay can use the tool to promote and share their visions of their communities. These visions can be developed in classrooms, community meetings, or in private homes and gatherings. The tool can also be further developed to take into account dynamic flood modelling results, to better evaluate ecosystem services and their valuation in monetary terms, and to accommodate new kinds of ecosystems proposed for the bay, such as tidal flood gates and sea walls. Finally we see the possibility of building on the example of Jamaica Bay in the Gateway National Recreational Area to develop Visionmaker deployments for other urban National Park Service properties.

Project Background

Hurricane Sandy in 2012 was a deadly reminder of the risks coastal storms pose for New York City (NYC). On the frontline of the NYC's natural defenses is Jamaica Bay, a unit of the Gateway National Recreation Area, on the southern shore of Long Island, New York. Jamaica Bay is a large lagoon characterized by coastal ecosystems: beaches, dunes, salt marshes, shallow and deep marine water surrounded and penetrated by diverse human communities and critical infrastructure. As a large natural area in a dense urban matrix, the resilience of Jamaica Bay – in terms of its ability to bounce back after a adversity such as Hurricane Sandy and its capacity to respond and recover from future adversities -- is critical for millions of people (and thousands of species) for whom the bay provides home, recreational opportunity, and coastal protection (NPS 2013).

Resilience is not only a matter of emergency response and rebuilding after a storm—it also about enabling more resilient behaviors and choices in the future on the part of government, private institutions, and the public (Hurricane Sandy Task Force, 2013). Past research suggests that the most productive forms of public engagement occur through joint, knowledge creation; tangible, placed-based scenarios; and the opportunity for everyone – not only government or university experts – to innovate at the interface between science, society, and policy (Lane et al. 2010; Heggar et al. 2011; Seijger et al. 2013).

It is an open question what more resilience in Jamaica Bay means and over what time scale. It also seems unlikely there is a single answer to the question of what resilience is given the complexity of the socio-ecological system of Jamaica Bay. What we do know is that the search for resilience is a shared one, that requires synthesis of ecosystem responses, lifestyle choices (including management decisions), and the best climate science. Understanding how visions of resilience vary between individuals, communities, and institutions will strongly influence the success of any management action taken on the part of the National Park Service and its partners in City government.

To respond to this challenge, we assembled a team of experts in ecology, economics, and natural resource management drawn from the consortium of institutions forming the Science and Resilience Institute at Jamaica Bay (SRIJB). Our project began with the premise that ecosystem resilience is not only a function of what ecosystems do; it's also about what people do to and with ecosystems. Many of those choices are rooted in lifestyles and value systems that are diverse, rarely articulated, and in transition as disturbances of all kinds (socio-economic as well as environmental) continue to influence Jamaica Bay communities. In some cases, the choices and values are part of historical processes and decisions that took root hundreds of years ago (Jamaica Bay Environmental Study Group, 1971; Black 1981) in the same way that our decisions will open and close opportunities over coming decades (Sanderson 2013).

The search for resilience thus raises issues of difference at the same time that collaboration and shared vision are essential for the long-term success of adaptation strategies. Fortunately advances in decision-support theory (Wilson & Arvai 2011), ecosystem models (Barbier 2012; Nobre et al. 2010), multimedia studies (Nucci & Kubey 2010) and Internet-enabled crowd-sourcing (Shirky 2008) provide new avenues for scientifically-informed community engagement about ecosystem

resilience to climate change, as manifested in a new tool that we developed through this project: Visionmaker Jamaica Bay.

Our hope at the project beginning was that engaging diverse communities in the creation of future scenarios will build capacity to address climate change and prepare for and recover from intense storm events. Participatory processes demonstrate the value that different stakeholders bring to environmental decision-making and climate adaptation planning, while accruing community benefits from a transparent planning process (Bierle 2002; Adger 2003; Tompkins and Adger 2004). Additionally, by including diverse stakeholders in the planning process there is both increased legitimacy of planning decisions made and participation in implementation of those decisions (Campbell and Vainio-Mattila 2003; Reed 2008).

Project Purpose

A cooperative agreement (#P14AC01473) between the National Park Service and the Wildlife Conservation Society, and its partners at Cornell University, New York Sea Grant, and Rutgers University (both New Brunswick and Newark campuses) provided funding for the work toward three objectives:

1. Objective 1: Adapt a spatially explicit planning tool (mannahatta2409.org) for resilience practice in Jamaica Bay of the Gateway National Recreation Area including elements that treat climate resilience, evaluate ecosystem responses to adaptation and restoration strategies, and identify sources of vulnerability;
2. Objective 2: Conduct workshops with different "communities of practice" and "communities of interest" to investigate visions of adaptation strategies to manage for and/or minimize impacts from sea level rise and climate change and enhance resilience; and
3. Objective 3: Analyze how visions of resilience are created, how they are shared or differ among different stakeholders, and understand the implications of different visions in terms of financial cost, ecosystem services, and species habitats.
4. Objective 4: Publish the results and prepare a final report.

For the purposes of this report, resilience is defined as: "1. able to bounce back after change or adversity; 2. capable of preparing for, responding to and recovering from difficult conditions;" or simply "tough" (NYC 2013). Urban resilience includes many overlapping social and ecological factors that can be studied at multiple scales, most often from the community or city scales. Visionmaker Jamaica Bay is a tool for the National Park Service, city officials, community members, and visitors to NPS sites around Jamaica Bay to investigate what resilience means in terms of water flows, carbon cycles, biodiversity, population and some selected economic metrics.

Objective 1: Adapt mannahatta2409.org to create Visionmaker Jamaica Bay

This section focuses on the methodological changes required to translate an earlier iteration of the tool, "mannahatta2409.org" into "Visionmaker.nyc/jamaicabay." The original form only covered Manhattan Island and had a more limited set of metrics. Visionmaker Jamaica Bay was launched in beta to the public on June 30, 2015.

Visionmaker Jamaica Bay (http://visionmaker.nyc/jamaicabay) enables people to use the Internet to develop and share climate-resilient designs the Jamaica Bay watershed based on rapid and well-understood models of environmental performance, specifically water, carbon, biodiversity, and population. Sixty-four environmental metrics (including greenhouse gas emissions, combined sewer flows, species richness, and daytime population density) are calculated for a user-defined section of the city (minimum size one city block). Metrics are also calculated for that same area of the city as it existed 400 years ago (based on data from the Welikia Project; Sanderson 2009). Finally, users can create their own visions, by modifying spatially-explicit ecosystem distributions (both built and natural ecosystems), choosing the lifestyles of the people living there, and selecting from different climate scenarios (past, present and future), including sea level rise. When users have completed a

vision, the interface allows users to keep their vision private, share it with a set of other users defined by email address, or with the public at large (by being searchable and accessible via the Visionmaker interface.)

As part of this project we adapted the interface in the following ways (1) we added new ecosystems reflecting management requirements in Jamaica Bay and parameterized them; (2) we developed and implemented new metrics of terms of the economic costs of ecosystem construction and demolition, including parameterization; (3) we developed, improved and implemented methods to predict species richness for visions, including improving the species-area calculations for diversity by taxa and a prediction of species composition; and (4) we optimized the application for larger visions. These adaptations are described in detail below.

New Jamaica Bay Relevant Ecosystems

For purposes of management of Jamaica Bay, we split the former "salt marsh" ecosystem into high and low salt marsh ecosystem types. We also split the former "estuary" ecosystem into shallow and deep estuary waters, using 4 m depth below mean sea level as the divider. (Hereafter "estuary" refers only areas with depths between 0 - 4 m.) We also added three airport related ecosystems related to John F. Kennedy International Airport: fuel storage tank, airfield, and airport terminal. We also added bridge and pedestrian bridge to the list of modifiers. Parameters associated with these new ecosystems along with source references are provided in Appendix 1.

Estimating Economic Costs of Ecosystem Change

Visionmaker NYC provides two types of costs related to each vision. First is the total construction cost of creating the vision. Second is the cost of demolishing the ecosystems that exist within the vision extent as of 2014. These costs only relate to any changes that are made within a particular vision relative to the base vision (i.e., the vision extent of 2014). Visionmaker lists 94 different elements that required costing. 87 of these were considered ecosystems in that they required modification of land itself (either by changing the land or building a structure on it). Seven elements were "modifiers," in that they were added to structures (such as cistern/rain barrel or photovoltaic panels). Recently we have also begun examining the economic benefits of ecosystem change in terms of the labor income earned and reinvested in the local economy, creating a multiplier effect.

Costs of Construction and Demolition

For each ecosystem, we obtained reports or data on costs to demolish each one of the various ecosystems in Visionmaker. These reports were for projects throughout the U.S. within the last decade, and each price was converted to New York City 2014 dollars, as described below. In general, the cost estimates assume the destruction/ removal of the ecosystem in question and the grading of the property for new development. Costs to build parameters (Appendix 2) and demolition cost parameters (Appendix 3) incorporated in Visionmaker Jamaica Bay can be found at https://visionmaker.us/nyc/jamaicabay/ and https://www.zotero.org/groups/69043/mannahatta_2409.

By and large, these estimates assume standard or typical costs of demolition and trash removal. This is to say, all estimates implicitly assume that the material is hauled away and placed in a landfill. We assume that the building materials are not recycled or resold. The data do not assume major structural

problem or large costs associated with toxin abatement (such as asbestos) and so on. Furthermore, we assumed there were no additional costs, such as Environmental Impact Assessments, legal fees, or any additional cost that might have be paid in a large demolition project in the city. As such our demolition cost estimates should be considered conservative.

Modifiers that were found to be currently on a structure were assigned to have 0 demolition costs, as we assumed that they were embedded in the demolition cost of the ecosystem (structure) on which they were attached.

For the purposes of providing demolition costs, the 87 ecosystems can be divided into three basic types. Type I are the ecosystems that contain a structure or some development that needs to be removed, such as a building, railroad tracks, or a windfarm (i.e. the built ecosystems). For these cases we found data on the per square foot demolition costs or the total demolition costs divided by the square footage of the project, or land area on which the project exists. Type II relate to the removal of natural elements, such as trees, that needed to be removed before another ecosystem (e.g. an apartment building) could be constructed. In these cases, we estimated removal per square foot or total costs divided by the land area. In cases where prices were given per unit (e.g. per tree), we estimated the number of trees per acres and created a per square foot cost. All of the assumptions are documented in Visionmaker's parameter database and are visible to the public by clicking on the information icon next to demolition costs in the data summary tab.

A third set of ecosystems were those that were not to be demolished per se, but rather were to be eliminated and have the site graded. These included wetlands, estuaries, and tunnels. In these cases, we had few actual costs projects to go by, and as a result, we simply calculated estimates of the total volume of the space, and assumed that the demolition costs are the combined costs of filling in the site with so many tons of sand and then graded and prepared for development. This assumption means that the demolition project is "done on the cheap." There are no Environmental Impact Assessments, retaining walls, piers, plumbing, pumps, etc.

Note that once per square foot costs were determined, they were then converted to per square meter costs to be in agreement with the measurement system used by Visionmarker.

Similar to the demolition costs, we obtained per square foot cost estimates for creating all of the ecosystems and modifiers, on the assumption that the site was graded, cleared, and ready for development. We did not include any additional costs beyond the ones chosen by the Visionmaker system. That is, we assume, for example, that if user creates an apartment building then plumbing pipes and electricity cables already exist under the streets and are hooked up to the new unit. To keep things simple, we did not include transaction costs, financing costs, or any other fees that are directly related to the project. Also note if the original vision had some wetland, then the cost estimates for a new wetland or body of water means that first the users "pays" the demolition costs and then second pays the construction cost for the new wetland. Again, similar to the demolition costs, we converted costs to New York City 2014 dollars (see below). Similar to demolition costs, all per square foot costs were converted to per meter costs compatible with Visionmaker area metrics.

To support visions that might include tall buildings we needed to address issues of construction cost with skyscraper height. In regard to building height, after some height, taller buildings become increasing expensive to construct on a per square foot basis than shorter ones. The reason is that as the structures become taller some costs increase at an increasing rate, thus causing the average costs to rise. In particular, taller buildings need more wind bracing, more elevators, stronger structural steel or cement, and larger or deeper foundations (Barr 2016). To this end, we estimate how construction costs vary with building height.

The website www.emporis.com provides a data base of nearly all tall buildings constructed in New York City. From this website we were able to obtain the total construction costs, name, address, type, and year of completion for 21 tall buildings completed in New York City between 2001 and 2015. The buildings ranged in height from 25 to 104 stories.

We were able to obtain the gross building area from either the Council on Tall Buildings and Urban Habitat's skyscraper database (http://www.ctbuh.org/TallBuildings/tabid/485/language/en-GB/Default.aspx) or the New York City Map Portal (http://maps.nyc.gov/doitt/nycitymap/). Finally, we obtained the value of the New York City metropolitan area Consumer Price Index (CPI) from the Bureau of Labor Statistics. The CPI was adjusted to so that the year 2014 was set to one (and thus previous years had lower price levels). The real total construction costs were calculated by taking the nominal construction costs and dividing them by the CPI value in the year in which the building was completed.

We also included total costs for four more buildings based on construction budgets that were we received from a real estate company in New York. Because of a confidentiality agreement we provide the real costs per square foot and the building height but withhold other information. Please note that some of these buildings are under construction. Future real costs were projected by assuming that the CPI grows at an annual rate of 2% for the next few years. Table 1-1 gives the data for the buildings.

Table 1-1. Data set of New York City buildings used for analysis of construction costs.

Building	Address	Type	Total Costs ($M)	Year Completed	NYC CPI* (2014=1)	Gross Building Area (in 100000 sq. ft.)	Stories	Real Costs per Square Foot ($2014)
The Westport	500 West 56th Street	Residential	75	2003	0.76	3.910	24	252
DoubleTree Hotel – Chelsea	128 West 29th Street	Hotel	17	2009	0.91	0.801	26	233
12 MetroTech Center	330 Jay Street	Office	360	2005	0.82	12.000	32	367
The Alex Hotel	205 East 45th Street	Hotel	70	2003	0.76	1.449	32	635
Capitol at Chelsea	55 West 26th St	Residential	76	2001	0.72	4.545	37	233
The Helena	601 West 57th St	Residential	160	2005	0.82	5.472	37	358
Lehman Bros Building	745 7th Ave	Office	250	2001	0.72	10.200	38	341
Millennium Point	25 Battery Place	Residential	175	2001	0.72	5.750	38	423
One Carnegie Hill	215 East 96th Street	Residential	103	2006	0.85	4.908	41	247
Tower 31	9 West 31st Street	Residential	98	2006	0.85	2.424	41	476
The Marc	260 West 54th	Residential	76	2004	0.79	4.354	42	222
325 5th Avenue	325 5th Avenue	Residential	190	2006	0.85	3.174	42	706
Hearst Tower	959 8th Avenue	Office	312	2006	0.85	8.639	46	426
Times Square Tower	7 Times Square	Office	230	2004	0.79	10.794	47	270
Seven World Trade Center	Seven World Trade Center	Office	700	2006	0.85	16.811	49	491
Random House Tower	1745 Broadway	Office	300	2003	0.76	8.600	52	459
New York Times Tower	620 8th Avenue	Office	850	2007	0.87	15.457	52	631
Bank of America Tower	West 42nd St	Office	1000	2009	0.91	21.000	55	523

*NYC CPI = New York City consumer price index

Tble 1-1 (continued). Data set of New York City buildings used for analysis of construction costs.

Building	Address	Type	Total Costs ($M)	Year Completed	NYC CPI* (2014=1)	Gross Building Area (in 100000 sq. ft.)	Stories	Real Costs per Square Foot ($2014)
Barclay Tower	10 Barclay St	Office	185	2007	0.87	5.650	56	375
Trump World Tower	845 UN Plaza	Residential	300	2001	0.72	8.977	72	465
One World Trade Center	One World Trade Center	Office	3900	2014	1.00	35.013	104	1114
Info withheld	Info withheld	Office	1050	2011	0.95	9.732	40	1133
Info withheld	Info withheld	Office	1214	2016	1.04	18.111	47	644
Info withheld	Info withheld	Office	906	2017	1.06	13.183	51	648
Info withheld	Info withheld	Office	2007	2014	1.00	25.499	65	787
Info withheld	Info withheld	Office	2552	2018	1.08	28.039	80	841

*NYC CPI = New York City consumer price index

The data set contains a total of 26 buildings. However, from this we removed one building from consideration: the 40-story 11 Times Square, which was a severe outlier in terms of its construction costs (Barr 2016). For each building height, we took the average of real per square foot cost for that height (if there were multiple observations for a particular height). If there was only a single observation, we just included that observation. This gave a sample of 18 observations. Figure 1-1 shows these average costs plotted against building height. The black line is the trend line and this was estimated using ordinary least squares. Table 1-2 presents the estimated coefficients, the predicted cost values and the residuals. Figure 1-1 also provides the per-square-foot costs for office buildings between one and 20 stories, as estimated by RSMeans (2013).

Table 1-2a. Regression statistics of construction costs per square foot ($ 2014).

Statistic	Value
Multiple R	0.878
R-Square	0.771
Adj. R-Square	0.757
Standard Error	109.000
Observations	18.000

Table 1-2b. Regression statistics of the number of stories of selected tall buildings in New York City and construction costs per square foot ($ 2014).

Statistics	Coefficients	Standard Error	t Stat	P-value
Intercept	8.19	72.84	0.11	0.91
Stories	9.83	1.34	7.35	0.00

Table 1-2c. Predicted construction costs per square foot ($ 2014) depending on the number of stories of tall buildings in New York City, with residuals, based on the regressions in Tables 1-2a and 1-2b.

Observation	Predicted Avg. Costs ($ / sq. ft.)	Residuals
1	244	8.28
2	264	-30.63
3	323	178.51
4	372	-76.77
5	382	0.37
6	411	-49.60
7	421	42.72
8	460	-34.02
9	470	-12.94
10	490	1.11

Table 1-2c (continued). Predicted construction costs per square foot ($ 2014) depending on the number of stories of tall buildings in New York City, with residuals, based on the regressions in Tables 1-2a and 1-2b.

Observation	Predicted Avg. Costs ($ / sq. ft.)	Residuals
11	510	138.01
12	519	25.40
13	549	-25.59
14	559	-183.19
15	647	140.04
16	716	-251.17
17	795	46.11
18	1031	83.36

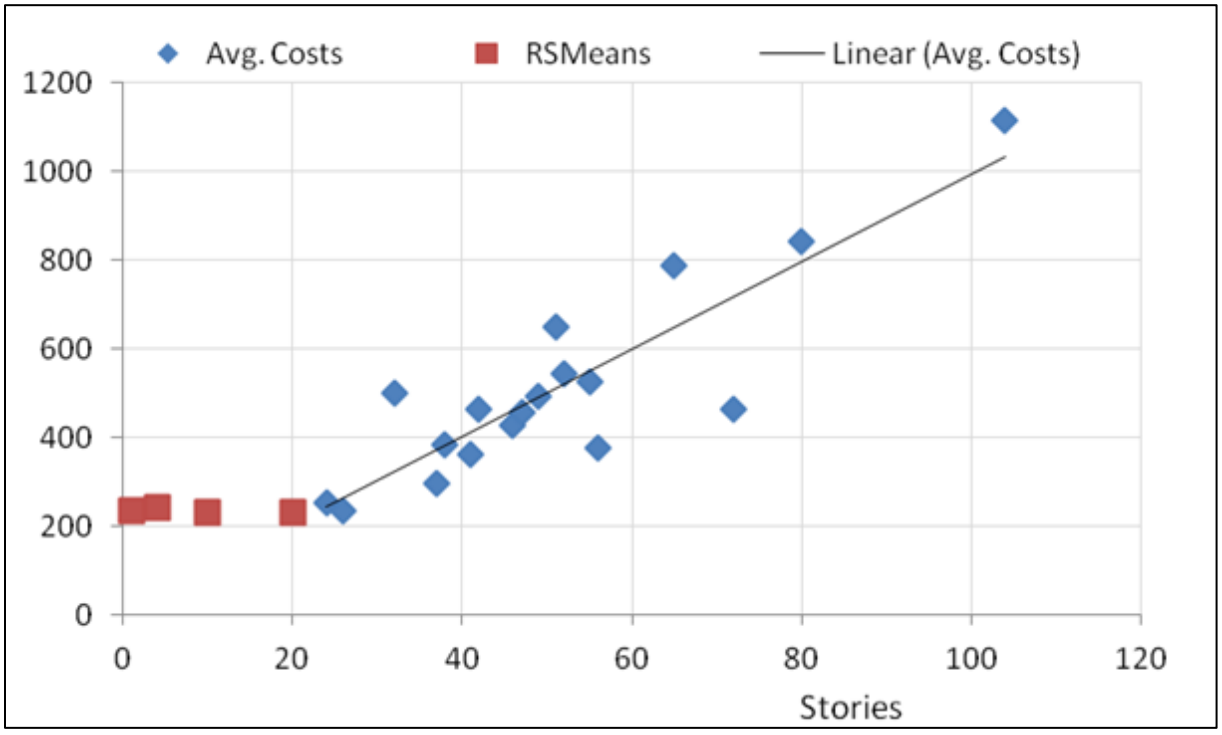


Figure 1-1. Average per square foot costs ($) in New York City versus building height.

RSMeans (2013) provides per square foot costs for buildings of different types of structures. Some structures, such as hospitals and data centers, have greater "base" per square foot costs, then do offices or apartment buildings, where the base costs represent the average per square foot cost for a low-rise version of the structure. Other structures, such as garages, have lower per bases. Table 1-3 provides information on the highest per-square foot costs for different types of structures under 25 stories. These represent our base costs. Note not all buildings types in Visionmaker are given in the table.

Table 1-3. Examples of United States versus New York City building types and based costs from RSMeans (2013).

Building Type	U.S. Base Cost ($ / sq. ft.)	NYC Base Cost ($ / sq. ft.)
Garage	65	85
Warehouse	108	141
Factory	135	177
Retail building	145	189
Office	183	240
School or university	190	248
Hotel	205	268
Restaurant	220	288
Apartment building	230	301
Computer data center	305	400
Hospital	341	446

In order to estimate the costs of different types of structures of varying heights we applied the following rules:

(a) If the building height was less than 25 stories, we used the maximum value of per-square foot costs for that building type, as provided by RSMeans (2013).

For example, for offices, the highest per square foot cost is a 2 - 4 story building (20,000 sq. ft.) at $183 per square foot. This gives a New York City base value of $240 per square foot.

(b) If a building was 25 stories are taller, we applied the following formula:

Per Square Foot Cost=(NYC base value-240+ 8.19)+(9.83*story).

For example, an office building of 50 stories will have estimated per square foot costs equal to 8.19+9.83*50=500.40. A 50-story hospital will have estimated costs equal to (446-240+8.19) +9.83*50=$705.69 per square foot. Once the per-square foot costs were determined, they were converted to per square meter costs.

As these calculations show, we use the office base price as the reference point, and costs are shifted up or down based on how much they deviate from the office base price. Also note that in this particular data set, there was no statistically significant difference in the costs between the different types of buildings. That is to say, in this data, offices, hotels and apartments, appear to have the same per square foot construction costs. RSMeans (2013), however, has apartment buildings having a higher base cost relative to offices; for consistency, we use this higher apartment base cost in the Visionmaker estimates. Note that formula (b) above suggests that average square foot costs rise about $10 per story added to the building above 24 stories.

Adjusting ecosystem and demolition costs to equivalent costs in New York City in 2014

Ecosystem and demolition costs estimated were based on values obtained throughout the U.S. and since 1991, though mostly in the last five years. Since Visionmaker relates to costs in New York City in the present (at the time of the project, taken to be 2014), it was necessary to adjust the costs across space and time so that they reflected New York City costs as of the end of 2014/early 2015. Thus, we created "conversion factors" so that each place-year cost can be adjusted to reflect New York 2014.

RSMeans (2013) provides a series of "location factors," which allow one to see how building costs differ across specific areas across the U.S., relative to average U.S. costs. For example, New Britian, CT has a location factor of 1.11 for residential costs. Thus, RSMeans (2013) calculates that building costs in New Britain are 11 percentage points higher than the national average. RSMeans (2013) gives location factors for both residential and commercial construction. We used the values from the residential column, though commercial values are quite similar.

For the cost analysis for Visionmaker2409, we used state averages for the location factors since we often had multiple cost estimates for each state. For New York City, RSMeans (2013) does not provide one New York City Location Factor, but rather provides several values within the city. To create the New York City Location Factor, we took the average values across the five boroughs.

Table 1-4 provides the locations and the average location factors for those locations (as of July 1, 2015). Again, each location factor is the cost of construction relative to the national average. Note that the New York City location factor is 1.312.

To convert a particular location to New York City costs, we applied the formula:

$$\text{Location Conversion Factor} = 1.312 / \text{Avg. Location Factor}$$

This formula converted a particular place's cost to New York City costs. For example, for a project in Vermont, the average location factor is 0.943, meaning that costs in Vermont are 5.7 percentage points less expensive relative to the national average. To convert Vermont costs to New York City costs we applied the formula 1.312/0.943=1.391. In other words, average construction costs are estimated to be 39.1% more expensive in New York City as compared to Vermont, on average.

Note that our conversion factors assume that the relative costs across regions do not change across years. That is to say, we assume that costs in Vermont have remained 39.1% less expensive across time. This is done for simplification, but we believe it to be a reasonable approximation for the time period under consideration.

Table 1-4. Average Location Factors from RSMeans (2013) and Location Conversion Factors, which converts a particular location's prices to New York City prices.

Location	Avg. RSMeans (2013) Factor	Location Conversion Factor
AK	0.742	1.769
CA	1.115	1.177
CT	1.109	1.183
FL	0.843	1.556
IL	1.086	1.208
MI	0.941	1.394
MT	0.879	1.493
NC	0.839	1.563
NV	0.978	1.342
NY	1.117	1.174
NYC	1.312	1.000
OK	0.782	1.678
PA	0.958	1.370
TX	0.766	1.713
US	1.000	1.312
VT	0.943	1.391
WA	0.981	1.337

Once each particular cost value was adjusted to New York City prices, we then adjusted this value for inflation, according to the New York City metro area Consumer Price Index (CPI) (see Table 1-5). For example, if the above Vermont cost was incurred in 2010, we first converted it to a New York City price and then adjusted that New York City price to 2014. Note that for simplicity, costs incurred in 2015 were assumed to have the same prices as 2014. This was done since costs for 2015 were likely posted early in the year and were likely very close to prices in 2014.

According to Table 1-5, the NYC CPI was 0.926 relative to 2014. Thus, we adjusted 2010 prices to 2014 by 1/0.926 = 1.08. That is, average prices have risen 8% between 2010 and 2014 in New York City.

In short, we created CPI-Year Conversion Factors by first adjusting the NYC CPI to have a value of 1 in 2014, and then we converted each year's adjustment factor by the formula of 1/CPI Value for a particular year. In the future, calculations could be implanted to any year for which the the corresponding NYC CPI is available - see Table 1-5.

Table 1-5. New York City Consumer Price Index* (CPI) and CPI-Year Conversion Factor.

Year	CPI (1983=100)	CPI Adjusted so that 2014=1	CPI-Year Conversion Factor
1990	138.50	0.532	1.879
1991	144.80	0.556	1.797
1992	150.00	0.576	1.735
1993	154.50	0.594	1.684
1994	158.20	0.608	1.645
1995	162.20	0.623	1.604
1996	166.90	0.641	1.559
1997	170.80	0.656	1.524
1998	173.60	0.667	1.499
1999	177.00	0.680	1.470
2000	182.50	0.701	1.426
2001	187.10	0.719	1.391
2002	191.90	0.737	1.356
2003	197.80	0.760	1.316
2004	204.80	0.787	1.271
2005	212.70	0.817	1.223
2006	220.70	0.848	1.179
2007	226.94	0.872	1.147
2008	235.78	0.906	1.104
2009	236.83	0.910	1.099
2010	240.86	0.926	1.080
2011	247.72	0.952	1.051
2012	252.59	0.971	1.030
2013	256.83	0.987	1.013
2014	260.23	1.000	1.000

*source: bls.gov

Given the average location factor from RSMeans (2013) and the CPI-year factor, we created location-year conversion factors by multiplying the average Location Conversion Factor by the CPI-Year Conversion factor to convert a cost value across both time and space. Using Tables 1=4 and 1-5, any location-time conversion factor can be created by taking the Location Conversion Factor and multiplying it by the CPI-Year Conversion Factor.

Validation of Visionmaker economic metrics

In addition, we have performed validation exercises with respect to the cost calculations and have found that, to a first approximation, Visionmaker provides reasonable estimates for the costs of demolishing and construction the various ecosystems. Construction costs are varied but of

approximately the right magnitude; wetland restoration projects appear to have their costs somewhat under-estimated by Visionmaker.

To validate the Visionmaker construction cost estimates, we used reports from seventeen New York City construction projects (Table 1-6). For each location, we created a vision in Visionmaker mimicking the construction project. We found that Visionmaker generally performed well when estimating building costs. On average, we found that the ratio to actual costs to predicted costs by vision maker was 1.14, suggesting that the actual costs, on average were about 14% more expensive. Note that our model we generally omitted planning costs and is conservative in other ways, as noted above. Also note we do not include demolition costs for this calculation.

Table 1-6. Actual construction projects in New York versus Visionmaker (VM) estimated costs.

Obs.	Project	VM Ecosystem	Actual Cost ($/sq. ft)	VM Estimate ($/sq. ft.)	Ratio (actual to estimate)	Table Note for Source
1	Office/business	Office building	156.16	182.06	0.86	a
2	Warehouse	Warehouse	104.79	187.54	0.56	a
3	Highway	Highway	18.69	15.35	1.22	b
4	Elmhurst branch library	Library	455.56	332.53	1.37	c
5	Queens auditorium	Library	777.78	332.53	2.34	d
6	High Rise Luxury Condominium, with garage on bottom	Apartment building	512.15	654.33	0.78	a
7	New York State Park Fields, Staten Island	Stadium	542.86	618.22	0.88	d
8	Yankee stadium	Stadium	1000.00	618.22	1.62	Area: e Cost: f
9	Rescue company 3, Bronx	Factory-with Green Roof/Solar Panels/Thermal panels	739.13	395	1.88	c
10	Central Harlem Health Center	Hospital	359.14	588.66	0.61	c
11	Riverside Health Center	Hospital	523.81	472.28	1.11	Cost: c Area: g
12	Bridge - NYC	Roads	14.01	12.68	1.11	b

a. https://www.cbre.us/real-estate-services/business-lines/valuation-and-advisory-services/assessment-and-consulting-services

b. http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP20-68A_09-05.pdf

c. https://www1.nyc.gov/assets/ddc/downloads/publications/about-ddc/dce-2007.pdf

d. http://www.nyc.gov/html/ddc/downloads/pdf/DCE_2008.pdf

e. www.turnerconstruction.com/experience/project/1573/yankee-stadium

f. www.athleticbusiness.com/stadium-arena/how-stadium-construction-costs-reached-the-billions.html

g. https://centerforactivedesign.org/riverside-health/

h. https://lib.dr.iastate.edu/cgi/viewcontent.cgi?referer=&httpsredir=1&article=4781&context=etd

i. https://www.transportation.gov/

j. https://manhattanville.columbia.edu/

Table 1-6 (continued). Actual construction projects in New York versus Visionmaker (VM) estimated costs.

Obs.	Project	VM Ecosystem	Actual Cost ($/sq. ft)	VM Estimate ($/sq. ft.)	Ratio (actual to estimate)	Table Note for Source
13	Road	Roads	36.73	12.68	2.90	b
14	I-787 Bridge-Reconstruction	Highway	18.69	17.76	1.05	h
15	Western Ave	Highway	2.30	17.76	0.13	h
16	Florida Street	Street	36.00	484.7	0.07	i
17	Columbia U. Expansion	School/university	400,000,000	391,412,010	1.02	j
Average		–	–	–	**1.15**	–
Standard deviation		–	–	–	**0.71**	–
Coefficient of variation		–	–	–	**0.62**	–

a. https://www.cbre.us/real-estate-services/business-lines/valuation-and-advisory-services/assessment-and-consulting-services

b. http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP20-68A_09-05.pdf

c. https://www1.nyc.gov/assets/ddc/downloads/publications/about-ddc/dce-2007.pdf

d. http://www.nyc.gov/html/ddc/downloads/pdf/DCE_2008.pdf

e. www.turnerconstruction.com/experience/project/1573/yankee-stadium

f. www.athleticbusiness.com/stadium-arena/how-stadium-construction-costs-reached-the-billions.html

g. https://centerforactivedesign.org/riverside-health/

h. https://lib.dr.iastate.edu/cgi/viewcontent.cgi?referer=&httpsredir=1&article=4781&context=etd

i. https://www.transportation.gov/

j. https://manhattanville.columbia.edu/

Figure 1-2 shows a scatter plot for the actual construction costs and the Visionmaker estimates of the projects in Table 1-6. Also included is the regression line of Visionmaker estimates versus actual costs. Note we set the constant equal to zero, since we aim to look at the slope of the line to see if it's close to one. Table 1-7 shows the full regression results. Note that the coefficient representing the slope = 1 remains within the 95% confidence interval; thus we cannot reject the null hypothesis that the slope is, in fact, 1. This again suggests Visionmaker estimates are proportionally accurate, even if there remains some scatter in the relationship due to site specific factors.

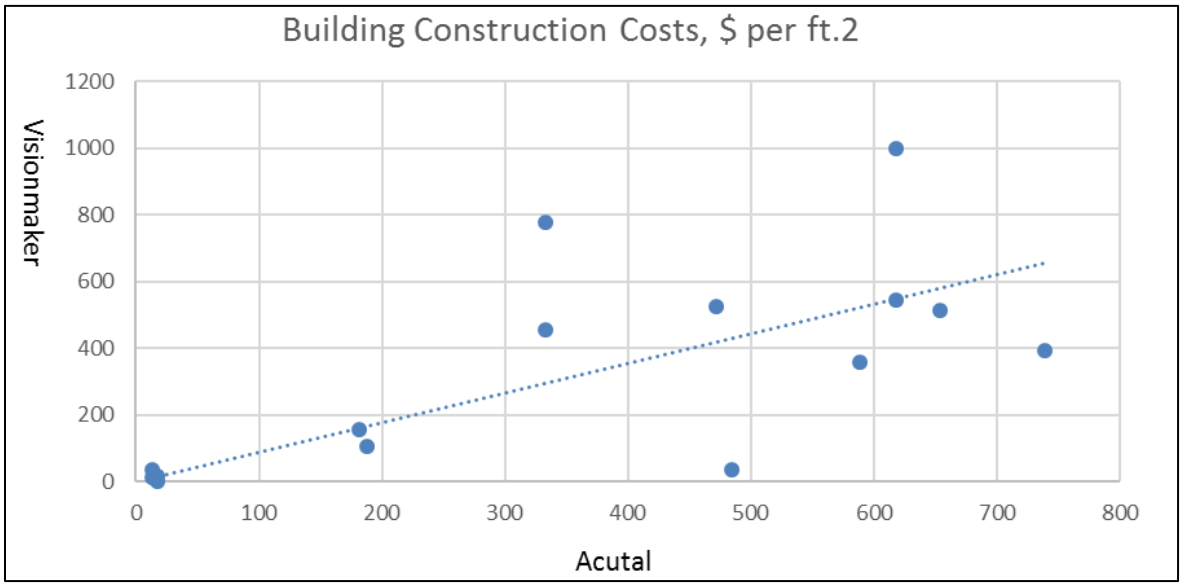


Figure 1-2. Scatter plot of Visionmaker estimated costs vs actual costs for New York City construction projects.

Table 1-7a. Summary of regression statistics validating the Visionmaker estimates of construction costs for buildings against known costs for selected tall buildings.

Statistic	Value
Multiple R	0.868
R Square	0.753
Adjusted R Square	0.686
Standard Error	221.049
Observations	16

Table 1-7b. Slope of regression line validating Visionmaker estimates of construction costs for selected tall buildings.

Statistic	Blank Header	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Slope	Actual	0.89	0.13	6.76	0.00	0.61	1.17

Note: Intercept is suppressed (i.e. set to zero).

Validation for Wetland Restoration Cost Estimates

To estimate the model's ability to predict wetland restoration projects we collected data on projects that were completed in and around New York City. We replicated them in Visionmaker as best we could, given the varied nature of these projects. Here we found more variation with our predictions vis a vis the actual costs. The model performed well when there were many different components to the project and was less accurate when there were fewer components. The Spring Creek South case was an example where Visionmaker predicted 98% of the cost. Note that Visionmaker does not include planning costs, which can often increase total costs by 25% and does not include the costs associated with reshaping the topography, which can be an important part of coastal wetland restorations like this. For our calculations, we reduced the actual costs by 25% in order to properly compare them with the costs calculated by Visionmaker. We also include demolition costs here.

Even so, the Visionmaker under-predicts the actual costs by about 33% on average. This is to be expected because of site specific characteristics that greatly impact the cost of reconstruction. We assumed in Visionmaker sites were relatively easy sites for construction and did not present unusual or unexpected circumstances. The high degree of variation in remediation costs is confirmed by the EPA's "Cost of Wetland Reconstruction Report."

Table 1-8. Construction costs and Visionmaker (VM) estimates (including demolition) for environmental restoration projects in Jamaica Bay.

Project Name	Actual Costs ($)	VM Estimated Costs ($)	Actual / Estimated Ratio
Paerdegat Basin	35,325,000	58,197,261	0.607
Fresh Creek	19,125,000	37,951,842	0.504
Bayswater State Park	2,400,000	1,233,342	1.946
Dubos Point	3,975,000	1,513,930	2.626
Brant Point	3,900,000	1,551,619	2.514
Hawtree	825,000	377,265	2.187
Spring Creek-south	36,750,000	36,091,115	1.018
Average	14,614,286	19,559,482	1.629
Standard deviation	15,846,101	24,007,574	0.901
Coefficient of variation	1.08	1.23	0.553

Source: Actual costs:
www.nan.usace.army.mil/Portals/37/docs/civilworks/projects/ny/ecor/JamBay/restoration.pdf

Figure 1-3 shows the scatter plot between the Visionmaker estimates and the acutal costs for 7 project. We can see a strong correlation between the two, though the slope appears greater than one. Table 1-9 shows the regression results of the Visionmaker estimates versus the actual costs. The estimated slope of the line is 1.37 (again, the constant is suppressed). While a slope of 1 remains in the 95% confidence interval, it is toward the bottom of the interval. Here we reject the null

hypothesis that the true coefficient is 1. In short, in regard to wetland remediation projects, our Visionmaker estimates tend to understate the true values on average. However, given the small sample of estimates, further testing would be required.

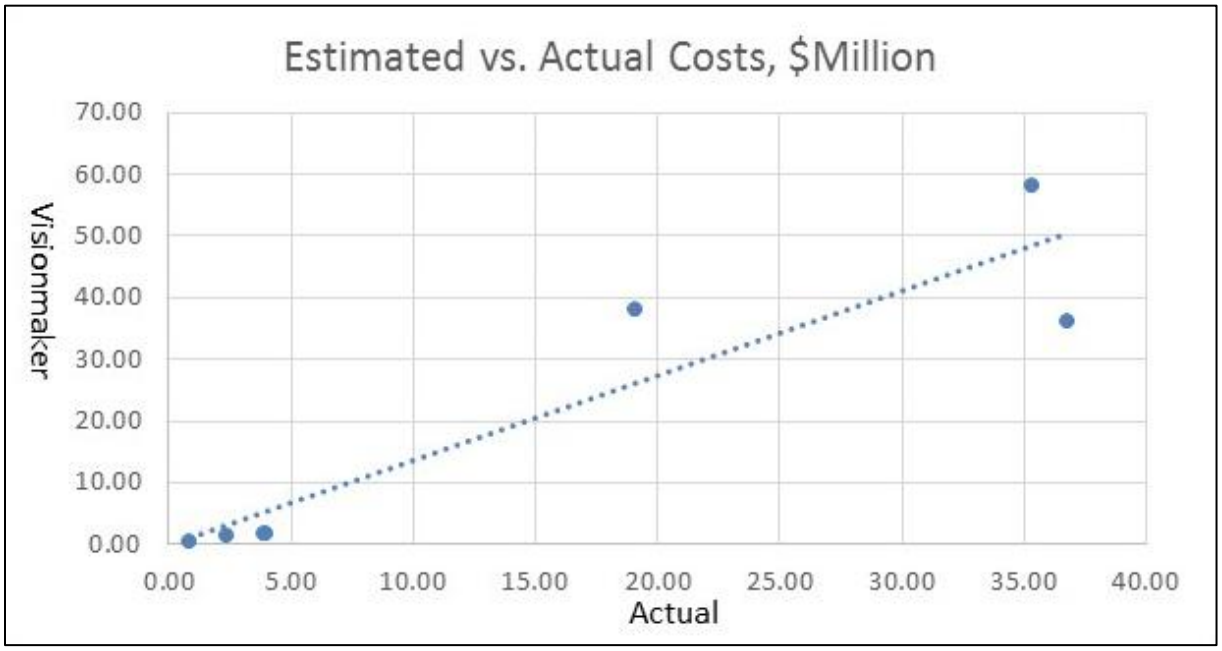


Figure 1-3. Scatter plot of Visionmaker estimated costs vs actual costs for wetland restoration projects in and around Jamaica Bay, New York. Trend line with constant suppressed.

Table 1-9a. Summary of regression statistics of Visionmaker estimated costs for wetland restoration projects in Jamaica Bay against known restoration costs.

Statistic	Value
Multiple R	0.9608
R Square	0.9231
Adjusted R Square	0.7564
Standard Error	8.8693
Observations	7

Table 1-9b. Slope of regression analysis of Visionmaker estimated costs for wetland restoration projects in Jamaica Bay against known restoration costs.

Statistic	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Slope	1.37	0.16	8.49	0.00	0.98	1.77

Note: Intercept is suppressed (i.e. set to zero).

Example of New Visionmaker Economic Functionality

Here we give an example of the functionality of the economic metrics. In this, case we've highlighted an area around Howard Beach, Queens, adjacent to Jamaica Bay (we called the vision "JFK" just for simplicity). In the new vision (for 2014; Figure 1-4a) we created we demolished all the structure buildings in the vision extent. Then we add one area with 15 story residential buildings, surrounded by a large meadow and low salt marsh. Roads connect the housing and the natural landscapes.

Figure 1-4a shows this new vision in the Visionmaker mapping interface. Figure 1-4b shows the estimated construction costs, which are over $500 million. This reflects the large housing complex in the upper left hand corner, which is aimed to house around 2884 people. Keep in mind that One World Trade Center in lower Manhattan cost around $4 billion, so this would be a very expensive project. While Visionmaker enables us to make cost estimates, it also provides a cautionary note about how expensive construction and demolition can be in New York City. The estimated demolition costs come in around $6.2 million (not shown), reflecting mostly the teardown of one and two family houses.

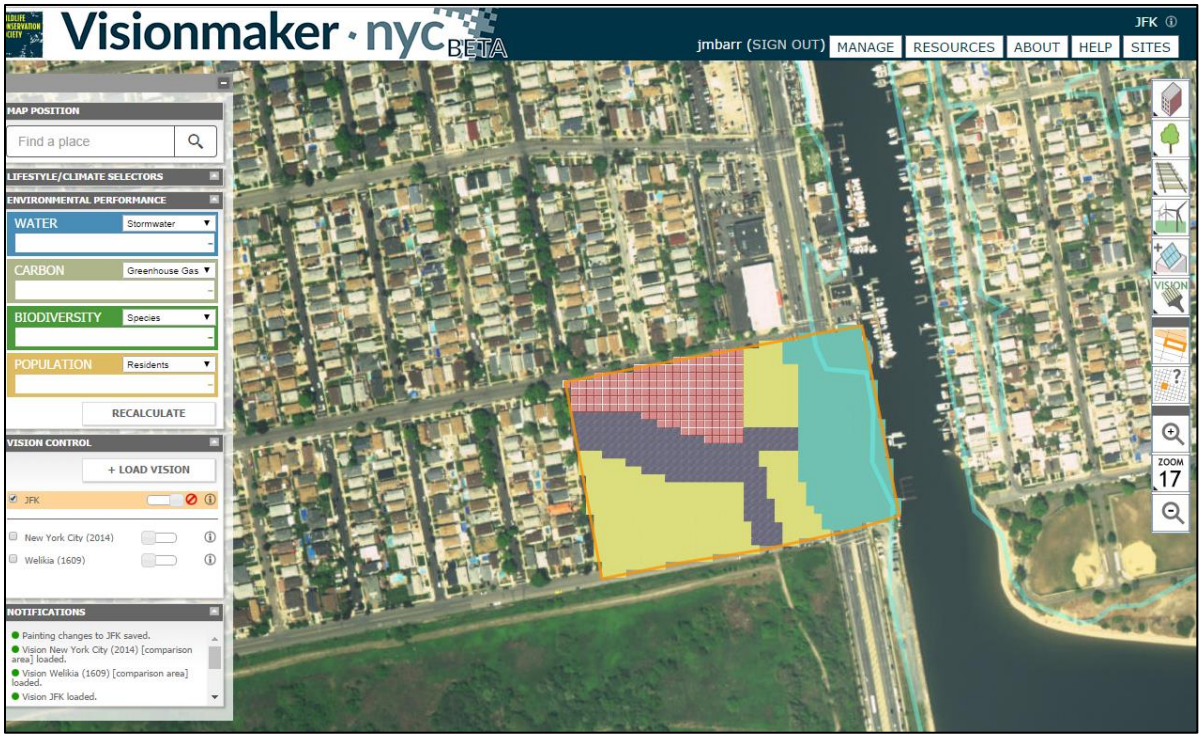


Figure 1-4a. A sample vision created with Visionmaker in the Howard Beach neighborhood of New York City.

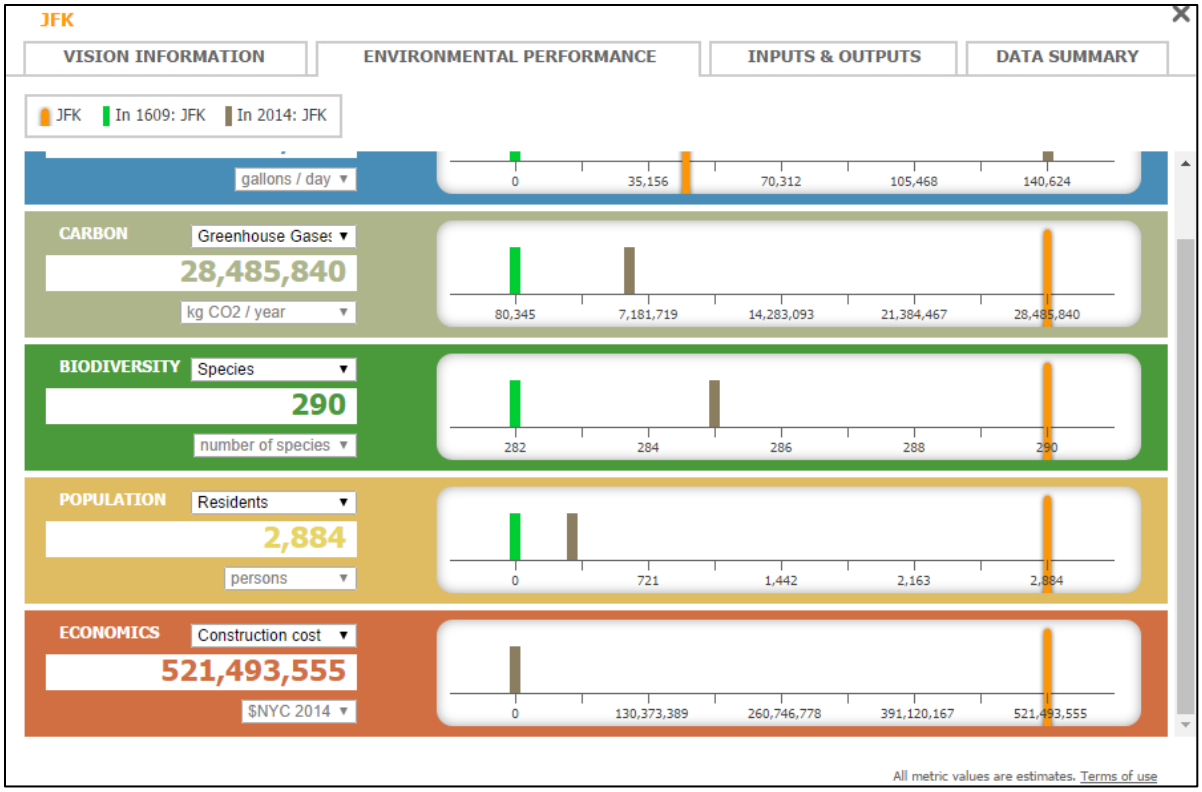


Figure 1-4b. Estimated construction costs for the vision shown in Figure 1-4a. Note the construction costs in the final red panel at the bottom of the environmental performance tab.

Improvement and Extension of Species Richness Calculations

To estimate the species richness and species composition of a vision, we used the following overall method:

1. Reclassify ecosystem areas into a smaller set of generic habitat types
2. Calculate the potential species richness by taxa using a species-area curve by climate scenario
3. Calculate species-specific habitat areas for Jamaica Bay/ New York City relevant species
4. Filter by minimum required area for each species
5. Sort filtered list by species habitat area, with largest species-specific habitat areas first
6. Take the top of the list until either it matches the potential species richness or no further species meet the minimum habitat requirement.

Reclassification into Generic Habitat Types

First, we estimate habitat areas based on the user's vision. We do this by reclassifying the ecosystems into generic habitat types (Table 1-10). Habitat types in this usage refers to how non-human organisms see the city, differentiating natural ecosystems into unique ecological community types and lumping built ecosystems into a generic "pavement and buildings" type. Most of the natural ecosystems have a corresponding habitat type (e.g. all of the area of the freshwater marsh ecosystem

becomes the freshwater marsh habitat type). We multiply the area of each ecosystem type in the user's vision by a parameter representing the proportion of the habitat in the ecosystem to determine the area of each of the nineteen habitat types. Generic habitat areas are expressed in square meters. Species habitat requirements will expressed in terms of these generic types as explained below.

Table 1-10. Percentage of ecosystem associated with generic habitat types in Visionmaker Jamaica Bay. Note zero values are not shown.

Habitat	Ecosystem	Percentage of ecosystem area associated with habitat type
Beach	Beach	100
Cliffs	Cliffs and rock outcrops	100
Conifer forest	Hemlock – northern hardwood forest	75
Cultivated field	Agricultural field / vegetable garden	80
Cultivated field	Orchard	100
Deep estuary	Deep water estuary	100
Disturbed Land	Agricultural field / vegetable garden	20
Disturbed Land	Disturbed Land	100
Disturbed Land	Landfill	100
Disturbed Land	Permeable pavers	40
Disturbed Land	Trail	100
Disturbed Land	Wind farm	50
Eelgrass meadow	Eelgrass meadow	100
Estuary	Estuary	100
Estuary	Tidal energy facility	50
Forested wetland	Hardwood swamp	100
Freshwater marsh	Bioswale	100
Freshwater marsh	Freshwater marsh	100
Garden	Ornamental garden	100
Garden	School or university	25
Garden	Street trees	100
Lawn	Airfield	5
Lawn	Lawn	100
Meadow	Meadow	100
Mixed deciduous forest	Hemlock – northern hardwood forest	25
Mixed deciduous forest	Oak hickory forest	100
Mixed deciduous forest	Park savanna	100
Pavement and buildings	Airfield	95
Pavement and buildings	Airport terminal	100
Pavement and buildings	Alley	100

Table 1-10 (continued). Percentage of ecosystem associated with generic habitat types in Visionmaker Jamaica Bay. Note zero values are not shown.

Habitat	Ecosystem	Percentage of ecosystem area associated with habitat type
Pavement and buildings	Apartment building	100
Pavement and buildings	Bike lane	100
Pavement and buildings	Boulevard (arterial)	100
Pavement and buildings	Bridge	100
Pavement and buildings	Cistern / rain barrels	100
Pavement and buildings	Cogeneration plant	100
Pavement and buildings	Compost bin	100
Pavement and buildings	Computer data center	100
Pavement and buildings	Cottages / Mobile home	100
Pavement and buildings	Derelict structures	100
Pavement and buildings	Diesel power plant	100
Pavement and buildings	Elevated train	100
Pavement and buildings	Factory	100
Pavement and buildings	Fuel storage tank	100
Pavement and buildings	Garage	100
Pavement and buildings	Gas station	100
Pavement and buildings	Geothermal pump	100
Pavement and buildings	Graywater recycling	1
Pavement and buildings	Heavy rail line	100
Pavement and buildings	Highway	100
Pavement and buildings	Hospital	100
Pavement and buildings	Hotel	100
Pavement and buildings	Light rail line	100
Pavement and buildings	Mixed use: office / residential building	100
Pavement and buildings	Mixed use: restaurant / office building	100
Pavement and buildings	Mixed use: restaurant / residential building	100
Pavement and buildings	Mixed use: restaurant / retail building	100
Pavement and buildings	Mixed use: retail / office building	100
Pavement and buildings	Mixed use: retail / residential building	100
Pavement and buildings	Natural gas power plant	100
Pavement and buildings	Office building	100
Pavement and buildings	Parking lot	100
Pavement and buildings	Paved ball field/court	100
Pavement and buildings	Pedestrian bridge	100

Table 1-10 (continued). Percentage of ecosystem associated with generic habitat types in Visionmaker Jamaica Bay. Note zero values are not shown.

Habitat	Ecosystem	Percentage of ecosystem area associated with habitat type
Pavement and buildings	Pedestrian street / plaza	100
Pavement and buildings	Permeable pavers	60
Pavement and buildings	Photovoltaic panels	100
Pavement and buildings	Pier	100
Pavement and buildings	Public assembly hall	100
Pavement and buildings	Restaurant	100
Pavement and buildings	Retail building	100
Pavement and buildings	School or university	75
Pavement and buildings	Sewage treatment plant	100
Pavement and buildings	Sidewalk	100
Pavement and buildings	Single family home	100
Pavement and buildings	Solar energy facility	100
Pavement and buildings	Solar heating panels	100
Pavement and buildings	Solid waste transfer plant	100
Pavement and buildings	Stadium	100
Pavement and buildings	Street (collector)	100
Pavement and buildings	Streetcar line	100
Pavement and buildings	Subway	100
Pavement and buildings	Swimming pool	100
Pavement and buildings	Tidal energy facility	50
Pavement and buildings	Traffic slowed street	100
Pavement and buildings	Tunnel	100
Pavement and buildings	Utility yard	100
Pavement and buildings	Warehouse	100
Pavement and buildings	Waste energy power plant	100
Pavement and buildings	Water treatment plant	100
Pavement and buildings	Water/wastewater storage tank	100
Pavement and buildings	Wind farm	50
Pond	Pond	100
Salt marsh	High salt marsh	100
Salt marsh	Low salt marsh	100
Shrubland	Shrub land	100
Stream	Stream	100

Estimating Potential Species Richness for Visions

Potential species richness (also known as species richness) is estimated using taxon-specific species-area relationships. A species-area relationship (SAR) represents how the number of species varies as a function of area, following a distinctive form that is one of the best known relationships in ecology (Rosenzweig 1995). A latitude sensitive version of the SAR published by Solymos and Lele (2012) was used in mannahatta2409.org, but was found to give anomalous results over small areas.

To improve the species area relationships, we compiled existing observation data of species numbers for the following taxa: plants, amphibians, reptiles, birds, freshwater fish, marine fish, and mammals found in national parks, non-profit land holdings (e.g. The Nature Conservancy) and public parks on the East Coast of the United States listed in Appendix 4.

From this dataset we fit regressions to the standard power law formulation of a species area curve, that is

$$S = c\,A^z$$

where, S = number of species, A is the area expressed in square kilometers, and c and z are fitted coefficients. We included a third parameter to represent the effect of latitude on the species-area curve, such that

$$S = c\,A^z\,(1/m*L)$$

Where, L = latitude of the site and m is the third parameter. We are interested in the latitudinal effect on species richness because we believe it can be used as a surrogate for climate change. As New York City's climate changes, we hypothesize that the city's climate will become more similar to locations farther south. Table 1-11 summarizes the coefficients for the species-area curves for the different taxa.

Table 1-11. Parameters associated with taxa-specific, latitudinally-adjusted species area curves in Visionmaker Jamaica Bay. In a species area curve, C represents the intercept and z represents the slope of the line defined by the log of area (on x-axis) and log of species number (on y-axis). m is a constant modifying latitude, such that $S = c*A^z*(1/m*L)$, where S is the number of species and A is the area. Psudeo-R2 measures the fit of the multivariate regression. See text for details.

Taxa	C	z	m	Pseudo-R2
Mammals	6694.90	0.1809	0.09	0.45
Reptiles	5304.10	0.1250	0.10	0.51
Amphibians	4588.40	0.1193	0.10	0.33
Birds	45167.00	0.1006	0.10	0.44
Plants	129913.00	0.2087	0.09	0.51
Freshwater fish	15419.00	0.1551	0.10	0.71
Marine fish	8904.70	0.2702	0.05	0.78

These parameter values have been shown to work with areas appropriate to visions that might be constructed with Visionmaker Jamaica Bay (Figure 1-5; Table 1-12).

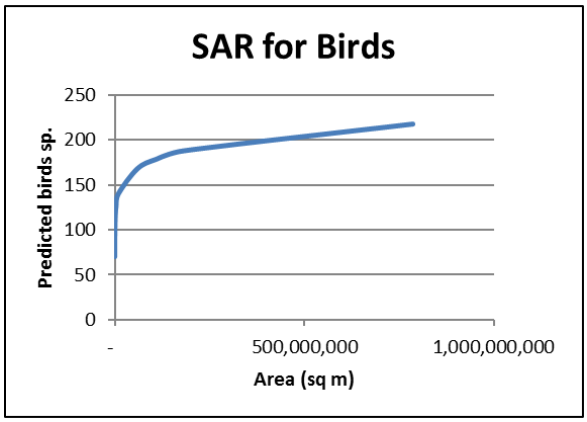


Figure 1-5. Species-area curve for bird species used in Visionmaker Jamaica Bay, New York.

Table 1-12. Predicted mammalian species richness in areas of different size in New York City using the latitudinally adjusted species-area relationship curves developed for Visionmaker Jamaica Bay.

Example places in New York City	Area (m^2)	Area (km^2)	Predicted number of mammal species assuming appropriate habitat types (Latitude)		
			Northernmost - including NYC (40.6 degrees)	Middle (35 degrees)	Southernmost (32 degrees)
A city block	10,000	0.01	7	7	8
Washington Square Park	39,457	0.04	9	10	11
Example area (approximately 10 city blocks)	100,000	0.10	10	12	13
Example area (approximately 100 city blocks)	1,000,000	1.00	15	18	20
Central Park	3,411,014	3.41	19	22	24
Example area (approximately 1000 city blocks)	10,000,000	10.00	23	27	29
Manhattan	59,500,000	59.50	32	37	41
Jamaica Bay	101,000,000	101.01	35	41	45
Bronx	108,700,000	108.70	36	42	46
Brooklyn	183,000,000	183.00	40	46	50
NYC	785,000,000	785.00	51	60	65

Validation of Visionmaker Species Richness Estimates

Model validation was accomplished by comparing field collected data (observed data) in published papers against model predictions. Only collections with complete species lists and defined areas were included. Some collections included latitude values. When latitudes were not available, we used place names in Google Maps to determine latitudes. Observed and predicted species richness values were compared for each taxa using correlation and general linear models (GLMs) in SAS. Statistical significance was tested at $\alpha = 0.05$.

All the taxa exhibited significant correlations between observed and predicted species richness values and together explained 62-92% of the variation (Table 1-13). Our predictive plant and mammal models each explained 92% of the variation in observed plant and mammal richness and values were highly correlated ($r = 0.96$, $n = 55$; $r = 0.96$, $n = 31$; respectively). Reptiles had a similarly strong and significant correlation ($R2 = 0.84$, $p < 0.001$, $r = 0.92$, $n = 19$). Our weakest model, though still significant, was our marine fish model ($R2 = 0.62$, $p = 0.0014$, $r = 0.79$, $n = 13$). Where differences existed, model predictions were generally higher than the observed species richness values.

Table 1-13. Validation results of observed and predicted species richness for sites on the East Coast.

Taxa	N	Correlation	R^2	F-value	*P*
Amphibians	14	0.86	0.74	33.91	<0.0001
Birds	9	0.80	0.64	12.56	0.0094
Fish (freshwater)	15	0.81	0.65	24.56	0.0003
Fish (marine)	13	0.79	0.62	17.97	0.0014
Mammals	31	0.96	0.92	331.10	<0.0001
Plants	57	0.96	0.92	668.75	<0.0001
Reptiles	19	0.92	0.84	91.62	<0.0001

Species Habitat Associations and Minimum Habitat Area

We compiled a list of species that have been observed in Jamaica Bay or the wider area of New York City as part of an earlier project (Sanderson 2009) and on-going work as part of the Wildlife Conservation Society's Welikia Project. Our current species list for New York City, including native and introduced species, of plants and vertebrate animals, includes 4,388 species. For each of these species we created a species-habitat association: the potential occupancy of species in habitat type, which varies from 0 – 100. In practice most parameters are either 0 or 100%, representing that the habitat type either is not or is potentially used by the species. The full database of occupancy values for natural habitats can be accessed via Visionmaker Jamaica Bay under Resources/Researchers/Model Description/Biodiversity.

For each of these species we also estimated a minimum habitat area (MHA) from the literature. MHA was used in the model to determine if the area of the user's vision was large enough to support each species, so they represent the smallest area of habitat where a species could be expected to be found. Species with MHAs larger than the vision were removed from the selected set of possible species during the model calculation process. If the literature listed several sizes for MHA, we chose the

smaller of the areas. For animal taxa (mammals, amphibians, and reptiles) these are based on home range estimates for individuals found in the literature. For fish and bird taxa, where home range estimates could not be found, we developed applied techniques based on body size, as explained below. For plant species, minimum habitat areas are based on dispersal distances, as described below. The full database can be accessed via Visionmaker Jamaica Bay under Resources/Researchers/Model Description/Biodiversity.

Special cases exist for three taxa for which the literature did not yield MHA values. Fish MHAs were predicted using the fork length (mm) of each species (Froese and Pauly 2015), generally obtained using the total (common) length and the length-length regression parameters to convert to fork length. In about half the cases, the species of fish had no forked tail. Female lengths were used in cases where species were sexually dimorphic. Fork length was then used in a regression formula (Kramer and Chapman 1999) of the form below:

$$log10\ MHA\ fish\ (m^2) = -5.71+3.53 * log10\ fork\ length\ (mm)$$

MHAs (sometimes termed breeding territory for birds) were primarily obtained from the online Birds of North America database (Poole 2005). For species where data were not available, we obtained body mass estimates from the CRC handbook of Avian body masses (Dunning 1993) and used the following formula to obtain predicted MHAs (Haskell et al. 2002), assuming carnivorous birds (insect or flesh eating) after which values were converted to m^2:

$$MHA\ birds\ (km^2) = 0.0257 * body\ mass\ (g)\text{^}1.374$$

We used Tamme et al. (2014) to define MHAs for plant species. For some species, dispersal distances existed (Tamme et al. 2014) and for those, we used the distance (m) in an area formula ($3.14*r^2$) with distance/2 as r to obtain MHA in m^2. For species whose dispersal distances were not readily available, we used a model in R (version 3.1.1) called DispeRsal (Tamme et al. 2014) to predict MHA using growth form (tree, shrub or herb; USDA plants database 2015) and dispersal syndrome (ant, animal, ballistic, wind (no special features), and wind special (with special characteristics like wings)). Information on dispersal method for each species was drawn first from the TRY global database of plant traits (Kattge et al. 2011), then from the LEDA plant trait database (Knevel et al. 2003) and finally, if the species was not listed in either database, a literature search was undertaken to locate the dispersal method for the species, genus or family, respectively. Finally, the dispersal model was run (model #5) in R using growth form and dispersal syndrome as independent factors and predictions were made for dispersal distance of each species. Dispersal distances were transformed into areas (in m^2) using the area formula ($3.14*r^2$) with distance/2 for r.

Estimating Vision Species Composition, With an Example

To estimate the composition of species that might be found in a vision, we calculate the species-specific habitat areas based on the species-habitat associations, by multiplying the area of the habitat type by the occupancy value and summing for the species. We remove any species from the list where the estimated species-habitat area is less than the minimum habitat area. We then sort the list

by species-habitat area from greatest to least and add species to the vision until we reach the estimated species richness for a given taxa or no species in that taxa remain on the potential list.

Example of New Visionmaker Biodiversity Calculation Functionality

To demonstrate the incorporation of these improved species richness / composition metrics in Visionmaker, we provide some screenshots in Figure 1-6. Figure 1-6a shows the inputs & outputs tab and Figure 1-6b shows an estimated species composition by taxa for a sample terrestrial vision (no marine or freshwater habitat); Figure 1-6c shows the estimated mammal species composition.

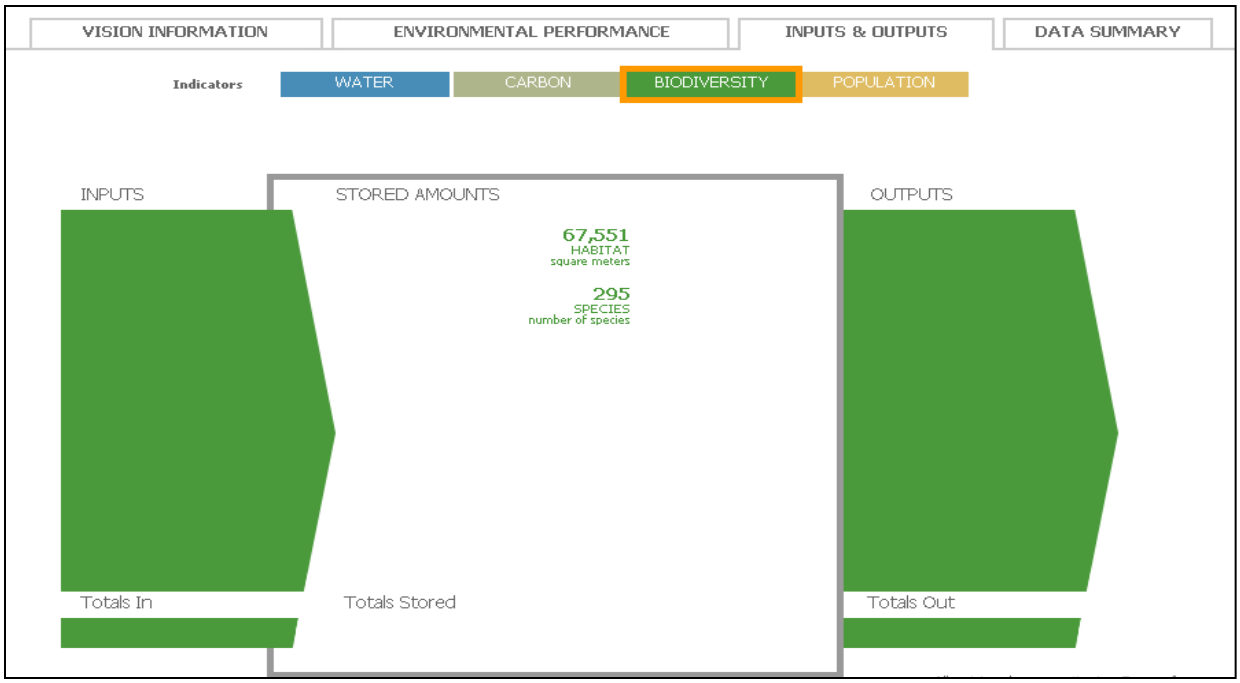


Figure 1-6a. Screenshot of the Visionmaker system showing inputs & outputs tab showing estimated habitat area and species number for a sample vision.

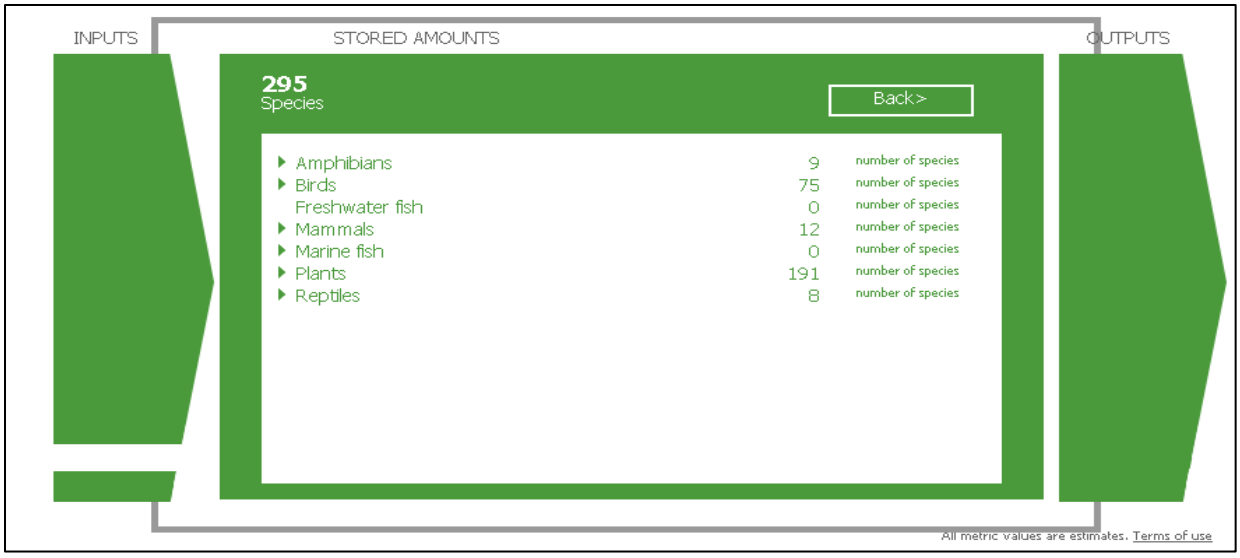


Figure 1-6b. Screenshot of the Visionmaker system showing species composition by taxa for a sample vision.

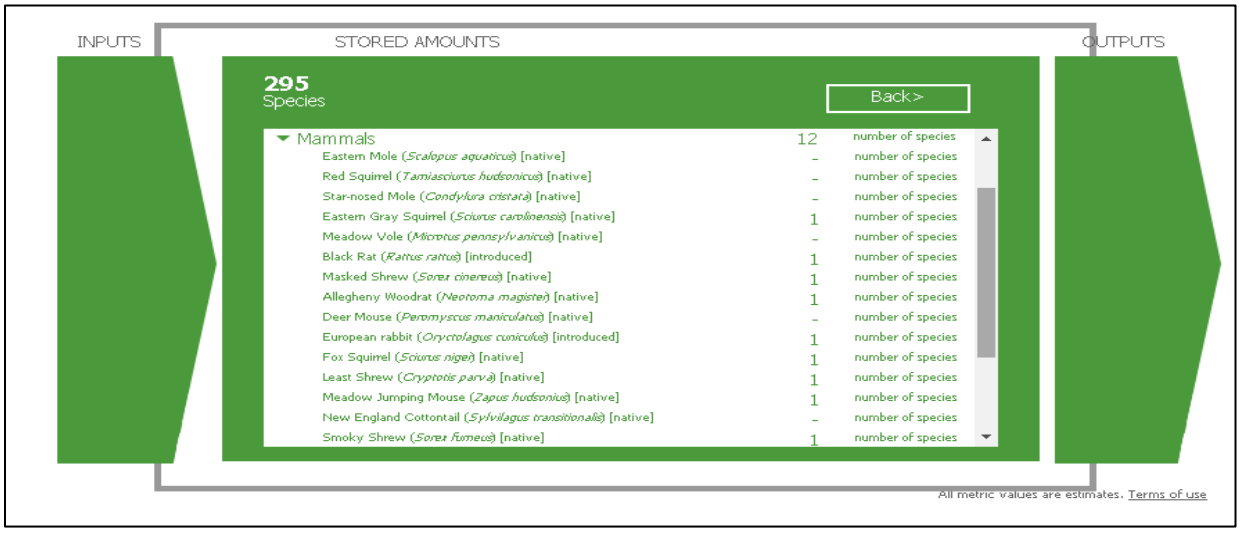


Figure 1-6c. Screenshot of the Visionmaker system showing mammalian species composition for a sample vision.

Optimization for Larger Visions

A problem with the original mannahatta2409.org application was that visions larger than several contiguous blocks caused the application to pause and sometimes to crash. Most visions on Manhattan were fairly small (one to several blocks in area) and most blocks were of relatively small area, so this was not a problem. Crashes however were a problem for the Jamaica Bay application, where areas of concern are significantly larger.

To address the issue of creating large visions, appropriate to the Jamaica Bay environment, we developed and implemented a vision tiling architecture to improve performance. In this new scheme, all vision rasters are divided into 'tiles' that are 256 cells by 256 cells.

All parts of Visionmaker that relate to vision data now use tiles:

- Vision rasters are stored in multiple tiles
- Only the tiles required for editing operations are retrieved, manipulated, and stored
- In the client browser, only tiles necessary to send changed cells are sent back to the server
- Cell values are edited per tile, resulting in faster client-side editing

Saving is now fully asynchronous: when a user sends vision raster edits back to the server, as soon as the data has finished being sent, the user can continue to work with the interface: pan, zoom, calculate, or even edit again. Meanwhile, the server adds the editing job to a separate queue, and worker 'daemons' on the server process jobs in the queue in the order received. The user's interface shows a progress indicator in the Notifications widget based on updated progress reports from the worker; since each worker handles just one tile at a time, the % complete is based on the number of tiles complete divided by the total number of tiles the user sent. Additionally, because workers handle exactly the same amount of data at a time, the server never becomes overwhelmed, and the total system load is evenly distributed, so that the processing rate for any given user is relatively consistent.

Figure 1-7 shows a screenshot of the Visionmaker system of notifications while processing large visions. Note the widget in the lower left corner

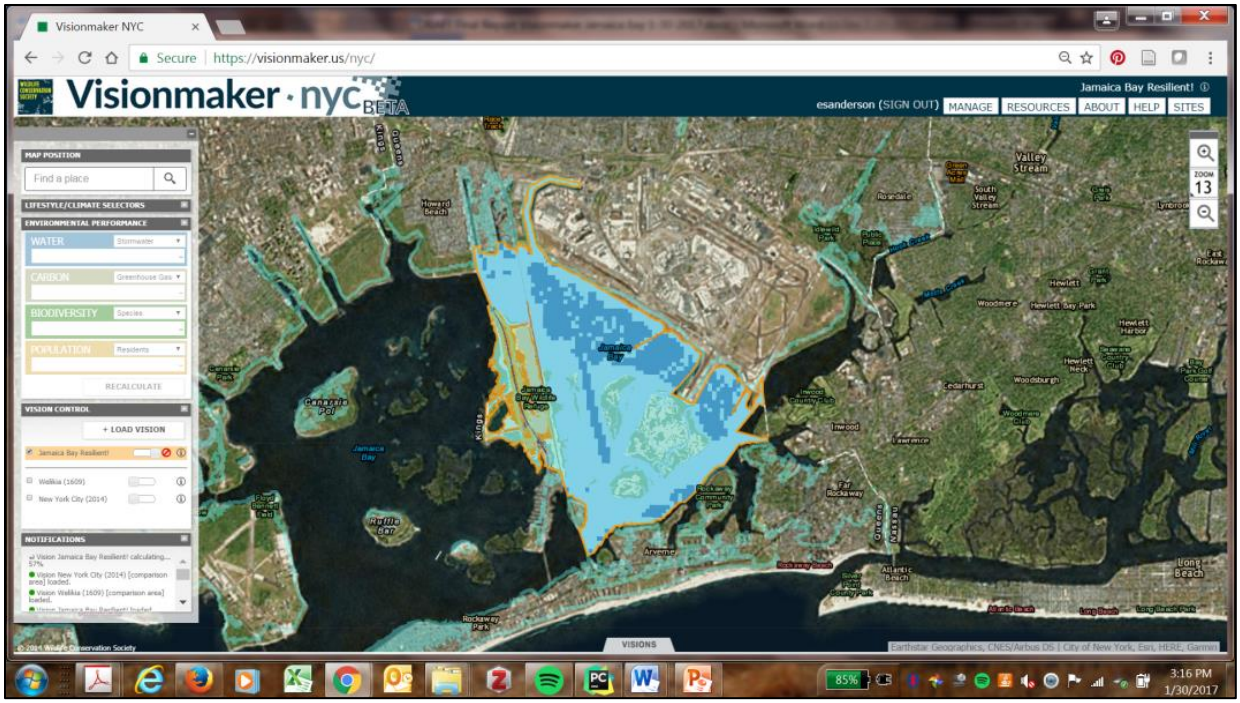


Figure 1-7. A screenshot of Visionmaker Jamaica Bay demonstrating notification widget while processing large vision in lower left corner.

Use of Visionmaker Over the Study Period

During the reporting period (November 1 2014 – December 31 2016), we had 61,302 user sessions, of which 32,704 (53%) were new user sessions. 12,326 new visions were created using Visionmaker.

Objective 2: Conduct Workshops with Different Communities of Practice Using Visionmaker Jamaica Bay

We conducted 12 workshops over the course of the project focused on five different "communities of practice" around Jamaica Bay: land managers, researchers, K-12 educators, environmental NGO-members, and Community Board members (i.e. residents.) Workshops were co-organized with the Science and Resilience Institute at Jamaica Bay in all cases and often also with other local institutions, whether non-profits, schools, or government agencies. All workshops were located within New York City, most within the watershed of Jamaica Bay. We intentionally varied workshop times during the week (weekdays and weekends; mornings, afternoons, and evenings) and tried where possible to plan our event at a time / place where members of the community of practice had another event (Table 2-1). Unfortunately despite our best efforts, workshop attendance was feeble; in the end only 82 people responded to our attempts to reach out to them. As noted above, however, public provision of Visionmaker resulted in considerably more user sessions city wide during the project period.

Workshops were planned for two hours and led by the same staff members (Mario Giampieri from WCS and Bryce DuBois from Cornell University) for consistency, though several other project participants also attended some of the workshops. We used the same powerpoint materials

(Sanderson 2016) and even recorded a video introduction to Visionmaker to assure consistency (www.youtube.com/watch?v=Anlj743fFhA). Before and after each workshop, participants were encouraged to fill out pre- and post-surveys about their experience (available on the NPS Integrated Resource Management Applications (IRMA) Portal); these are analyzed under Objective 3. Surveys were conducted on-line and could be filled out at the workshop site since participants had computers and Internet access in order to use Visionmaker. The surveys enabled us to assign a unique identifier to each vision and connect it to an individual, though data analysis was conducted without any personally identifying information.

Prior to the workshop, we received approval from the Cornell University Institutional Review Board (IRB) because our research included human subjects; we abided by all the rules of Cornell University with regards to this research. Participants were asked to sign a consent form informing them about the nature of the research and how their data would be used (available on the NPS Integrated Resource Management Applications (IRMA) Portal)

Table 2-1. Workshops with Visionmaker Jamaica Bay conducted during the project period.

Date	Time	Target Community of Practice	Location	Number of Attendees
17-Jul-15	2-4 PM	SRIJB affiliates	New York Aquarium: 602 Surf Ave, Brooklyn, NY 11224	13
3-Nov-15	12-2 PM	Educators	New York Aquarium: 602 Surf Ave, Brooklyn, NY 11224	0
4-Nov-15	7-9 PM	Community Board	Knights of Columbus: 333 Beach 90th St, Rockaway Beach, NY 11693	0
5-Nov-15	9-11 AM	Researchers; Public Agency	The Graduate Center (before SRIJB Mid-Project Meeting): 365 5th Ave, New York, NY 10016	14
5-Dec-15	10 AM-12 PM	NGO; Public Agency	Salt Marsh Nature Center: 3301 Avenue U, Brooklyn, NY 11234	4
7-Dec-15	7-9 PM	Community Board	Kingsborough CC: 2001 Oriental Blvd, Brooklyn, NY 11235	0
28-Jan-16	6:30-8:30 PM	NGO; Public Agency	Jamaica Bay Wildlife Refuge: Broad Channel, NY 11693	7
29-Jan-16	1-3 PM	Researchers	The Graduate Center, room 9206/9207: 365 5th Ave, New York, NY 10016	6
30-Jan-16	2-4 PM	Educators	New York Hall of Sciences.	16

Table 2-1 (continued). Workshops with Visionmaker Jamaica Bay conducted during the project period.

Date	Time	Target Community of Practice	Location	Number of Attendees
1-Feb-15	12-2 PM	Educators	New York Aquarium: 602 Surf Ave, Brooklyn, NY 11224	0
2-Feb-16	10-12 PM	Public Agency; NGO	Central Park Zoo Board Room: 64th St and 5th Ave, New York, NY 10021	6
13-Mar-16	11-1 PM	NGO	Co-hosted by Rockaway Waterfront Alliance. Arverne View Community Room 57-17 Shore Front Pkwy, Arverne, NY 11692	4
26-Mar-16	12-2 PM	NGO; Community Board	Co-hosted by the National Parks Conservation Association and Coney Island Beautification Project, Inc. Coney Island Library - 1901 Mermaid Ave, Brooklyn, NY 11224.	11
16-Apr-16	3-4 PM	Educators (Only open to SCONYC registrants.)	Stuyvesant High School, 345 Chambers St, New York, NY 10282.	1
26-Apr-16	8-9 PM	Community Board	Community Board 17 Offices	13

Objective 3: Analyze Visions of Resilience Using Visionmaker Jamaica Bay

Based on the workshops with Visionmaker Jamaica Bay, we have written two articles describing our results and analyzing the visions of resilience. The first, entitled "Participatory resilience visioning of the Jamaica Bay watershed" is currently in peer review. The second, entitled "Designing resilience: lessons from applying Visionmaker, a free digital ecological democracy tool, to the Jamaica Bay watershed in New York City" has been reviewed, accepted and published, in Urban Ecosystems:. These two works represent our primary results of our study, in addition to the methodological developments presented under objective 1, so we present pre-print versions of the papers in full *below.*

Participatory Resilience Visioning of the Jamaica Bay Watershed

Authors: DuBois, B., Allred, S., Sanderson, E.W., Giampieri, M., Bunting-Howarth, K.

Abstract

The resilience of urban coastal communities and urban social-ecological systems is of increasing interest to practitioners from a variety of sectors. Landscape visualization tools offer an opportunity for increasing cross-sector participation in resilience planning. Using a community of practice framework we sought to identify and understand how various communities of practice—community board members, K-12 educators, non-governmental organization employees, public agency land managers, and researchers—conceptualized resilience for the Jamaica Bay, NY watershed using the new landscape visualization tool, Visionmaker. We recruited eighty-nine participants to undertake resilience visioning sessions. In pre and post-workshop surveys we sought to understand participant

visions, resilience definitions, their ideas for future use of the visioning tool, and the impact of the tool on their knowledge, concern, and belief about adaptation needs in the Jamaica Bay watershed. Thematic analysis of open-ended questions suggests that participants tended to focus on ecological aspects of resilience above all else. While there were some differences between communities of practice on governance, social, and social-ecological attitudes, results reveal little variation between groups from before and after using the tool. Also, participants identified several educational and planning applications for Visionmaker. This suggests that resilience was a relatively static term amongst our participants, but that Visionmaker offers the ability for communities to engage in long-term practices that may help support innovative resilience thinking.

Introduction

Climate change and sea-level rise are projected to double the frequency and intensity of coastal flooding along with possible increases in the frequency and intensity of tropical cyclones that would further exacerbate these flooding projections (NPCC, 2015). Coastal communities are at the greatest risk for climate related impacts, which is exacerbated by a human population that is concentrated on the world's coasts (Jacob, Gornitz & Rosenzweig, 2007). Nearly 80% of the US and Canadian population is considered urban (UN-DESA, 2011) and populations in large cities such as New York City are growing (McPhearson, Auch & Alberti, 2013). Visualization tools have emerged to support knowledge, awareness and action, primarily around climate change and adaptation issues in coastal communities (Sheppard, 2015). However, visualization tools have not attempted to engage participants specifically in ecological modeling in an attempt to support thinking around social-ecological resilience.

Here we present a case study on community perceptions and visions of resilience for the Jamaica Bay watershed. First we present a review of the literature related to socio-ecological systems, resilience, and landscape visualization tools. Second we present the study area in the Jamaica Bay watershed of New York City and our analytical methods. Third we present the results of our case study regarding whether the use of a landscape visualization tool, Visionmaker, led to changes in thinking about resilience, concern, adaptation, and knowledge among participants. We also examine how participants defined resilience for the Jamaica Bay watershed and how those community-based definitions compare to efforts to define resilience emerging from the academic and professional literature. Finally discuss the implications of our research across our overall sample and between different communities of practice that represent subsets of populations that we expected to have different understandings of what resilience means for the Jamaica Bay watershed. We also discuss the limitations of our study.

Literature Review

Socio-Ecological System Resilience

Social-ecological system (SES) resilience has gained popularity among ecosystem scientists and emphasizes that the adaptation or transformation of practices hinges on the role of learning, especially about the outcomes of various management efforts (Berkes 2004; Armitage et al. 2008). SES resilience also counters a steady state hypothesis that was common to early conceptualizations of resilience and suggests that small and large-scale changes are a defining feature of ecosystems

rather than only as potential impacts to the status quo (Matyas & Pelling, 2015; Meerow, Newell & Stults, 2016). Berkes and Ross (2013) argue that SES resilience is particularly appropriate for communities interacting closely with their environment, or communities of place (Maida, 2007).

Academic disciplinary boundaries have led to the formation of distinct conceptualizations of resilience. Psychological resilience was a term developed in the early 1970s to describe people that thrived despite facing severe difficulties (Luthar et al. 2000, Bonanno 2004). Searching for a term to describe the stability or process of transformation of an ecological system that contribute to ecological resilience, ecologist Buzz Holling coined the term adaptive capacity (Holling, 1973). Engineering resilience is described as the time taken for recovery after a disturbance and can apply to ecological or other aspect (Pimm 1984). Other fields followed, including sociology and community psychology in an effort to define community resilience (CARRI 2013), as well as in engineering to describe the speed by which a structure would spring back (Holling 1996). In the following sections we highlight threads in SES literature relevant to our research, notably community resilience, urban resilience, and urban coastal resilience.

Community Resilience

Community is a useful as a boundary-framing concept when discussing resilience and differs from SES resilience because of the singular focus on dimensional outcomes for human communities. Longstaff et al. (2010) defines a community as, "a group of people who share a common physical environment, resources, and services, as well as risks and threats" (pg. 4). Research on community resilience and adaptation tends to focus on a community's ability to respond to crises in a way that improves the community bonds and capacity to cope while expanding resources (Chenoweth et al., 2001).

The ability for a community to leverage resources to thrive in an environment characterized by change, uncertainty, unpredictability and surprise is particularly important (Magis, 2010). Communities respond to crises through stakeholder participation in more formal governance processes. Community resilience is also expressed through ground-up stewardship efforts that contribute to resilience and adaptation, through efforts such as allotment gardens in Stockholm (Barthel, et.al., 2010) and environmental stewardship organizations in New York City (Connolly, et.al., 2013). These community level responses result in social learning and social-ecological memory as community members engage in long-term adaptation to change, such as flooding (Tewari & Bhowmick, 2015).

There have been efforts to define frameworks for measuring community resilience. Using the community as the scalar unit, Longstaff et al. (2010) argues that community resilience is a function of resource robustness (performance, redundancy and diversity) and adaptive capacity (institutional memory, innovative learning, and connectedness). Longstaff et al. (2010) suggests that these two aspects can be improved upon in each of five key community subsystems (ecological, economic, civil society, governance, and physical infrastructure). Similarly, Susan Cutter et al.'s (2008) Disaster Resilience of Place model (DROP) offers an intriguing model for investigating community resilience. This model includes ecological, social, economic, institutional, infrastructure, and community competence dimensions. Each of these dimensions includes a number of candidate variables, each of

which promotes a community's resilience to future hazards. While these models suggest key aspects of community resilience, they do not describe the key hazards and context of urban coastal environments.

Urban Resilience

Urban contexts have unique attributes that researchers have highlighted. Urban resilience necessarily recognizes nuanced conceptualizations of community types as well as the unique context of human-dominated ecosystems. In the most recent review of urban resilience Meerow, Newell & Stults (2016) recognized that there has been an evolution in the term relating to the notion of dynamic non-equilibrium (Picket, Cadenasso & Grove, 2004), similarly picking up on the SES resilience notion of constant change and no stable state. This is a change from theorizing around single-state or multistate equilibrium and is leading many scholars away from the idea of 'bouncing back' (Matyas & Pelling, 2014). As a result, Meerow, Newell & Stults (2016) offer the following definition of urban resilience:

> 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. (pg. 45)

This definition is notably similar to the one used by the City of New York, which defines resilience as: "1. able to bounce back after change or adversity; 2. capable of preparing for, responding to and recovering from difficult conditions;" or simply "tough" (NYC 2013).

Meerow, Newell & Stults (2016) go on to suggest four levels of their urban resilience framing, "governance networks, networked material and energy flows, urban infrastructure and form, and socioeconomic dynamics" (pg. 45). These scales are identified explicitly to deal with six tensions that they identified in the literature: characterization of urban; notion of equilibrium; resilience as a positive concept; pathway to resilience; understanding of adaptation; and the timescale for action. These tensions represent emerging debates about resilience, for example resilience is widely recognized as a positive trait where systems can maintain functioning and also improve that system. But some acknowledge that not everyone will benefit equally and that the desirability of a state is a normative concept that may represent the prioritization of factors that unequitably benefit a particular group of people (i.e. Cote & Nightingale, 2011; Friend & Moench, 2013; Joseph, 2013). These tensions seem to avoid the natural ecosystem function in urban resilience.

Urban contexts are particularly challenging places for developing governance strategies that are equitable. Many researchers suggest that practitioners should ask the question, resilience to what and for whom? (e.g. Cutter et al., 2016; Walker & Salt, 2006). Concerns over power and agency in the development of resilience practices has led Meerow & Newell (2016) and others (c.f., Davidson, 2013) to suggest that practitioners expand these questions and wrestle collectively in open and inclusive processes with the question, urban resilience for whom, what, when, where, and why? Ecosystem services specifically are affected by power because they are produced through political

struggle that is based on value articulation and discourse (Ernstsen, 2013). As a result urban resilience scholars argue for governance structures that are multi-scalar and specifically attend to questions of resilience for whom and by whom (Friend & Moench, 2013).

Urban resilience is a multi-scalar concept that uses the city as a boundary-defining object. As a result there is increasing interest to develop assessments of city-level resilience. Ernstson et al. (2010) suggests that cities are part of a system of cities that includes the flow of energy, matter, and information through technical and social network relationships. Several research teams have begun to develop integrated frameworks to investigate resilience at the city level. Abdrabo & Hassaan (2015) argue for an integrated assessment based on the functioning of a city-level system in response to a specific disaster, in their case climate change. Abdrabo & Hassaan (2015) argue for an index that includes the socioeconomic context measured around demographic and socioeconomic conditions related to adaptive capacity; the physical context as the provision and quality of infrastructure and services; the environmental context as the environmental quality and natural resource uses; the institutional context as the institutional setup and governance; emergency preparedness as related to specific shocks and sudden events; and climate change as related to vulnerability to sea-level rise inundation impacts. Dasgupta & Shaw (2015) applied a similar coastal community resilience indicator assessment to rural communities in India. Unlike Abdrabo & Hassaan (2015), the Rockefeller Foundation and Arup International Development (Da Silva & Morera, 2014) have argued for a city-level resilience assessment frame that is disaggregated from disasters and focuses instead on gradual or dynamic characteristics. The city resilience index (Da Silva & Morera, 2014) includes four dimensions that are similar to and overlapping with the community-level indicators offered by Cutter (2008) and Longstaff et al. (2010) and include, health and well-being, economy and society, infrastructure and environment, leadership and strategy. Following Hurricane Sandy, former Mayor Bloomberg commissioned the Special Initiative for Rebuilding and Resiliency for the City of New York, which defined resilience as: “1. able to bounce back after change or adversity; 2. capable of preparing for, responding to and recovering from difficult conditions;” or simply “tough” (NYC 2013). Urban resilience includes many overlapping social and ecological factors that can be studied at multiple scales, most often from the community or city scales.

Urban Coastal Resilience

The above city-level resilience assessments have been applied to urban coastal cities, but there have been additional efforts to theorize urban coastal resilience specifically. Urban coastal resilience is frequently framed from a social-ecological system perspective or related urban planning and development lens. SES resilience in urban coastal areas is primarily framed around the impacts of the urbanization process on land use and ecological functioning (Schewenius, McPhearson & Elmqvist, 2014). Neil Adger and colleagues (2005) describe a number of human actions that can respond to urban coastal issues. Urban coastal resilience in hurricane-affected areas involves multiple issues that each require human actions. These include government interventions or other means to regulate how people use coastal ecosystems, such as disincentivizing activities that destroy natural capital (Adger et al, 2005), as well as efforts to respond to future risks such as climate change. They suggest that multilevel governance systems are necessary to build adaptive capacity to enhance and prepare for a future of change and uncertainty (Adger et al., 2005).

From a planning perspective, infrastructure and governance are highlighted as key dimensions of urban coastal resilience. In planning, self-organizing of urban residents to facilitate appropriate action at appropriate scales is understood to mediate natural, technological, economic, and human stressors in these ecosystems (Desouza & Flanery, 2013). A multi-scalar approach is once again highlighted in the context of urban coastal resilience, an approach that includes environmentalists, NGOs (at different levels), different branches and levels of government, and scientists (and research institutes) engaged in collaborative decision-making networks (i.e. Vogel, Moser, et al., 2006; Ahern, 2011; Lu, & Stead, 2013; Hurlimann et al., 2014). Additionally, adaptive planning argues for multifunctionality, redundancy and modularization (Ahern, 2011). Furthermore, urban coastal resilience is a concept that can clearly communicate environmental limits in planning the development of coastal and marine environments, especially in light of climate change and sea-level rise (Lloyd, Peel, & Duck, 2012). Urban coastal resilience planning and decision-making is shifting to include public participation that necessitates innovative approaches to incorporate many forms of knowledge.

Landscape Visualization and Perceptual Shifts

In light of the complex impacts of climate change on urban coastal environments there are evolving strategies to communicate and engage the public in planning using visualizations. Previous research on visualization tools has focused on the communication of climate change and not on urban social-ecological systems. Sheppard (2015) suggests that there are three principles to engage the public on climate change more meaningfully; make it local, visual, and create connected interfaces amongst users. Using such designs, researchers have found that visual communication can increase engagement and enhance understanding of complex environmental issues, for example in forest management (Sheppard and Meitner, 2005).

Visualizations are important to raise awareness and motivate local climate change action (Sheppard, 2005). The way visuals are constructed can affect people's awareness of the climate change message as well as attitudes and emotions about climate change (Nicholson-Cole, 2005). Sheppard (2005) proposes a spectrum among types of responses to different forms of stimuli. Cognitive responses are suggested to improve or accelerate understanding often use visualizations of the future conceptual impacts of climate change. When the future impacts are conceptually understood people are thought to acknowledge or understand the need to mitigate and adapt to climate change. Emotional or affective responses to climate change imagery involve realistic visualizations of the impacts of climate change in a real world setting, such as the melting of icebergs or drought stricken and denuded landscapes. This is proposed to draw people to feel an emotional need to mitigate and adapt to climate change.

Landscape visualizations oriented around climate change have primarily focused on intentionally influencing viewers through the visualization of future scenarios at both global and local levels. Researchers investigating the use of a global climate change visualization tool, GeoDome (Wibeck, Neset & Linnér, 2013) found that participants saw some opportunity to use the tool in their work, but did not otherwise describe being influenced by the tool. However, in their presentation format participants were not able to influence the selection of parameters meaning there was very little

opportunity for communal visioning. In the local context, a recent project led by Sheppard and colleagues (2011) called the Local Climate Change Future Visioning Process introduced future climate scenarios to residents in Delta, BC. Their visualizations included 3d renderings of various local landscape futures given different development choices. After using the tool, participants were found to increase in their understanding of the urgency of responding to climate change as well as their awareness of future local climate change impacts and the different options available to respond to those impacts. These landscape visualization tools are oriented around influencing participants to respond to future climate change scenarios and do not emphasize the modeling of ecosystems.

Watersheds are complex transboundary social-ecological systems and so they pose challenges for managers seeking public participation (Rhoedes, 2000; Nelson & Wechsler, 2001; Johnson, 2008). In the case of watersheds, the common practice has been to create opportunities for public participation in watershed modeling through formal workshops. These workshops pair community members with experts to show how physical and chemical processes of hydrology and water quality are represented in computer simulations (Johnson, 2008). Public participation is sought because people contribute to the degradation of these ecosystems and are similarly benefited by the economic and ecosystem services provided by watersheds (Rhoades, 2000). Such complex issues are begging for improved opportunities for easy-to-use visualization tools that support democratic deliberation around ecosystem planning, similar to approaches to visualizing climate change.

Research Questions

In this research we investigate the use of Visionmaker, a new landscape visualization tool that offers the ability to visualize ecosystems as well as future sea-level rise and a number of other attributes in New York City and the Jamaica Bay watershed, specifically. This tool is an innovation on previous visualization tools because it emphasizes social-ecological system aspects rather than climate change alone. The Visionmaker.NYC online interface allows users to draw or paint a vision of the ecological future of New York City on top of current street/building and satellite data, and to compare the calculated consequences of that vision in terms of carbon, water, population, and biodiversity to ecological conditions in 1609 and in the present. Figure 3-1 shows the visionmaker interface at the bottom is a carousel showing previously constructed visions. On the left-hand side is a drop-down menu with a search box to locate map position, lifestyle and climate scenario selectors (not shown), environmental performance indicators, vision control to select and fade between the current vision, and 1609 and 2014 map layers. On the header are drop-down links to manage the account, resources, about, help and site information. On the right hand side are ecosystem types and modifiers used to paint a vision, along with buttons to choose vision extent and zoom. The main screen shows the map, which in this case the selection includes the area of Mill Basin, Brooklyn surrounded by an orange line. Visions such as what is shown can be saved and shared on the website. Additional areas of the website provide support and context for the web map including a home page, account/profile maintenance area, vision search/browse, explanation/documentation areas, curriculum, contact and acknowledgments. For more information on Visionmaker.NYC, see Sanderson et al. (2016).

Additionally, participatory watershed modeling approaches have investigated differences between experts and the public, but have not explored specific communities of practice. Therefore, this study

addresses this research gap through the investigation of a diverse range of actors and institutions whose decisions shape the Jamaica Bay watershed. To do this we employed a community of practice (Wenger 2011) framework targeting researchers, members of NGOs, K-12 educators, public agency officials, and community board members and asked them to describe resilience before and after using a map-based planning tool.

It is not known how different governance networks in urban coastal cities understand and articulate resilience for the Jamaica Bay watershed and whether a visualization tool can help participants to innovate. Therefore, the following research questions guided the research presented in this article, 1) Does participant knowledge, concern, or perceived need for adaptation change after using Visionmaker? 2) What are the themes of resilience definitions and visions among the different communities of practice and how do they relate?



Figure 3-1. A screenshot of Visionmaker Jamaica Bay depicting a vision of Mill Basin, Brooklyn, New York City.

Methods

Study Area

The Jamaica Bay watershed is a complex and transboundary social-ecological system that is impacted by, and in turn, provides benefits to urban residents. A number of factors can contribute to the resilience of the Jamaica Bay urban coastal social-ecological system and each of these has a human decision component (Adger et al., 2005), and indeed there have been many critical human-system interactions in the Jamaica Bay watershed over the last four centuries (Allred et al., 2016). Communities in New York City are exposed to coastal flooding, hurricanes, strong winter storms, and the transmission of marine-related infectious diseases. Climate change is expected to increase the

severity of these hazards (Gornitz, Couch, & Hartig, 2002). Furthermore, the anthropogenic impacts on salt marshes in Jamaica Bay are amplified bysea-level rise and coastal subsidence in the mid-Atlantic (Hartig et al., 2002).

For the purposes of this research we focused on the New York City areas within the Jamaica Bay watershed (Figure 3-2). Watersheds are areas of land where water flows diverge into a similar basin. The Jamaica Bay watershed includes communities in southern Brooklyn and southern Queens, as well as several southwestern Nassau County townships that were outside of the scope of this study. Historically, Jamaica Bay was an important source of fish and shellfish to the native Lenape and continued to be so for European settlers from the seventeenth century to the 1920's, when pollution concerns led to restrictions on shellfish harvesting (Kurlansky, 2007). The abutting land was also transformed into farmland and then urbanized for residential and commercial purposes during the seventeenth to nineteenth centuries (Steinberg, 2014). As New York City's population grew, urbanization spread to these neighborhoods while a summer resort community grew on the Rockaway peninsula. Land cover change has shifted substantially from 1609 to present day. In 1609, the area is estimated to have been sixty-two percent open water, twenty-six percent deciduous and mixed forest, eleven percent emergent herbacious wetlands, and one percent or less of crops, barren land, grassland and other land cover types (Handel et al., 2016). In contrast, 2011 estimates include fifty percent open water, twenty-one percent high intensity developed land, fifteen percent medium intensity land, four percent low intensity land, four percent emergent herbaceous wetlands, and one percent or less of deciduous mixed forest, shrub/scrub, and other land cover types (Handel et al., 2016). At the center of the watershed is Jamaica Bay, which is part of a system of parks that make up the Gateway National Recreation Area, part of the National Park Service. Alone, the Bay has twenty-six city, state, and federal agencies that are involved in the management of the bay with additional community and civic groups also acting to support governance, recreation, natural resources, and other aspects of the bay and its resources.

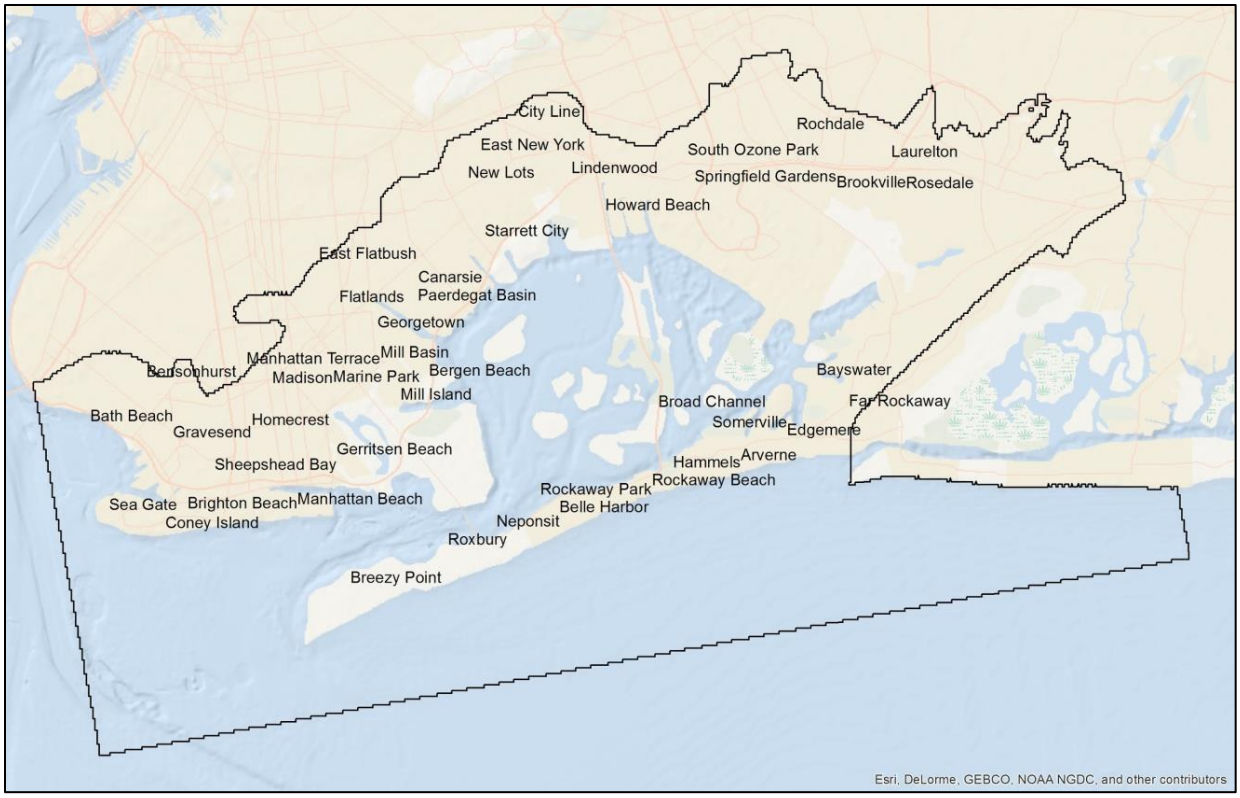


Figure 3-2. The Jamaica Bay watershed in New York City. The black line shows the watershed boundary used for this study. Different communities / neighborhoods around Jamaica Bay are labelled by name. The base map is from Environmental Systems Research Institute (ESRI).

Participants

We purposively sampled participants representing five communities of practice (COPs) in the Jamaica Bay watershed area. Wenger (2011) defines communities of practice as" …groups of people who share a concern or passion for something they do and learn how to do it better as they interact regularly." A dimensional triad—the domain, the community, and the practice—defines communities of practice. The domain of a community of practice can be vary and formal 'expertise' is not a prerequisite. Rather, COP's are a shared domain of interest that group members make some form of commitment to and therefore have some competence in. A second dimension is the community. The defining feature of a community is that they interact and learn together although they may work separately and interact infrequently. Finally, the practice dimension defines members as practitioners that share a repertoire of resources. That is, COPs share stories, tools, and other information with each other that they use in their work. We settled on five communities of practice that we thought, given that they have different approaches, represent different subsets of the watershed population that have different understandings of what resilience means—community board members, non-governmental organization employees, public agency officials, researchers, and K-12 educators.

Potential participants were identified using a snowball sampling methodology, whereby we identified key "champions" in each community of practice and asked them to share a flyer about the workshops with their network and/or to provide us with contact information. We also attended community

events, or an analogous event, for each community of practice and handed out flyers and spoke about the workshops. We also created a Facebook page and used that to post information about upcoming workshops on key organization public pages. Finally, we posted workshop information on the websites of the Science and Resilience Institute at Jamaica Bay (SRIJB) and the Metropolitan Waterfront Alliance. Each flyer had a list of workshop dates, by COP, as well as information about the workshops and a link to sign up online. When participants signed up online they were sent a thank you email with a link to a pre-workshop survey. The workshops were taking place under the umbrella of SRIJB, which is a research institute that seeks to produce integrated knowledge in order to increase biodiversity, well-being, and adaptive capacity in coastal communities and waters surrounding Jamaica Bay and New York City. Overall, we held eleven workshops across the Jamaica Bay watershed with eighty-nine total attendees, seventy-six completed the pre-survey, fifty-five completed the post-survey, with thirty-nine matched pairs in that sample. Out of this sample, fifty-three provided vision descriptions.

Workshop Design

We organized a series of workshops using a standard 2-hour protocol. The workshop design included pre and post-workshop surveys that are the basis for results presented in this article. These surveys bookended a workshop that introduced participants to the free web-based tool, Visionmaker (Visionmaker.NYC) and involved them in a visioning session. The workshop included four main parts. In part one, workshop participants were welcomed and instructed to complete a pre-workshop survey if they hadn't already completed it online. In part two, we introduced participants to the tool using a standard powerpoint and brief introductory video, along with a live-demonstration on how to use the tool. We then moved to part three and instructed participants to create their own vision of resilience for the Jamaica Bay watershed using Visionmaker on their laptop. The workshop facilitators provided individual assistance to participants to create individual visions. Technical support was provided by the authors in the iterative development of their visions beginning with choosing a vision extent, manipulating ecosystems, reviewing the outcomes of their changes, and then revising their vision until they were satisfied with the outcomes. After an hour we reconvened and moved to the final part of the workshop that included a share-out of visions across workshop participants, a discussion of Visionmaker features that they liked and didn't like, and a post-workshop survey.

Data Collection

This paper is based on pre and post-workshop surveys on resilience and adaptation in the Jamaica Bay watershed. In this survey, we asked open-ended questions to participants:

- What does the term "resilience" mean to you?
- How would you define resilience for the Jamaica Bay watershed?
- What does resilience look like in the Jamaica Bay watershed?
- Please describe the vision that you created in the workshop

Additionally, we asked participants how knowledgeable they felt they were about the following issues in Jamaica Bay: Lifestyle impacts on the environment; Stormwater runoff; Greenhouse gas

emissions; Biodiversity; Population impacts on the environment; financial costs of environmental improvement effort; response categories were measured on a likert-type scale, where 1= no knowledge and 5=very knowledgeable. We also asked participants how much they agreed or disagreed with the statements about their concern on a likert scale, where 1=strongly disagree and 5=strongly agree: the impacts of climate change to Jamaica Bay watershed; the impacts of sea-level rise in Jamaica Bay watershed; the impacts of storm surge in Jamaica Bay watershed; the impacts of hurricanes in the Jamaica Bay watershed; human impacts on ecosystems in the Jamaica Bay watershed; shoreline development of Jamaica Bay; the impacts of JFK International Airport to the Jamaica Bay watershed; the impacts of domestic terrorism (e.g. 9/11) to the Jamaica Bay watershed; the impacts of wastewater in the Jamaica Bay watershed; the impacts of landfills in the Jamaica Bay watershed. Lastly, we asked participants how much they agreed or disagreed that the following are important adaptation activities for the Jamaica Bay watershed, on a likert scale, where 1= strongly disagree and 5=strongly agree: Reduce human land-use impacts; Protect key areas; Restore habitats; Reduce greenhouse gas emissions; Protect human health of those living in the area; Protect area from coastal flooding; Provide homeowner assistance for hazard mitigation; Remove humans from areas with high risk of coastal storm impact; Provide improved public transit; Improve stormwater management; Help provide infrastructure improvements (such as flood and storm proofing to) so vulnerable populations (poor, elderly, disabled, sick) adapt; Storm and flood-proof existing structures; Strengthen community-based planning efforts; Other.

Data Analysis

Quantitative survey items were uploaded to SPSS, a statistical software package. Summative scales were created for knowledge about the Jamaica Bay watershed, concern about the bay, and on need to adapt aspects of the bay. We used ANOVA with post-hoc test to determine significant differences in means between COP. The Gabriel post-hoc test was chosen because of variations in sample sizes among groups. We also used paired sample t-tests to compare overall sample mean changes on these pre and post survey scales. Qualitative survey items for Jamaica Bay resilience definitions (pre- and post-workshop) and vision descriptions (post-workshop only) were uploaded to NVivo, a qualitative data analysis software package. We used indicator models of resilience theory to inform our thematic coding of resilience definitions. We primarily combined Susan Cutter's (2008) Disaster Resilience of Place model and Patricia Longstaff et al.'s (2010) Local Resilience Assessment model to define resilience themes (Table 3-1, with example quotations). We also incorporated an open-coding procedure to identify themes not accounted for in the above-mentioned resilience indicator models. These codes were then moved to Excel for further mixed methods analysis in order to quantify the frequency by which each term was mentioned. Similarly, we used a thematic qualitative analysis approach to describe general themes among participant descriptions of their visions.

Table 3-1. Resilience Coding Scheme and Example Quotes.

Dimension	Example Quote
Ecological	"Preserving and re-establishing natural marshes, dunes, oyster reefs, and other formations that traditionally absorb impact from storms and also filter water; creating green infrastructure in developed areas that serves this same purpose, in particular in decreasing the impact of flooding…" (K-12 Educator)
Social/Community	"Access to the Bay for local communities and sense of stewardship in same communities" (Researcher)
Social-Ecological	"Healthy social-ecological system, with healthy natural systems and socio-economic systems, including access to the Bay for local communities and sense of stewardship in same communities; harmony; symbiosis." (Researcher)
Economic	"Creating economic and recreational opportunities that support local residents as well as conservation efforts" (K-12 Educator)
Physical Infrastructure	"Housing that can handle occasional floods" (NGO)
Civil Society (Institutional)	"Many, many agencies working together with community residents & scientists (HUD, FEMA, MTA, DOT, NPS, Parks, etc.)" (NGO)
Governance	"The empowerment of people to participate in reshaping their future vision of their communities, neighborhoods, environments." (Researcher)
Adaptive Capacity	"I would say that resilience refers to the ability of systems to survive, learn and adapt in an ever changing world." (Researcher)
Community Competence	"Building a neighborhood or community that is well informed and able to take action and help neighbors when in need." (NGO) "…creating neighborhood systems of communication, short-term self-support, or evacuation in the case of power, telephone, road, water, or other infrastructural damage." (K-12 Educator)

Results

Socio-demographics Characteristics of Participants

We had eighty-nine attendees across 12 workshops. In total, we had twenty-two NGO employees or long-term volunteers, nineteen researchers, seventeen community board members, sixteen k-12 educators, and fifteen public agency officials. Across all COPs the workshop attendees tended to be women (65%), have a college education (76%), and among those that provided a political affiliation the majority self-identified as left-leaning (73%). Most participants described experiencing extreme weather (84% of NGO, 90% Public Agency, 93% Researcher, 63% Community board, 100% K-12 educators) and climate change (100% NGO, 80% Public agency, 100% researchers, 75% community board members, and 93% of K-12 educators). Participants mentioned several potential applications for the use of Visionmaker, after using the tool. A majority of participants agreed or strongly agreed that Visionmaker could be used to educate about New York City ecosystems (99%), for community advocacy (93%), for participatory planning (93%), community engagement (91%), and to model outcomes of restoration (91%).

Knowledge, Concern and Adaptation Before and After Workshop

We found no significant differences prior to the workshop between communities of practice on self-perceived knowledge, concern, or adaptation. On average, participants noted that they have some

knowledge about the Jamaica Bay watershed (M=3.70, SD=0.72), they are concerned about impacts on the Jamaica Bay watershed (M=4.31, SD=0.51), and agree that there is a need to adapt in the Jamaica Bay watershed (M=4.37, SD=0.52). Post-workshop, participants rated that they had some knowledge (M=3.53, SD=0.62), agreed that they had concern about Jamaica Bay impacts (M=4.32, SD=0.49) and that there was a need to adapt (M=4.37, SD=0.38). In the comparison across COPs at both pre and post-workshops there was a main effect only for knowledge at post-test, $F(3,38)= 2.904$, $p=.047$. Post-hoc test did not reveal a significant difference between any one particular COP, although differences between K-12 Educators and Public Agency employees approached significance ($p=.069$).

We also compared matched pairs pre and post-workshop survey scores by each COP and then collapsed for all groups. No statistically significant differences were noted between pre and post survey scores on knowledge for NGO ($t(12)=-0.52$, $p=0.61$), public agency ($t(9)=1.48$, $p=0.17$), researcher ($t(8)=-1.34$, $p=0.21$), nor K-12 educator participants ($t(10)=-1.43$, $p=0.18$). Similarly no statistically significant differences were noted for concern between pre to post surveys for NGO ($t(12)=0.16$, $p=0.87$), public agency ($t(9)=1.29$, $p=0.23$), researcher ($t(8)=-1.02$, $p=0.33$), nor K-12 educator participants ($t (10)=-0.75$, $p=0.47$). And again similarly no statistically significant differences were noted for adaptation score changes pre to post surveys for NGO ($t(12)=0.46$, $p=0.65$), public agency ($t(9)=1.67$, $p=0.13$), researcher ($t(8)=-1.24$, $p=0.25$), nor K-12 educator participants ($t(10)= 0$, $p=1.00$).

Thematic Results of Participant Resilience Definitions and Visions

In the following pages we summarize resilience definitions and participant descriptions of their visions, by COP (for a detailed analysis of geographically referenced data from visions, please see Sanderson et al., in preparation; see next section). We share example quotations representative of common themes and then compare definitional themes across COPs and provide tables showing rates by which participants referenced the resilience attribute (Table 3-2), vision descriptions (Table 3-3), and thematic frequency of vision themes (Table 3-4).

K-12 Educators

Educators used a range of ideas to describe resilience in Jamaica Bay in pre-surveys. They wrote about ecological aspects, including especially restoration efforts for marshes and oysters as well as water quality issues, as well as an ability to withstand disturbances. In post-surveys they added an emphasis on increasing diversity of species (ecological resource robustness) and adapting to future climate change and other man-made disturbances (Table 2). Several K-12 educators discussed multiple characteristics that contributed to resilience and five participants mentioned ecological and climate change or extreme weather characteristics in their definitions at post-survey. Two participants added ecological and social-ecological characteristics at post-survey.

Educators described creating visions that were thematically aligned with five areas (Table 3 and Table 4). They created visions focused on green infrastructure, including investigating water use and impacts of their visions as well as restoring marshes. One participant investigated a multi-dimensional approach to energy production in Floyd Bennett Field, while another explored green roofs and found them to be quite expensive in the economic modeling on VM, “I noticed this was

very costly. With more time, I would have compared cost & impact of fewer green roofs but more tree pits, etc." Finally, exploration was another theme of many k-12 educator visions, including time spent to figure out all of the capabilities of the tool itself.

3.2b NGO

Pre-survey resilience descriptions for the Jamaica Bay watershed reflected a focus on ecological aspects, especially restoration, native species, and salt marsh/oyster restoration while also including references to a nested system especially related to water quality. Post surveys shifted slightly to focus on governance, ecological diversity, and resilience to future disturbances and climate change (Table 2). Additionally, at post-survey, several NGO participants mentioned flooding, climate change and extreme weather along with ecological characteristics in their definitions. Also, a few described governance characteristics along with ecological aspects.

NGO participants described creating visions that were thematically aligned with five areas (Table 3 and Table 4). Participants used green infrastructure and created visions focused on increasing water absorption through bioswales and through restoring ecosystems to a, "more natural state." Several NGO participants also added solar panels and other modifiers to buildings, while exploration was a key attribute of at least one participant's work.

Public Agency

Pre-survey responses by public agency officials about resilience for the Jamaica Bay watershed focused on ecological aspects and about particular species responding to disturbances. In their post-surveys they remained relatively unchanged with the exception of adding climate change impacts (Table 2). At post-survey, public agency participants had the fewest amount of co-occurring characteristics in their definitions, while a couple participants mentioned ecological and climate change characteristics in their definitions.

Public agency participants described creating visions that were thematically aligned with five areas (Table 3 and Table 4). Public agency participants incorporated green infrastructure, "to create a natural barrier to coastal/storm impact" and also restored wetlands. They also modified the population density near the water's edge as well as building rooftops. Again, exploration was a focus of at least one participant that was interested in comparing present day ecosystems in Sheepshead day with historical ecologies, for example.

Researcher

Researchers did not change a great deal in how they defined resilience for Jamaica Bay pre to post survey. They had similar emphasis on ecological aspects and included references to social and community aspects, sometimes explicitly describing these as overlapping systems. In post-surveys, the most obvious change was in describing access to Jamaica Bay as a social issue. Additional urbanization, economic, and infrastructure ideas were added by individual participants, but did not represent a trend. There were no overt references to climate change in post-surveys, but there were discussions of extreme weather and other impacts related to changing climate and weather patterns (Table 2). Researcher participants had the most complex descriptions of resilience for the Jamaica

Bay watershed. Several researcher descriptions included descriptions of ecological aspects of the bay in relation to the people or social characteristics in the same system.

Across our researcher sample vision descriptions corresponded to all five of the themes that came out of coding (Table 3 and Table 4). They described adding green infrastructure to buffer coastal storms as well as restoring marshes to, "assess how those changes would affect flooding, carbon storage, and biodiversity." They also described developing current infrastructure through modifications, "Modifying existing structures w/ sustainability interventions", and also demolishing buildings in flood zones. Finally, researchers used Visionmaker to explore future climate scenarios.

Community Board

In pre-surveys, participants were tentative and spoke about being unsure about how to define resilience for the Jamaica Bay watershed, and also broad concepts related to problem solving water quality issues and native species restoration. There was little overlap in the characteristics described by community board members with the exception of several members mentioning being unsure or unfamiliar with the bay. A post-survey respondent described management, another wrote about "seeing the bigger picture," and still a third was unsure (Table 3-2).

Community board members described creating visions that were thematically aligned with three areas; development (modifying existing structures and built new structures), exploration, and ecosystem (wetland) restoration (Table 3-3 and Table 3-4). They described visions to modify existing structures, "placing solar energy panels & photovoltaic panels for energy conservation on roof tops of highrise buildings to reduce tenant's expenses in receiving low cost energy supplies from these sources. Maintaining affordable rents and housing expenses!" Community board members also used Visionmaker to explore, stating, "it helps us envision what is possible and what things we can bring to the planning board." Finally, they mentioned restoring wetlands.

Resilience Definition and Vision Comparisons across COPs

Participants across all COPs mentioned ecological aspects of the Jamaica Bay watershed more than any other characteristic (Table 3-2). Educators increased in their references to ecological aspects and nearly three-fourths of participants mentioned such aspects in their definitions. Educator definitions also became more parsimonious, mentioning only five different characteristics in the post-survey as opposed to ten on the pre-survey. NGO participants slightly decreased in their references to ecological aspects, although more than half still mentioned them. A greater percentage of NGO participants mentioned governance than other participants. Surprisingly, a few NGO participants and researchers mentioned being unsure about resilience for the Jamaica Bay watershed at post-survey that had not mentioned it in the pre-survey. Similar to educators, public agency participants simplified their descriptions over all, public agency participants mentioned four characteristics at post-survey as opposed to eight at pre-survey. Interestingly, public agency participants were the only group not to discuss storms and climate change in their post-survey descriptions. Finally, researchers mentioned social aspects of the watershed more than any other group. A few researchers also incorporated social-ecological system references into their descriptions, a rate higher than any other group.

Table 3-2. Post-Survey Resilience Dimensions by Community of Practice.

COP	n	Dimensions	Example Quotations
K-12 Educator	11	Ecological (73%), SES (9%), Governance (9%)	How can the area sustain climate change as an urban landscape that is home to natural flora/fauna, including human beings?"
NGO	12	Ecological (58%), Governance (33%), Civil Society (25%), Social (8%), Economic (8%), Community Competence (8%)	Managing the land so that it can support functional ecosystems in the face of a range of weather events and changing sea levels. Also, engaging an informed community to co-create management solutions that address environmental, social and economic needs."
Public Agency	5	Ecological (40%), Civil Society (20%), Community Competence (20%)	Resilience for the JB watershed means understanding what this environment once was, how we have altered or impacted natural space, and how can we plan for future environmental and climate change impacts."
Researcher	8	Ecological (38%), Social (38%), SES (38%), Economic (13%), Civil Society (13%), Governance (13%)	Connectivity and equity between systems and people to provide the needed resources and access to resources, for successful co-habitation and sustainable futures."
Community Board*	3	Ecological, Community Competence, Unsure	We all have to look at the bigger picture on how things affect each other."

*Percentages not reported due to not paired sample

Across COPs participant visions aligned under a number of themes (Table 3-3 and Table 3-4). Three thematic areas stand out among the visions and include ecosystem restoration of marshes or wetlands, modifying existing structures for energy production or green roofs, and more general exploration. A fourth theme, green infrastructure as a coastal buffer, was common among NGO, public agency, researcher, and educator participants. These visions represent partial fulfillment of the resilience definitions that participants offered. While participants modeled ecological and social-ecological system aspects of their definitions they were not similarly able to model societal variables such as governance, civil society, and community competence.

Table 3-3. Participant Descriptions of Visions.

Vision	Example Quotation
Development/modification of existing structures	Added wind/solar plants, green roofs on warehouses, and bioswales in parking lots. (NGO)
Exploration	It helps us envision what is possible and what things we can bring to the planning board. (Community Board)
Ecosystem restoration	I did extensive (~ hundreds of acres) of marsh restoration on the islands in the Bay (Researcher)
Green infrastructure	The vision I created focused on Gerritsen Beach in Marine Park, Brooklyn. Gerriten Beach is almost completely devoid of natural, native vegetation (a buffer) where the water meets the sand. With the amount of time during the first workshop, I added vegetation along the coastline, while viewing just how much the beach had changed over time by comparing the projected maps from the past. (Public Agency)
Retreat/decrease population	Demolished lots of buildings in Rockaway and turned area into salt marsh (both low & high marsh) making shoreline more resilient & more diverse biologically. (Researcher)
Renewable energy production	looked at Floyd Bennett Airfield as possible renewable energy source provider- solar, wind and tidal energy producer (K-12 Educator)

Table 3-4. Participant descriptions of Visions, by community of practice (COP).

	Community of Practice					
Vision	**K-12 Educator (*n*= 11)**	**NGO (*n*=14)**	**Public Agency (*n*=12)**	**Researcher (*n*= 12)**	**Community Board (*n*= 4)**	**Total**
Green infrastructure	5	7	5	2	0	19
Exploration	5	5	3	3	1	17
Ecosystem restoration	1	4	4	5	2	16
Development/modification of existing structures	1	3	1	3	3	11
Renewable energy production	2	4	0	1	1	8
Retreat/decrease population	0	0	1	1	0	2

Discussion

Participant Similarities

Our main finding was that there were more similarities among the communities of practice than there were differences. We expected to see significant differences between COP definitions and visions of resilience for the Jamaica Bay watershed, given the different approaches of these groups. However, all COP participant definitions tended to highlight ecological system aspects in their resilience

definitions and visions. It may be that this is a reflection of our research sample, which was self-selecting in that they had an interest in the Visionmaker tool that was described as a landscape visualization tool and therefore may have had a propensity for attracting participants that held an ecological frame of resilience. Alternatively, the lack of differences may represent what Tidball (2016) refers to as a social-ecological trap. An SES-trap is one where society locks itself into a cycle of whereby humans contribute to ecosystem decline and respond through development, which further increases vulnerability and ecosystem decay leading to more development. In our case, the trap appears to be one where participants spoke about ecosystem restoration and urban modifications, such as natural buffers, but few spoke about retreat or moving people away from the shore. Overall there was limited change in definitions from pre- to post-workshop surveys and similarly no statistically significant changes among participants on knowledge, concern, or ideas about adaptation. Despite the modeling of dynamic ecosystem change, ecological aspects of resilience were the central dimensions amongst all COPs. This seems to relate to research that suggests there is institutional and social inertia that makes change or innovation difficult (Childers, et. al., 2014).

Where did COP definitions converge and diverge from academic definitions?

Participants did not explicitly match urban, community, or coastal resilience trends, but rather incorporated dimensions of resilience that link to academic definitions. One of the most profound aspects of these definitions is what was missing in the post-survey—that is that there were no references to bouncing back or maintaining a steady state and instead there was an increase in discussion around governance and decision-making. While it is true that participants reflected that pre-European ecosystems in Jamaica Bay represented ecological systems with the greatest adaptive capacity, there were not overt references to bouncing back or staying the same. This suggests some level of recognition of the idea of systems as a part of a dynamic equilibrium where change is a constant (Picket, Cadenasso & Grove, 2004). The post-survey response could be the result of the Visionmaker tool that highlights the impacts of the urbanization process as well as sea-level rise and therefore models ecosystem change representative of an SES resilience frame (Schewenius, McPhearson & Elmqvist, 2014).

There was moderate focus on governance and an increase in that dimension along with civil society and community competence in post-surveys that seemed to represent a shift from a dominant ecological emphasis in the pre-surveys. Researchers in urban coastal resilience (i.e. Adger et al., 2005) and other fields suggest that governance in human dominated ecosystems is a key aspect of resilience. That is because of the lopsided influence of human influence and therefore there exists a necessity for multi-scalar human decisions. The hope is that Visionmaker can function to provide a virtual place for sharing, reflecting, and discussing visions created at multiple and overlapping geographic and governance scales. The tool has the potential to engage concretely with questions of resilience for whom and by whom that are specifically multi-scalar governance issues (Friend & Moench, 2013) and so these workshops are an early step towards bringing these five COPs into conversation with one another by facilitating sharing virtually, through Visionmaker.

The Visualization Process

Participants generated visions that imagined opportunities to modify existing structures, restore ecosystems, and create green infrastructure as a coastal buffer. Sheppard et al. (2011) argues that participatory visioning tools offer improved opportunities for public debate on climate change at the local level than other options, and breakdown barriers for engaging in planning processes for climate change adaptation. Given that our workshop series was designed to retain the siloed boundaries of each COP it may be that future workshops with a diverse group of people can better facilitate sharing and potentially lead to innovation amongst participants. Jude (2008) suggests that visualizations can help to communicate how coastal policies or management interventions will shape the coast, in order to gain wider acceptance for the shift towards 'soft' forms of coastal protection. This opportunity seems to resonate with participants, the majority of whom identified opportunities to use the tool in future participatory planning opportunities.

Limitations

There are several limitations to this research that require mention here. The first issue relates to difficulty attracting participants to our workshop series, especially community board members. Despite efforts to identify and work with local "champions", representatives from each COP, to plan and organize each workshop we found only one community board member willing to fervently collaborate with us on our efforts. This limited our ability to attract community board members and meant that this sample was too small to generate a thematic analysis of resilience definitions based on a paired sample. Second, we designed a two-hour workshop protocol in order to fit within the busy schedules of participants as suggested by our COP champions. However, we had an ambitious schedule that included a pre and post survey as well as a visioning session. This compressed time schedule led to several incomplete survey responses.

Conclusions

As sea-levels rise and environments continue to degrade due to human impacts the need for an SES resilience approach expands. But questions remain as to how to engage "the public" or a diversity of actors in a conversation around these topics, especially in watersheds. Formal watershed workshops and participatory planning events are one approach, but they are often top-down and expert driven often lacking in transparency and a wide range of involvement from different actors (Korfmacher 2001). In turn, online visualization tools offer an innovative frontier for democratic exploration (Sheppard, 2015).

In this case study we showed how Visionmaker was used to support resilience visioning for various COP's in the Jamaica Bay watershed. Although participants did not shift significantly in their framing of resilience, the tool allowed them to envision and test ideas. Academics have long disagreed on how to define resilience and as resilience gains prominence as a community planning strategy these differences move from theoretical disagreements to friction over application of the term. The SRIJB has been organized in order to focus on Jamaica Bay as an example case for working out such complex issues related to the application of resilience theory. This research represents a step towards understanding the frames that different communities of practice hold in conceptualizing resilience for Jamaica Bay watershed. And of great interest is the value that the

participants saw in the tool, for modeling NYC ecosystems and future participatory planning and community modeling opportunities.

We take up these issues in the second paper about designing resilience, reproduced in pre-print form *below.*

Designing resilience: lessons from applying Visionmaker, a free digital ecological democracy tool, to the Jamaica Bay watershed in New York City
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Abstract
Resilience to extreme weather events and other sudden changes is an issue facing many communities in the early 21st century. Planning to respond to disasters and recover quickly is particularly complicated in densely inhabited, multi-jurisdictional urban social-ecological systems like the urban watershed of Jamaica Bay. Here successful resilience planning and response requires participation from a wide variety of civil society players each with different levels of knowledge, value systems, and expectations about what exactly should be made resilient and how. Here we report the results of investigation into how "visions" of resilience differed among several of communities living in or concerned with Jamaica Bay, New York, a large urbanized estuary on the south side of New York City. This area, managed as a wildlife refuge by the National Park Service, is surrounded by communities that were heavily impacted by Hurricane Sandy in 2012. We deployed a free, Internet-based modelling framework called Visionmaker that enabled interactive scenario creation and testing. Through a series of standardized workshops we recruited participants from a variety of different communities of practice (i.e. researchers, land managers, educators, non-governmental organization staff, and community board members) to design "visions of resilience". Visions spanned the terrestrial and marine environments, and natural and built ecosystems. Most users favored increasing resilience through enhancing salt marsh and green infrastructure while, for the most part, keeping the built city landscape of streets and buildings intact. We compare and contrast these visions and discuss the implications for future resilience planning in coastal cities.

Introduction
Resilience, defined as the ability for a system to return to its previous state after a shock or disruption (Sanderson et al. 2016), is an issue facing many communities in a time of climate change, which almost assuredly will continue to produce many shocks and disruptions in the future. Unfortunately, past experiences with disasters including hurricanes in New Orleans and New York City, tornadoes in Joplin, Missouri, fires in the San Gabriel Mountains near Los Angeles, and devastating floods along the Mississippi and in southern Louisiana suggests there is often a rush to "rebuild the familiar" in post-disaster response (Kates et al. 2006). Rebuilding in place to pre-storm conditions, while no doubt comforting to the people impacted, may in the long-run create further risks and the potential for even greater damages.

Recognizing the need to plan for resilience differently, a variety of high profile attempts have been made to provide information and jumpstart the innovation process. For example, in the wake of

Hurricane Sandy, the US Department of Housing and Urban Development and Rockefeller Foundation launched "Rebuild by Design" (rebuildbydesign.org), commissioning ten "world-class, interdisciplinary teams" to develop "transformative planning and design approaches" after the storm. The US Army Corps of Engineers "Hurricane Sandy Coastal Management Division" has launched integrated studies to analyze strategies to promote the resiliency of the North Atlantic coast in preparation for future extreme weather (USACE 2013). The NOAA Coastal Services Center created "Digital Coast," a website (www.csc.noaa.gov/digitalcoast) designed help people "turn data into information they can use," including county-level reports, a sea level rise and coastal flood impacts viewer, videos and a blog.

While important and necessary, these efforts focus on traditional models of public engagement, where experts create knowledge (like flood maps) or ideas (like novel architectural designs) that are subsequently communicated to the public. The public is conceived of as recipient of information and knowledge and not a participant in knowledge creation about and design for resilience strategies (Lane et al. 2010). Researchers in public understanding of science have called into question the effectiveness of this mode of knowledge production and dissemination, especially where changes in public behavior or policy are necessary (Hegger et al., 2011; McNie 2007; Callon 1999). More effective appear to be shared, interactive modes of knowledge production, especially when dealing with complex, interdependent environmental problems, on the interface between science, society, and policy, like climate-related disasters (e.g. Seijger et al. 2013; Hegger et al., 2011; Lane et al. 2010).

Clearly the Internet opens new opportunities for joint knowledge creation that go beyond traditional models of public engagement (Wilsdon and Willis, 2004). Digital mapping efforts, on top of Google Maps and or a web-deployed geographic information system (like Digital Coast), offer spatially-explicit scientific information for anyone with a connection (Sullivan et al. 2009; Kingston 2007). Search engines are making scientific information easier to find, and counter-intuitively, more trusted (Brossard & Scheufele 2013), and social media has transformed the human ability to converse and network in spatially- and temporally-distributed ways (Shirky 2008). As a result new forms of networking are emerging (from Wikipedia to eBird to Occupy Sandy), with the potential for new knowledge and innovations to emerge not only from the experts, but from "the wisdom of the crowd" (sensu Surowiecki 2004).

This paper presents a cautionary tale from our experience using a new, Internet-based tool designed for ecological democracy. Visionmaker is a free, Internet-based forum designed to enable anyone (land managers, politicians, neighborhood residents, schoolchildren, etc.) to develop and share climate-resilient designs for their own neighborhood in New York City. Visionmaker combines social media tools, environmental modeling, scenario analysis, and geographically explicit data to support participatory processes, acknowledge needs of different stakeholders, and accrue community benefits from a transparent planning (Adger, 2003; Reed, 2008). Visionmaker is explicitly designed to foster a robust and informed conversation about resilience, though as will be seen, a platform does not a conversation make.

Methods

Study Site

Our work focuses on Jamaica Bay (centered at 40°36'14" N, 073° 50' 07" W), a tidal lagoon protected by the Rockaway Peninsula on the southeast side of New York City. Like many other urban estuaries, the boundaries of the bay and its environs before extensive urbanization were dynamic and less-defined (Buxton and Shernoff 1995; Sanderson 2016). Shifts occurred gradually, as with century-long changes in sea level, or at punctuated moments, with stochastic disturbance events, such as the hurricanes or nor'easter storms (Swanson et al. 2016). Although human impacts on the local ecology and landscape have long been felt, from the subsistence fishing and hunting of the Lenape Native Americans through the colonial and early American agricultural period (Black 1981), it was during the twentieth century that the edges of the bay became a more industrialized and residential space. Land reclamation, waste dumping, and large-scale infrastructure development made the bay's boundaries and jurisdictions more relevant in the everyday experience of area residents. The Jamaica Bay watershed encompasses nearly half of the boroughs of Brooklyn and Queens, which had populations of nearly 2.6 million and 2.3 million, respectively, in 2014 (U.S. Census Bureau 2014a; 2014b). Meanwhile, in 1971, the management of the undeveloped interior marsh lands and waters was passed from the City of New York to the National Park Service, with a mandate "to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." (National Park Service Organic Act 1916)

Hurricane Sandy reminded the public of the damage that winds, floods and storm surge from coastal storms can inflict on the nation. In Sandy's case, 159 people were killed, more than 650,000 homes were damaged or destroyed, thousands of businesses temporarily shuttered, and millions of lives were disrupted in only a few days' time (Hurricane Sandy Rebuilding Task Force 2013). The temporary closure of John F. Kennedy International Airport resulted cancelled or delayed flights. Unfortunately, Sandy was not the first, nor the last, severe storm to threaten the region. At least four hurricanes have made direct hits on NYC over the last 400 years, while many others have made near misses (Scileppi and Donnelly, 2007; Talke et al. 2013). Severe "nor'easter" storms have caused seas to rise 2.0-2.5 m (over the same period?) and occur more frequently than hurricanes (Orton et al., 2012). Climate change predictions for NYC suggest the future will see increased precipitation, higher temperatures, and rising sea levels (Horton & O'Grady 2009; NYC Panel on Climate Change 2013) for the nation's most important economic region, which contributes 9.5 percent of the nation's gross domestic product (U.S. Bureau of Economic Analysis 2013) and houses 1 in 16 Americans (US Census Bureau 2013).

Visionmaker Platform

Visionmaker.nyc includes the geography of all five boroughs of New York City including the waters of the upper and lower harbor, the Hudson and East Rivers, and Jamaica Bay. Users are presented with maps on a 10 m grid showing the city in terms of 70 "ecosystems", where ecosystems include building types, transportation infrastructure, utilities of various kinds, and managed open space, as well as more natural, indigenous ones (forests, wetlands, etc.). Ecosystems can be terrestrial or marine; and built or natural. A distinction is also made between "base" ecosystems that entirely fill a

cell and allow no other base ecosystem type (e.g. a cell is either a building or a lawn or a forest) and "modifier" ecosystems, that can be placed on or below other ecosystems, modifying their characteristics (e.g. a green roof modifies a building, a bike lane modifies a street, an eelgrass meadow modifies shallow estuary). Users are presented a version of the historical ecosystems of New York City at the time of European Contact from the Welikia Project (welikia.org), which builds on the Mannahatta Project (Sanderson 2009) alongside ecosystems for the contemporary city in 2014.

Using Visionmaker.nyc, users create concepts or "visions" by first choosing a bounded area of interest. Vision extents are selected by aggregating city blocks, with blocks created by dividing along the street-center line. For parts of the city where there are no streets (e.g. in natural areas and in the estuary waters), approximations of blocks are created using paths, islands, or other convenient geographic boundaries. The minimum size of a vision is one block. Users also have the option of attributing a year to their vision (i.e. what year are you imagining?).

Visions are constructed of three inputs beside the geographic boundaries: ecosystems, lifestyle choices, and climate scenarios. Ecosystems are of two types: base ecosystems, of which there can be only one type per 33-square-foot (10 m^2) cell, and modifiers, of which there can be multiple types per cell. Base ecosystems refer to the main use type of the cell, including buildings, transportation types, or natural ecosystems. Modifiers change the ecosystem parameters of the cell, but do not replace the base ecosystem. For example, a green roof changes the biomass and water-holding capacity of an apartment building, but does not change the amount of floor area available for residential use. Similarly, street trees, bike lanes, trails in a forest, and piers in an estuary all model modifications, but not wholescale changes, to ecosystems.

Lifestyle choice options are made up of parameterizations for average American, average New Yorker, average earthling, average Lenape person—a Native American, representing a semihorticultural lifestyle as existed in the predevelopment New York City landscape—and an environmentally conscious, "eco-hipster" lifestyle. The selected lifestyle choice determines how metrics including transportation choices, household size, and residential density are modeled within the vision area. Climate scenarios draw on work from the New York City Panel on Climate Change (Horton et al., 2015). Visionmaker calculates metrics of environmental performance to compare the user's vision with the current condition based on modern geographic data describing the city today (color plate VI) and historical condition based on the Welikia Project (color plate I; Sanderson, 2009). Current models include a storm-event precipitation and runoff model (the "water" model); an energy, transportation, and ecosystem carbon cycling model (the "carbon" model); a species habitat and diversity model (the "biodiversity" model); a residential and worker model (the "population" model); and costs of demolition and construction (the "economics" model), all of which are explained briefly below. After a period of editing and revision, users may then choose to share their visions with selected others or with the public at large. Users may also issue "challenges" in terms of vision metrics.

Visionmaker Workshops

From July 2015 – April 2016 we held 12 workshops in the communities around Jamaica Bay or in nearby locations directed toward people interested in Jamaica Bay from five "communities of practice": primary and secondary school teachers, researchers, land managers, staff or affiliates of environmental non-governmental organizations, and community board members. Each workshop was conducted in the same way by the same people (authors: Giampieri and DuBois.) Participants were asked to fill out pre-workshop surveys with basic demographic information and to assess their previous knowledge of climate change effects and resilience planning; the survey instruments received previous approval from the Cornell University Institutional Review Board. At the workshop, participants were given short presentations about different kinds of disturbances to the estuary system, the Science and Resilience Institute at Jamaica Bay (SRIJB) and the Visionmaker project and goals. They were then given a brief tutorial on using Visionmaker. With this background, they were given 45-75 minutes to create a vision of what resilience for Jamaica Bay means to them. Afterwards they discussed their visions through a moderated discussion and filled out a post-workshop survey instrument. Each participant was given a unique identifier that enabled us to connect the survey results with their vision.

Results

Participants

Through the twelve workshops, we had 87 participants which produced 46 visions of resilience for Jamaica Bay, or a successful completion rate of 53%. As reported elsewhere (DuBois et al., in review; first paper under this objective) we had participants drawn from five communities of practice, including 21 NGO affiliates, 15 public agency staff, 19 researchers, 17 from community boards and 15 K-12 educators. Based on surveys before the workshop, participants were all adults, predominantly female (58 out of 76), inclusive of people between 18 and over 65 years of age (largest age group, 35-44 years old), well-educated (14+33+15 / 65 had a college degree, and 33+15 / 65 had a graduate degree), most described themselves as liberal or very liberal (31+14 / 62). Nearly all had experienced extreme weather (59/67) or climate change (58/62), although only 38% (25/65) reported formal resilience training. Only about half (55-37/55) lived within the Jamaica Bay watershed. Because there were no large differences between the pre- and post-survey results among participants from the different communities of practice, and because of the low overall sample size, we lumped all visions for further analysis.

Visions

Participants created visions that varied from 1.5 – 990 ha in extent, with the mean area of a vision 198 ha (SD = 282 ha) (Table 3-5). For comparison, a block on Manhattan Island is approximately 2.26 ha, so visions ranged from a single block to an area equivalent to approximately 100 blocks on Manhattan. Most visions were in the Jamaica Bay watershed or adjacent areas of Coney Island (where some of the workshops were held). Interestingly none of the visions were made in the water or marshlands east of Cross-Bay Boulevard, closer to John F. Kennedy Airport.

Three-quarters of visions (76%; 36 of 46) were terrestrially focused with extents more than 75% on land (Table 3-5). Most vision extents included both built and natural ecosystems; 15 visions were

created in areas that were 75% or more built; an additional 11 in extents that were 50-75% built; 8 that were 25-50% built; and 8 between 0 – 25% built. Three visions were created entirely in natural ecosystems.

Table 3-5. Vision extents and composition in Jamaica Bay, New York.

Internal Vision ID	Vision Extent				Vision Changes				
	Area (ha)	Modifier Area (ha)	Terrestrial (%)	Built (%)	Base Ecosystem (%)	Modifier (%)	Terrestrial (%)	Marine (%)	Built (%)
16473	989.8	0.1	12	0	14	0	12	16	0
21546	896.2	25.7	97	36	0	0	0	0	0
19628	887.0	8.8	18	12	8	<1	9	7	8
16477	863.5	1.5	11	0	<1	0	<1	<1	0
16479	665.4	2.9	<1	1	0	0	0	0	0
21544	525.3	7.2	12	11	1	<1	1	<1	1
21542	506.5	5.8	9	6	<1	1	1	<1	1
21545	496.1	27.7	99	87	0	<1	0	0	<1
19627	493.5	5.2	7	4	2	<1	2	2	1
19561	459.3	2.9	98	34	9	<1	18	<1	12
19559	459.3	2.9	98	34	0	0	0	0	0
19535	222.7	3.3	100	85	1	2	2	<1	3
19625	186.2	14.6	78	66	1	<1	1	2	1
16472	164.0	3.5	96	33	8	<1	10	6	5
19557	120.6	5.6	59	11	0	0	0	0	0
16487	108.4	0.8	1	2	2	0	<1	3	0
16475	107.1	0.0	85	<1	0	0	0	0	0
17154	105.1	7.4	5	11	<1	0	<1	<1	<1
19549	103.7	6.1	98	73	4	6	7	1	3
20792	69.6	2.2	95	64	0	4	4	0	7
20789	65.6	1.0	100	65	0	4	3	0	6
19538	64.5	2.7	97	58	0	24	0	0	24
16474	53.9	5.6	78	79	10	<1	10	11	9
16471	50.3	0.1	95	36	0	0	2	0	<1
19534	45.0	2.9	93	50	2	34	3	1	12
19560	42.3	1.0	99	87	35	10	59	12	46
19555	35.0	5.5	100	99	0	25	24	0	46
17152	32.7	0.0	95	0	0	0	0	0	0

Table 3-5 (continued). Vision extents and composition in Jamaica Bay, New York.

Internal Vision ID	Vision Extent				Vision Changes				
	Area (ha)	Modifier Area (ha)	Terrestrial (%)	Built (%)	Base Ecosystem (%)	Modifier (%)	Terrestrial (%)	Marine (%)	Built (%)
19479	32.1	0.4	100	71	100	4	169	31	71
20788	29.8	1.0	97	39	0	0	0	0	0
20790	28.3	0.5	91	61	15	14	25	5	23
22722	24.8	4.3	100	100	0	<1	3	0	2
19567	24.6	0.2	98	78	0	0	0	0	0
19480	23.8	0.0	81	40	29	0	37	22	26
19565	23.3	1.4	100	84	0	0	0	0	0
20791	23.3	0.1	95	45	0	0	0	0	0
19473	20.2	1.1	100	94	34	4	53	14	35
21550	20.0	1.3	99	63	0	1	3	0	3
19533	16.2	0.3	95	64	34	1	33	35	21
19537	15.7	0.3	100	73	0	18	6	0	13
16478	13.5	1.3	100	91	0	55	0	0	0
19532	7.9	0.1	100	94	0	0	0	0	0
19630	7.1	0.4	100	79	15	<1	15	15	11
19566	2.6	0.1	100	80	0	8	13	0	7
19478	2.4	0.1	97	89	95	2	139	52	85
21543	1.5	0.0	100	78	0	14	0	0	14

Participants attributed a variety of different years to their visions. The most common year that participants imagined in the future was 2050 (17 of 46 visions); the second most common was 2020 (11 out of 46). Only two visions were attributed to past 2050, even though 2050 is only 35 years into the future from the date of the workshop; the longest range was a single vision attributed to 2100. Three visions were backdated (one to 2012, when Hurricane Sandy hit, and two to 2014.)

Participants nearly all chose the average New Yorker lifestyle (40 of 46 visions), which is also the default. Four visions were constructed using the "Eco-conscious" lifestyle, two with the Lenape lifestyle, and one with the Average American lifestyle.

Participants mainly chose the baseline climate (1970 – 2010) (31 out of 46 visions), which is also the default; 6 chose the 2020 climate scenario, 5 the 2050 climate scenario, and only 1 the 2080 climate scenario. Four visions were attributed to the past climate reconstruction from 1609.

For use in the water model, participants can also select a precipitation event. Most participants retained the default selection of "Showers" (38 out of 46 visions). All the other visions chose more severe precipitation events: rainy day (1), thunderstorm (3), and severe storm (5). The exact definitions of these precipitation events depend on the climate scenario selection.

Ecosystems

In the 46 visions created by participants, they changed the base ecosystems in less than half of the instances (20 of the 46 visions). Another 11 visions changed only modifier ecosystems, which left 16 visions without any ecosystem changes at all. (Recall that visions could be composed of only lifestyle or climate scenario changes.)

The most commonly changed ecosystems, of those visions that changed a base ecosystem, were sidewalks and "pavement (other)" category, which represents pedestrian plazas, alleys, driveways, and other paved surface that are not dedicated roadways (Table 3-6). More than half of the visions included an alteration in one of these two ecosystems; in all cases the change was to reduce the area of these paved types. Similarly, nearly half of visions altered collector streets, ornamental gardens, lawns and park savannas (which are lawns with scattered trees, as in a park), mainly by decreasing them in favor of gains in high and low salt marsh and agricultural fields (which we interpret as desire for increased community gardening space).

Table 3-6. Use of ecosystems in visions of resilience for Jamaica Bay, New York.

Ecosystem	Terrestrial / Marine	Visions with change to this ecosystem (%)	Number of visions with change	Number of visions with reduction in ecosystem area	Number of visions with gain in ecosystem area
Pavement (other)	terrestrial	54	25	25	0
Sidewalk	terrestrial	52	24	24	0
Street (collector)	terrestrial	48	22	22	0
Ornamental garden	terrestrial	46	21	20	1
Park savanna	terrestrial	43	20	16	4
Shallow estuary	marine	43	20	18	2
Lawn	terrestrial	37	17	17	0
Disturbed Land	terrestrial	35	16	16	0
High salt marsh	marine	35	16	0	16
Boulevard (arterial)	terrestrial	33	15	14	1
Parking lot	terrestrial	33	15	14	1
Low salt marsh	marine	33	15	2	13
Apartment building	terrestrial	30	14	12	2
Garage	terrestrial	26	12	11	1
Beach	terrestrial	24	11	8	3
Single family home	terrestrial	24	11	11	0
Agricultural field	terrestrial	22	10	2	8
Public assembly hall	terrestrial	22	10	8	2
Shrub land	terrestrial	22	10	5	5
Deep water estuary	marine	20	9	8	1
Conifer forest	terrestrial	17	8	7	1
Freshwater marsh	terrestrial	13	6	2	4
Mixed use: retail / residential building	terrestrial	13	6	3	3
Paved ball field/court	terrestrial	13	6	5	1
Pond	terrestrial	13	6	2	4
Retail building	terrestrial	13	6	5	1
School or university	terrestrial	13	6	3	3
Traffic slowed street	terrestrial	13	6	6	0
Warehouse	terrestrial	13	6	5	1
Derelict structures	terrestrial	11	5	5	0
Oak hickory forest	terrestrial	11	5	0	5
Office building	terrestrial	11	5	4	1
Solar energy facility	terrestrial	11	5	0	5

Table 3-6 (continued). Use of ecosystems in visions of resilience for Jamaica Bay, New York.

Ecosystem	Terrestrial / Marine	Visions with change to this ecosystem (%)	Number of visions with change	Number of visions with reduction in ecosystem area	Number of visions with gain in ecosystem area
Tidal energy facility	terrestrial	11	5	0	5
Factory	terrestrial	9	4	4	0
Greenhouse / vertical farm	terrestrial	9	4	0	4
Hardwood swamp	terrestrial	9	4	1	3
Meadow	terrestrial	9	4	2	2
Mixed use: restaurant / residential building	terrestrial	9	4	1	3
Gas station	terrestrial	7	3	3	0
Mixed use: restaurant / retail building	terrestrial	7	3	2	1
Orchard	terrestrial	7	3	0	3
Sewage treatment plant	terrestrial	7	3	2	1
Cottages / Mobile home	terrestrial	4	2	1	1
Highway	terrestrial	4	2	2	0
Hospital	terrestrial	4	2	2	0
Mixed use: office / residential building	terrestrial	4	2	0	2
Swimming pool	terrestrial	4	2	1	1
Utility yard	terrestrial	4	2	2	0
Wind farm	terrestrial	4	2	0	2
Airfield	terrestrial	2	1	1	0
Camp	terrestrial	2	1	0	1
Cliffs and rock outcrops	terrestrial	2	1	0	1
Computer data center	terrestrial	2	1	0	1
Heavy rail line	terrestrial	2	1	1	0
Hotel	terrestrial	2	1	1	0
Light rail line	terrestrial	2	1	0	1
Mixed use: restaurant / office building	terrestrial	2	1	0	1
Mixed use: retail / office building	terrestrial	2	1	1	0
Natural gas power plant	terrestrial	2	1	0	1
Restaurant	terrestrial	2	1	0	1
Stadium	terrestrial	2	1	1	0
Waste energy power plant	terrestrial	2	1	0	1

Table 3-6 (continued). Use of ecosystems in visions of resilience for Jamaica Bay, New York.

Ecosystem	Terrestrial / Marine	Visions with change to this ecosystem (%)	Number of visions with change	Number of visions with reduction in ecosystem area	Number of visions with gain in ecosystem area
Water treatment plant	terrestrial	2	1	0	1
Water/wastewater storage tank	terrestrial	2	1	1	0
Airport terminal	terrestrial	0	0	0	0
Alley	terrestrial	0	0	0	0
Cemetery	terrestrial	0	0	0	0
Cogeneration plant	terrestrial	0	0	0	0
Diesel power plant	terrestrial	0	0	0	0
Elevated train	terrestrial	0	0	0	0
Fuel storage tank	terrestrial	0	0	0	0
Landfill	terrestrial	0	0	0	0
Restaurant/Office	terrestrial	0	0	0	0
Restaurant/Residential	terrestrial	0	0	0	0
Restaurant/Retail	terrestrial	0	0	0	0
Solid waste transfer plant	terrestrial	0	0	0	0

In terms of modifier ecosystems, the most commonly altered modifier were green roofs, followed closely by street trees and bike lanes (Table 3-7). While most users were in favor of increased green roofs, the changes made to street trees included both increases and decreases. The decreases in street trees may have been unintentional consequences to modification of paved ecosystems (as above) and the users not restoring “street trees” that had been eliminated. Users eliminated piers, a kind of hardscape, and added cisterns/water barrels, photovoltaic panels, bioswales, and streams.

Table 3-7. Uses of modifier ecosystems in visions of resilience for Jamaica Bay, New York.

Ecosystem	Terrestrial / Marine	Visions with change to this ecosystem (%)	Number of visions with change	Number of visions with reduction in ecosystem area	Number of visions with gain in ecosystem area
Green roof	terrestrial	33	15	1	14
Street trees	terrestrial	30	14	8	6
Bike lane	terrestrial	26	12	7	5
Pier	marine	17	8	7	1
Cistern / rain barrels	terrestrial	15	7	1	6
Photovoltaic panels	terrestrial	13	6	1	5
Bioswale	terrestrial	9	4	0	4
Stream	terrestrial	9	4	0	4
Compost bin	terrestrial	7	3	0	3
Solar heating panels	terrestrial	7	3	0	3
Trail	terrestrial	4	2	0	2
Graywater recycling	terrestrial	2	1	0	1
Pedestrian bridge	terrestrial	2	1	0	1
Permeable pavers	terrestrial	2	1	0	1
Bridge	marine	2	1	1	0
Subway	terrestrial	2	1	1	0
Geothermal pump	terrestrial	0	0	0	0
Streetcar line	terrestrial	0	0	0	0
Eelgrass meadow	marine	0	0	0	0
Tunnel	marine	0	0	0	0

Discussion

Based on the nature of the changes made across visions, participants approached the exercise by focusing on relatively short-term (i.e. within their lifetimes) and small-scale changes. Most visions were relatively small in relation to the watershed, on the order of about 10 city blocks. Many, although not all, participants chose the default settings for climate and lifestyle scenarios, while others explored more distant or more extreme options.

Participants that lived within the watershed tended to create visions for areas in their own neighborhood, expressing a close relationship between where they lived and where they imagined. Participants who lived outside the watershed almost always created visions directly adjacent to or including the shoreline and nearshore waters. 78% of all visions included or were adjacent to the shoreline, suggesting that participants approached resiliency planning as something that takes place at or along the coast. Of the visions that did abut or include the shoreline, half (18/36) added salt marsh to the shoreline in efforts to soften the shore edge. Of the remaining 18 visions that include shoreline but did not soften the shoreline, 10 did not include any ecosystem changes, suggesting the

possibility that participants were interested in addressing issues of resiliency at the coast but were unable to due to technical or other issues. The remaining coastal visions that did not soften the shoreline made interventions further inland, ranging from adding vegetable gardens to more residential area. These visions did not necessarily address resilience to extreme weather events directly, instead focusing on other place-specific issues (i.e. new schools, more housing) or improving environmental performance in general.

Participants largely adhered to the existing street grid, limiting their ecosystem modifications to coastal areas or other open spaces, suggesting a desire to engender resilient response while staying within what is deemed as pragmatic and least disruptive. When viewed alongside the relatively near-term scope of overall visions, it becomes apparent that participants favored incremental changes that could be achieved within their lifetimes. This tendency was made more clear by the generally small, conservative adaptations, potentially interpreted as means to maintain the status quo in the face of a disturbance event. Participants made more changes to modifier ecosystems (as opposed to base ecosystems), further displaying a preference for making minor non-invasive modifications to existing built forms as opposed to proposing new forms. The reliance on modifiers, and particularly green roofs, signals a tendency to prefer localized interventions as opposed to district- or system-wide changes. Participants generally expressed the desire to improve environmental performance and quality of live overall within their vision extent.

For users that did make meaningful changes, it is clear that their interest lay in smaller scale interventions as opposed to watershed-level changes. While the introductory presentation framed the resilience in terms of the watershed, the amount of time given for exploration and intervention only allowed for a certain level of implementation. What's more, even users with well-defined opinions on resilience and interventions seemed prone to expressing those values and strategies at smaller scales. Even if individuals agree with general intervention strategies (i.e. to soften shorelines or add street trees or green roofs), they are likely to express these notions in specific, small-scale locations. In sum, the most common ecosystem changes like adding salt marsh and green roofs could be extrapolated to suggest a general support for such policies.

Limitations

A critical element of implementing a tool like Visionmaker across heterogenous communities in an urban watershed is participation. Despite considerable efforts to advertise the workshops and to work through local community groups to encourage participation, the showing at the Visionmaker workshops was much less than desired or anticipated. The nature of the tool, in which participants are invited to create alternatives for their neighborhoods using a web-based tool, does not fit into traditional models of engagement. Oftentimes, the metrics calculated by Visionmaker (i.e. carbon dioxide, trip miles, stormwater runoff) is presented as static information (see Digital Coast) that is presented to the end user, as opposed to being synthesized through a vision making process. Models of knowledge production are often confined to academic or agency research settings, or are exercised through more qualitative community-based participation. Visionmaker instead offers users a means to create different scenarios themselves and measure the results against quantitative information, individually or in small groups. This model of engagement—of offering a tool for people to design

and evaluate novel scenarios—does not fit either model, and proved difficult to frame in such a way that participants felt comfortable in engaging or iterating their own visions for an area.

A second problem is that for even those who attended the workshops, only a little more than half actually produced a vision, despite the fact that participants were mainly educated, interested and motivated to do so. The workshops were designed to fit a two-hour window. In hindsight, that was not enough time to train the users, allow them to experiment with the various functions and attributes and then create a final vision. Workshop protocols were amended during the study to further define activities using Visionmaker and to ensure that participants saved their work. Access to appropriate technology limited participants' ability to participate. Several participants did not have access to a laptop to bring to the workshop, requiring some participants to work in small groups. In some cases, poor internet connection inhibited participants' ability to effectively use the tool. As of this writing, Visionmaker is not suited for use on touch screen devices, further limiting some participants from being able to participate despite having internet enabled tablets or smart phones. Low sample size no doubt limits our interpretation.

Areas for Future Research

The Visionmaker platform has proven to be an effective design tool for prototyping different scenarios; however, it is a complex tool that requires participants to be somewhat familiar with web-based GIS tools to be able to express nuanced visions of resilience. Future studies should include more time for training and engagement with the tool to allow participants to engage meaningfully.

Oftentimes participants expressed qualitative ideas for pursuing resilience or stances on certain interventions that were expressed during workshops. Some participants were able to articulate those thoughts spatially using the Visionmaker platform in the time given, but others had difficulty in doing so. Future experiments combining non-spatial identification of preferred interventions (i.e. better transportation, more flood protection, more access to agricultural land, etc.) followed by spatial visioning could allow participants to organize their intervention strategy and produce more articulate visions.

The workshops were open ended to the point that some participants did not have time to determine the specific problem to respond to, much less respond to it. A more guided visioning session (perhaps determined to some extent by participant interest) could help frame the experience and produce more robust visions. Alternatively, future experiments could begin by presenting an explicit scenario to participants (i.e. sea level is predicted to rise by x inches over the next x years) and asking them to respond to that scenario.

Objective 4: Publications and Presentations

Project deliverables included publications and public presentations as summarized below.

Publications

During the course of this project, the following papers/book chapters related to the resilience of Jamaica Bay were published by the project team.

Allred, S., B. DuBois, K. Bunting-Howarth, K. Tidball, and W. D. Solecki. 2016. Social-ecological system transformation in Jamaica Bay. Eds. E. W. Sanderson, W. D. Solecki, A. S. Parris, & J. R. Waldman. In Prospects for Resilience: Insights from New York City's Jamaica Bay. Island Press.

Barr, J. M. 2016. Building the Skyline: The Birth and Growth of Manhattan's Skyscrapers. Oxford University Press.

Giampieri, M., B. DuBois, S. Allred, K. Bunting-Howarth, K. Fisher, J. Moy, and E. W. Sanderson. 2017. Designing resilience: lessons from applying Visionmaker, a free digital ecological democracy tool, to the Jamaica Bay watershed in New York City. Urban Ecosystems: DOI 10.1007/s11252-017-0701-2.

Handel, S., et al. 2016. Ecology of Jamaica Bay: History, status and resilience In (Eds.) E. W. Sanderson, W.D. Solecki, J. R. Waldman, and A. S. Parris. Prospects for Resilience: Insights from New York City's Jamaica Bay. Island Press, Washington, D.C.

Hopper, T. and M. S. Meixler. 2016. Modeling Coastal Vulnerability through Space and Time. PloS one, 11(10), e0163495. doi: 10.1371/journal.pone.0163495

Meixler, M. S. 2017. Assessment of Hurricane Sandy damage and resulting loss in ecosystem services in a coastal-urban setting. *Ecosystem Services* 24:28-46.

Parris, A. S., W. D. Solecki, E.W. Sanderson, and J. R. Waldman. 2016. The future of Jamaica Bay: Putting resilience into practice. In (Eds.) E. W. Sanderson, W. D. Solecki., J. R. Waldman, and A. S. Parris. Prospects for Resilience: Insights from New York City's Jamaica Bay. Island Press, Washington, D.C.

Sanderson, E. W., P. Orton, J. Fischbach, D. Knopman, H. Roberts, W. D. Solecki, J. Fitzpatrick, and R. Wilson. 2016. Computational modelling of the Jamaica Bay system. In (Eds.) E. W. Sanderson, W. D. Solecki., J. R. Waldman, and A. S. Parris. Prospects for Resilience: Insights from New York City's Jamaica Bay. Island Press, Washington, D.C.

Sanderson, E. W. 2016. Cartographic Evidence for Historical Geomorphological Change and Wetland Formation in Jamaica Bay, New York. *Northeastern Naturalist* 23(2):277-304.

Solecki, W. D., E. W. Sanderson, J. R. Waldman, and A. S. Parris. 2016. Why prospects for resilience for Jamaica Bay? In (Eds.) E. W. Sanderson, W. D. Solecki., J. R. Waldman, and A. S. Parris. Prospects for Resilience: Insights from New York City's Jamaica Bay. Island Press, Washington, D.C.

Swanson, L., M. Dorsch, M. Giampieri, P. Orton, A. Parris, and E. W. Sanderson. 2016. Dynamics of the biophysical systems of Jamaica Bay. In (Eds.) E. W. Sanderson, W. D. Solecki., J. R. Waldman, and A. S. Parris. Prospects for Resilience: Insights from New York City's Jamaica Bay. Island Press, Washington, D.C.

The following manuscript is being revised for publication (the text is reproduced under objective 3):

DuBois, B., S. Allred, E. W. Sanderson, M. Giampieri, K. Bunting-Howarth. (In review.) Participatory resilience visioning of the Jamaica Bay watershed. *Journal of Environmental Psychology*.

The following manuscripts are in preparation:

Barr, J., R. Uzinger, K. Fisher, and E. W. Sanderson. (In preparation.) On-the-fly calculations of construction and demolition costs in an environmental scenario application.

Meixler, M. S., E. W. Sanderson, K. Fisher. (in review). Visionmaker Jamaica Bay: Analysis of Predicted Species richness of Adaptation Strategies to Enhance Resilient Ecosystems in Jamaica Bay post-Hurricane Sandy, New York.

Meixler, M. S., E. W. Sanderson, K. Fisher. (in preparation). Latitude adjusted species-area curves for multiple taxa.

Meixler, M. S., C. Kauninger, J. Epiphan, and S. Handel. (in preparation). Marsh migration opportunity modeling.

Piana, M., A. Kleinbeck, and M. S. Meixler. (in preparation). Modeling the projected impact of local sea level rise on the urban-coastal fringe ecosystem services of Jamaica Bay, New York.

Public Presentations (in addition to workshops listed in Table 2-1)

Staten Island School for Civic Engagement, Staten Island, on mannahatta2409.org, 28 October 2014

TEDYouth, Brooklyn Museum, Brooklyn, New York, on mannahatta2409.org/visionmaker, 15 November 2014

Stony Brook University, Stony Brook, New York, on Visionmaker for Jamaica Bay, 16 January 2015

NJ Assoc. of Landscape Architects, Atlantic City, NJ, on Mannahatta/Mannahatta2409.org, 27 January 2015

Science & Resilience Institute at Jamaica Bay, New York, on coastal resilience planning, 28 January 2015

WCS Teaching Academy, Bronx New York, webinar on mannahatta2409.org, 3 February 2015

Science & Resilience Institute at Jamaica Bay, New York, on Jamaica Bay history, 25 February 2015

SF Environment, San Francisco, CA, on SFB4/Visionmaker, 30 March 2015

TNC California, San Francisco, CA, on SFB4/Visionmaker, 31 March 2015

San Francisco Estuary Institute, Richmond, CA, on SFB4/Visionmaker SF, 1 April 2015

George Wright Society biennial meetings, Oakland, CA, on Visionmaker Jamaica Bay, 2 April 2015

CUNY Graduate Center, New York, on Visionmaker Jamaica Bay, May 7, 2015

University Consortium of GIScience, Alexandria, VA, on Visionmaker, 28 May 2015

Cary Institute for Ecosystem Studies, Millbrook, NY, on Mannahatta/Visionmaker, 27 June 2015

Public launch of Visionmaker.nyc, New York Aquarium, July 17, 2015

Fox5 television interview, Manhattan, NY, on New York City nature, July 29, 2015

New York City Department of City Planning, Manhattan, New York, on resiliency planning, August 3, 2015

Ecological Society of America, Baltimore, MD, Modelling biodiversity on the New York City urban fringe, August 14, 2016

NYU Capstone seminar, on Visionmaker, September 14 – December 14, 2015

Natural Areas Conservancy Advisory Board, Columbia Univ., Nature Goals 2050, September 17, 2015

MakerFaire, New York Hall of Science, Queens, NY, Visionmaker, September 25-27, 2015

CUNY Graduate Center seminar, Manhattan, NY, on Visionmaker, October 21, 2015

Rutgers University, special topics in ecology, evolution and natural resources seminar, October 21, 2015

Wood is Good Conference keynote, Bronx Zoo, on Bottleneck/Breakthrough, October 30, 2015

Brooklyn Historical Society-teacher education, Brooklyn Navy Yard, on Welikia, November 3, 2015

National Park Service Jamaica Bay projects review, CUNY Grad Center, November 5, 2015

New York chapter of the American Planning Association, Manhattan, NY, on Visionmaker, December 11, 2015

City Parks Foundation, Manhattan, NY, on Visionmaker, February 1, 2016

Urban Ecology Research Consortium keynote, Portland OR, on Mannahatta/Visionmaker, February 8, 2016

North American Wildlife and Natural Resources Conference, Pittsburgh, PA, keynote talk on cities and wildlife, including Visionmaker, March 15, 2016

New York City Department of City Planning, Bronx Zoo, presentation on Visionmaker, March 18, 2016

Island Press board meeting, Washington D.C., presentation on Visionmaker Jamaica Bay and walk through Washington, D.C., April 13, 2016

University of Maryland – College Park, seminar to geography department, on Visionmaker, April 14, 2016

Visionmaker Faire (high school students), Bronx Zoo, on Visionmaker, April 18, 2016

Nexus Impact Investing, Durst Organization, Manhattan, NY, on Visionmaker, April 27, 2016

WCS Leadership Meeting, Bronx Zoo, on Visionmaker, May 2, 2016

RPA Regional Assembly, Manhattan, NY, live demo of Visionmaker, May 6, 2016

Visionmaker Faire (middle school students), Bronx Zoo, on Visionmaker, May 9, 2016

WNYC radio interview, on historical ecology of Jamaica Bay, June 20, 2016

NY 1 (Queens) television interview, on historical ecology of Jamaica Bay, June 30, 2016

Ecological Society of America, Ft. Lauderdale, FL, on historical ecology and urban sustainability using Visionmaker, August 9, 2016

New York University, Environmental Studies capstone course about Visionmaker, September – December 2016

New York City Department of Education, Imagining the past and future of New York City, September 29, 2016

Rutgers University, special topics in ecology, evolution and natural resources seminar, October 21, 2016

Roosevelt House – City University of New York, book launch, including description of Visionmaker Jamaica Bay, November 18, 2016

Rutgers University, Central New Jersey GIS day seminar, November 16, 2016

Hunter College, City University of New York and NYCH2O, lecture about Jamaica Bay, December 9, 2016

Next Steps

The next steps with Visionmaker are to expand its use in and around Jamaica Bay. The National Park Service should use Visionmaker to evaluate and share its visions of the future of its properties, especially given sea level rise. Communities around Jamaica Bay can use the tool to promote and share their visions of their communities. These visions can be developed in classrooms, community meetings, or in private homes and gatherings. The tool can also be further developed to take into account dynamic flood modelling results, to better evaluate ecosystem services and their valuation in monetary terms, and to accommodate new kinds of ecosystems proposed for the bay, such as tidal flood gates and sea walls. Finally we see the possibility of building on the example of Jamaica Bay in the Gateway National Recreational Area to develop Visionmaker deployments for other urban National Park Service properties.

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Appendix 1. Ecosystem parameters for new ecosystems added to Visionmaker Jamaica Bay.

Note that some parameters may seem irrelevant to particular ecosystems (for example, air changes/hour for airfield), but for purposes of calculations all ecosystem-parameter pairs need to have a value. They are included here for completeness. Costs to build parameters, demolition cost parameters, and full references are available online at https://visionmaker.us/nyc/jamaicabay/ and https://www.zotero.org/groups/69043/mannahatta_2409.

Appendix 1 Table A. Ecosystem parameters for new ecosystems added to Visionmaker Jamaica Bay.

Ecosystem	Parameter	Value	Units	Location	Reference
Airfield	air changes per hour	0.000000	air changes / hour	New York City: Urban Area	Assumed
Airfield	construction multiplier	1.540000	unitless coefficient	USA:NYC: All	Barr (in prep.)
Airfield	cost to build	20.000000	$FL 2011 / ft^2	Florida: Airfield (2011)	Florida Department of Transportation 2011 Airport Costs
Airfield	demolition cost	4.350000	$NYC 2015 / ft^2	Upper West Side: Airfield (2015)	Homewyse 2015 Cost to Grade Lot
Airfield	demolition cost	9.699044	$CA 2012 / ft^2	Los Angeles: Airfield (2012)	LAWA 2012 Appendix G LAX Cost Estimates
Airfield	demolition multiplier	1.140000	unitless coefficient	USA: All	Northwest Economic Research Center (2016)
Airfield	electricity production rate density	0.000000	kWh / m^2 / yr	New York City: Urban Area	Assumed
Airfield	harvest rate density	0.000000	kg / m^2 / yr	New York City: Urban Area	Assumed
Airfield	herbivory rate density	0.000000	kg / m^2 / yr	New York City: Urban Area	Assumed
Airfield	impervious storage capacity	3.000000	mm	New York City: Urban Area	Assumed
Airfield	labor fraction cost to build	0.051000	proportion (0-1)	USA: Airfield	RSMeans Building Construction Cost Data 2014: Airfield

Ecosystem	Parameter	Value	Units	Location	Reference
Airfield	labor fraction cost to demolish	0.565000	proportion (0-1)	USA: Airfield	RSMeans Building Construction Cost Data 2014: Airfield
Airfield	litterfall biomass density	0.000000	kg / m^2	New York City: Urban Area	Assumed
Airfield	litterfall rate density	0.000000	g C / m^2 / year	New York City: Urban Area	Assumed
Airfield	net primary productivity	0.000000	g C / m^2 / year	New York City: Urban Area	Assumed
Airfield	open water depth	0.000000	mm	New York City: Urban Area	Assumed
Airfield	pervious (soil) storage capacity	0.000000	in / ft of depth	New York City: Urban Area	Assumed
Airfield	plant biomass density	0.000000	kg / m^2	New York City: Urban Area	Assumed
Airfield	proportion of impervious surface	100.000000	% proportion (0 - 100)	New York City: Urban Area	Assumed
Airfield	proportion of rainfall intercepted	0.000000	proportion (0-1)	New York City: Urban Area	Assumed
Airfield	soil organic carbon biomass density	0.000000	kg / m^2	New York City: Urban Area	Assumed
Airfield	soil respiration rate density	0.000000	g C / m^2 / year	New York City: Urban Area	Assumed
Airfield	steam production rate density	0.000000	kg steam / m^2 / yr	New York City: Urban Area	Assumed
Airfield	stormwater drainage capacity	0.850000	unitless coefficient	New York: urban landscape (2012)	NYC DEP 2012- Guidelines for the Design and Construction of Stormwater Management Systems
Airfield	stream drainage capacity	0.000000	mm	New York City: Urban Area	Assumed
Airfield	U factor of roof	0.000000	BTU / (h * deg F * ft^2)	New York City: Urban Area	Assumed
Airfield	U factor of walls	0.000000	BTU / (h * deg F * ft2)	New York City: Urban Area	Assumed
Airfield	wildlife biomass density	0.000000	kg / m^2	New York City: Urban Area	Assumed

Ecosystem	Parameter	Value	Units	Location	Reference
Airport terminal	air changes per hour	0.450000	air changes / hour	Global: airport terminals (2011)	Parker James et al. 2011 Using Building Simulation to Evaluate Low Carbon Refurbishment Options for Airport Buildings
Airport terminal	construction multiplier	1.540000	unitless coefficient	USA:NYC: All	Barr (in prep.)
Airport terminal	cost to build	250.000000	$FL 2011 / ft^2	Florida: Airport terminal (2011)	Florida Department of Transportation 2011 Airport Costs
Airport terminal	demolition cost	1.480000	$NYC 2015 / ft^2	New York City: Airport terminal (2015)	BuildingJournal.com 2015 Demolition Cost Calculator
Airport terminal	demolition cost	55.980000	$CT 2014 / ft^2	Connecticut: Airport terminal (2014)	The Airport News 2014 Bradley Terminal B Demolition
Airport terminal	demolition multiplier	1.140000	unitless coefficient	USA: All	Northwest Economic Research Center (2016)
Airport terminal	electricity production rate density	0.000000	kWh / m^2 / yr	New York City: Urban Area	Assumed
Airport terminal	harvest rate density	0.000000	kg / m^2 / yr	New York City: Urban Area	Assumed
Airport terminal	herbivory rate density	0.000000	kg / m^2 / yr	New York City: Urban Area	Assumed
Airport terminal	impervious storage capacity	3.000000	mm	New York City: Urban Area	Assumed
Airport terminal	labor fraction cost to build	0.528000	proportion (0-1)	USA: Airport terminal	RSMeans CostWorks CDRom Square Foot Costs 2016: Airport terminal
Airport terminal	labor fraction cost to demolish	0.436000	proportion (0-1)	USA: Airport terminal	RSMeans Building Construction Cost Data 2014: Airport terminal
Airport terminal	litterfall biomass density	0.000000	kg / m^2	New York City: Urban Area	Assumed
Airport terminal	litterfall rate density	0.000000	kg / m^2 / yr	New York City: Urban Area	Assumed
Airport terminal	net primary productivity	0.000000	g C / m^2 / year	New York City: Urban Area	Assumed

Ecosystem	Parameter	Value	Units	Location	Reference
Airport terminal	open water depth	0.000000	mm	New York City: Urban Area	Assumed
Airport terminal	pervious (soil) storage capacity	0.000000	mm	New York City: Urban Area	Assumed
Airport terminal	plant biomass density	0.000000	kg / m^2	New York City: Urban Area	Assumed
Airport terminal	proportion of impervious surface	100.000000	% proportion (0 - 100)	New York City: Urban Area	Assumed
Airport terminal	proportion of rainfall intercepted	0.000000	proportion (0-1)	New York City: Urban Area	Assumed
Airport terminal	soil organic carbon biomass density	0.000000	kg / m^2	New York City: Urban Area	Assumed
Airport terminal	soil respiration rate density	0.000000	kg C / m^2 / yr	New York City: Urban Area	Assumed
Airport terminal	steam production rate density	0.000000	kg steam / m^2 / yr	New York City: Urban Area	Assumed
Airport terminal	stormwater drainage capacity	0.950000	unitless coefficient	New York: urban landscape (2012)	NYC DEP 2012- Guidelines for the Design and Construction of Stormwater Management Systems
Airport terminal	stream drainage capacity	0.000000	mm	New York City: Urban Area	Assumed
Airport terminal	U factor of roof	0.500000	BTU / (h * deg F * ft2)	India: Airport terminal (2014)	GMR 2014 Emission reduction projects and infrastructures at IGIA
Airport terminal	U factor of walls	0.400000	BTU / (h * deg F * ft2)	Wisconsin: airport terminal (2015)	Dubbe Matt 2015 Performance Takes Off
Airport terminal	wildlife biomass density	0.000000	kg / m^2	New York City: Urban Area	Assumed
Bridge	air changes per hour	0.000000	air changes / hour	New York City: Urban Area	Assumed
Bridge	construction multiplier	1.540000	unitless coefficient	USA:NYC: All	Barr (in prep.)
Bridge	cost to build	152.500000	$FL 2014 / ft^2	Florida: Bridge (2014)	Florida Department of Transportation 2014 Bridge Costs

Ecosystem	Parameter	Value	Units	Location	Reference
Bridge	demolition cost	47.500000	$FL 2014 / ft^2	Florida: Bridge (2014)	Florida Department of Transportation 2014 Bridge Costs
Bridge	demolition multiplier	1.140000	unitless coefficient	USA: All	Northwest Economic Research Center (2016)
Bridge	electricity production rate density	0.000000	kWh / m^2 / yr	New York City: Urban Area	Assumed
Bridge	harvest rate density	0.000000	kg / m^2 / yr	New York City: Urban Area	Assumed
Bridge	herbivory rate density	0.000000	kg / m^2 / yr	New York City: Urban Area	Assumed
Bridge	impervious storage capacity	3.000000	mm	New York City: Urban Area	Assumed
Bridge	labor fraction cost to build	0.065000	proportion (0-1)	USA: Bridge	RSMeans Site Work & Landscape Cost Data 2014: Bridge
Bridge	labor fraction cost to demolish	0.546000	proportion (0-1)	USA: Bridge	RSMeans Site Work & Landscape Cost Data 2014: Bridge
Bridge	litterfall biomass density	0.000000	kg / m^2	New York City: Urban Area	Assumed
Bridge	litterfall rate density	0.000000	kg / m^2 / yr	New York City: Urban Area	Assumed
Bridge	net primary productivity	0.000000	g C / m^2 / year	New York City: Urban Area	Assumed
Bridge	open water depth	0.000000	mm	New York City: Urban Area	Assumed
Bridge	pervious (soil) storage capacity	0.000000	mm	New York City: Urban Area	Assumed
Bridge	plant biomass density	0.000000	kg / m^2	New York City: Urban Area	Assumed
Bridge	proportion of impervious surface	100.000000	% proportion (0 - 100)	New York City: Urban Area	Assumed
Bridge	proportion of rainfall intercepted	0.000000	proportion (0-1)	New York City: Urban Area	Assumed
Bridge	soil organic carbon biomass density	0.000000	kg / m^2	New York City: Urban Area	Assumed

Ecosystem	Parameter	Value	Units	Location	Reference
Bridge	soil respiration rate density	0.000000	kg C / m^2 / yr	New York City: Urban Area	Assumed
Bridge	steam production rate density	0.000000	kg steam / m^2 / yr	New York City: Urban Area	Assumed
Bridge	stormwater drainage capacity	0.850000	unitless coefficient	New York: urban landscape (2012)	NYC DEP 2012- Guidelines for the Design and Construction of Stormwater Management Systems
Bridge	stream drainage capacity	0.000000	mm	New York City: Urban Area	Assumed
Bridge	U factor of roof	0.000000	BTU / (h * deg F * ft2)	New York City: Urban Area	Assumed
Bridge	U factor of walls	0.000000	BTU / (h * deg F * ft2)	New York City: Urban Area	Assumed
Bridge	wildlife biomass density	0.000000	kg / m^2	New York City: Urban Area	Assumed
Deep water estuary	air changes per hour	0.000000	air changes / hour	New York City: Urban Area	Assumed
Deep water estuary	construction multiplier	1.540000	unitless coefficient	USA:NYC: All	Barr (in prep.)
Deep water estuary	cost to build	442000.000000	$US 2003 / acre	USA: Deep water Estuary (2003)	Evergreen Funding Consultants 2003 estuary:A Primer on Habitat Project Costs
Deep water estuary	demolition cost	24.120000	$NYC 2015 / ft^2	Ohio: Deep water estuary (2015)	Weidle Corp. 2015 Sand Price List
Deep water estuary	demolition multiplier	1.140000	unitless coefficient	USA: All	Northwest Economic Research Center (2016)
Deep water estuary	electricity production rate density	0.000000	kWh / m^2 / yr	New York City: Mannahatta	Assumed
Deep water estuary	harvest rate density	0.000000	kg / m^2 / yr	New York City: Mannahatta	Assumed
Deep water estuary	herbivory rate density	11.940000	g C / m^2 / year	Global: deepwater estuary (2015)	NOAA 2015 Data compilations for primary production herbivory decomposition and export for different types of marine communities 1962-2002 (NODC Accession 0054500)

Ecosystem	Parameter	Value	Units	Location	Reference
Deep water estuary	impervious storage capacity	0.000000	mm	New York City: Urban Area	Assumed
Deep water estuary	labor fraction cost to build	0.215000	proportion (0-1)	USA: Deep water estuary	RSMeans Site Work & Landscape Cost Data 2014: Deep water estuary
Deep water estuary	labor fraction cost to demolish	0.170000	proportion (0-1)	USA: Deep water Estuary	RSMeans Building Construction Cost Data 2014: Deep water Estuary
Deep water estuary	litterfall biomass density	0.000000	kg / m^2	New York City: Urban Area	Assumed
Deep water estuary	litterfall biomass density	0.103000	g / m^2	Global: deepwater estuary (2015)	NOAA 2015 Data compilations for primary production herbivory decomposition and export for different types of marine communities 1962-2002 (NODC Accession 0054500)
Deep water estuary	litterfall rate density	37.661000	g C / m^2 / year	Global: deepwater estuary (2015)	NOAA 2015 Data compilations for primary production herbivory decomposition and export for different types of marine communities 1962-2002 (NODC Accession 0054500)
Deep water estuary	net primary productivity	125.000000	g C / m^2 / year	Global: deep water estuary (2011)	Kirchman David L. 2011 Processes in Microbial Ecology- Ch. 4 Microbial primary production and phototrophy
Deep water estuary	open water depth	10740.000000	mm	New York City: Mannahatta	Assumed
Deep water estuary	pervious (soil) storage capacity	1000.000000	mm	New York City: Urban Area	Assumed
Deep water estuary	plant biomass density	0.000000	g / m^2	New York City: Urban Area	Assumed
Deep water estuary	proportion of impervious surface	0.000000	% proportion (0 - 100)	New York City: Mannahatta	Assumed
Deep water estuary	proportion of rainfall intercepted	0.000000	proportion (0-1)	New York City: Mannahatta	Assumed
Deep water estuary	soil organic carbon biomass density	0.002900	g / m^2	Mixed hardwood site: Hardwood swamp (1977)	Day 1979 Litter accumulation...Dismal Swamp VA

Ecosystem	Parameter	Value	Units	Location	Reference
Deep water estuary	soil respiration rate density	0.240000	Âµmol / m^2 / s	Yellow River Estuary China: Estuary (November 2009)	Luo & Xing 2010 - Comparative Study on Characteristics and Influencing Factors of Soil Respiration
Deep water estuary	steam production rate density	0.000000	kg steam / m^2 / yr	New York City: Urban Area	Assumed
Deep water estuary	stormwater drainage capacity	0.000000	mm	New York City: Urban Area	Assumed
Deep water estuary	stream drainage capacity	0.000000	mm	New York City: Urban Area	Assumed
Deep water estuary	U factor of roof	0.000000	BTU / (h * deg F * ft2)	New York City: Mannahatta	Assumed
Deep water estuary	U factor of walls	0.000000	BTU / (h * deg F * ft2)	New York City: Mannahatta	Assumed
Deep water estuary	wildlife biomass density	1.760000	g / m^2	Global: deepwater estuary (2015)	NOAA 2015 Data compilations for primary production herbivory decomposition and export for different types of marine communities 1962-2002 (NODC Accession 0054500)
Estuary	air changes per hour	0.000000	air changes / hour	New York City: Urban Area	Assumed
Estuary	construction multiplier	1.54	unitless coefficient	USA:NYC: All	Barr (in prep.)
Estuary	cost to build	300000	$US 2003 / acre	US: Estuary (2003)	Evergreen Funding Consultants 2003 estuary:A Primer on Habitat Project Costs
Estuary	demolition cost	14.16	$NYC 2015 / ft^2	Ohio: Estuary (2015)	Weidle Corp. 2015 Sand Price List
Estuary	demolition multiplier	1.14	unitless coefficient	USA: All	Northwest Economic Research Center (2016)
Estuary	electricity production rate density	0.000000	kWh / m^2 / yr	New York City: Mannahatta	Assumed
Estuary	harvest rate density	0.000000	kg / m^2 / yr	New York City: Mannahatta	Assumed

Ecosystem	Parameter	Value	Units	Location	Reference
Estuary	herbivory rate density	2075.76	g C / m^2 / year	Global: deepwater estuary (2015)	NOAA 2015 Data compilations for primary production herbivory decomposition and export for different types of marine communities 1962-2002 (NODC Accession 0054500)
Estuary	impervious storage capacity	0.000000	mm	New York City: Urban Area	Assumed
Estuary	labor fraction cost to build	0.215	proportion (0-1)	USA: Estuary	RSMeans Site Work & Landscape Cost Data 2014: Estuary
Estuary	labor fraction cost to demolish	0.188	proportion (0-1)	USA: Estuary	RSMeans Building Construction Cost Data 2014: Estuary
Estuary	litterfall biomass density	3	mg C / liter	New York City Harbor: Estuary (1999 - 2001)	Kirchman et al. 2004 Changes in bacterial activity and composition ... to dissolved organic matter in the Hudson River New York
Estuary	litterfall rate density	650	g C / m^2 / year	Hudson River Estuary: estuary	Findlay 2011 Primary production ... Hudson [River Estuary]
Estuary	net primary productivity	270	g / m^2 / year	Lower Hudson River Estuary: Estuary	Howarth et al. 2006 - Wastewater and Watershed Influences etc.
Estuary	net primary productivity	121839.1	mol C / m^2 / year	Haverstraw Bay ("HB"): Estuary (1996 -1998)	Taylor et al. 2003 - Planktonic Carbon Cycling and Transport etc.
Estuary	open water depth	5000	mm	New York City: Mannahatta	Assumed
Estuary	pervious (soil) storage capacity	1000	mm	New York City: Urban Area	Assumed
Estuary	plant biomass density	0.000000	g / m^2	New York City: Urban Area	Assumed
Estuary	proportion of impervious surface	0.000000	% proportion (0 - 100)	New York City: Mannahatta	Assumed
Estuary	proportion of rainfall intercepted	0.000000	proportion (0-1)	New York City: Mannahatta	Assumed
Estuary	soil organic carbon biomass density	0.002900	g / m^2	Mixed hardwood site: Hardwood swamp (1977)	Day 1979 Litter accumulation...Dismal Swamp VA

Ecosystem	Parameter	Value	Units	Location	Reference
Estuary	soil respiration rate density	1.060000	µmol / m^2 / s	Yellow River Estuary China: Estuary (May 2009)	Luo & Xing 2010 - Comparative Study on Characteristics and Influencing Factors of Soil Respiration
Estuary	soil respiration rate density	0.240000	µmol / m^2 / s	Yellow River Estuary China: Estuary (November 2009)	Luo & Xing 2010 - Comparative Study on Characteristics and Influencing Factors of Soil Respiration
Estuary	soil respiration rate density	0.065000	µmol / m^2 / s	Liaohe River Estuary China: Estuary (May 2009)	Luo & Xing 2010 - Comparative Study on Characteristics and Influencing Factors of Soil Respiration
Estuary	soil respiration rate density	0.110000	µmol / m^2 / s	Liaohe River Estuary China: Estuary (November 2009)	Luo & Xing 2010 - Comparative Study on Characteristics and Influencing Factors of Soil Respiration
Estuary	steam production rate density	0.000000	kg steam / m^2 / yr	New York City: Urban Area	Assumed
Estuary	stormwater drainage capacity	0.000000	mm	New York City: Urban Area	Assumed
Estuary	stream drainage capacity	0.000000	mm	New York City: Urban Area	Assumed
Estuary	U factor of roof	0.000000	BTU / (h * deg F * ft2)	New York City: Mannahatta	Assumed
Estuary	U factor of walls	0.000000	BTU / (h * deg F * ft2)	New York City: Mannahatta	Assumed
Estuary	wildlife biomass density	0.000000	kg / m^2	New York City: Mannahatta	Assumed
Fuel storage tank	air changes per hour	0.000000	air changes / hour	New York City: Urban Area	Assumed
Fuel storage tank	construction multiplier	1.540000	unitless coefficient	USA:NYC: All	Barr (in prep.)
Fuel storage tank	cost to build	401.810000	$FL 2011 / ft^2	Florida: Fuel storage tank (2011)	Florida Department of Transportation 2011 Airport Costs
Fuel storage tank	demolition cost	0.920000	$NYC 2015 / ft^2	New York City: Fuel storage tank (2015)	BuildingJournal.com 2015 Demolition Cost Calculator
Fuel storage tank	demolition multiplier	1.140000	unitless coefficient	USA: All	Northwest Economic Research Center (2016)

Ecosystem	Parameter	Value	Units	Location	Reference
Fuel storage tank	electricity production rate density	0.000000	kWh / m^2 / yr	New York City: Urban Area	Assumed
Fuel storage tank	harvest rate density	0.000000	kg / m^2 / yr	New York City: Urban Area	Assumed
Fuel storage tank	herbivory rate density	0.000000	kg / m^2 / yr	New York City: Urban Area	Assumed
Fuel storage tank	impervious storage capacity	0.000000	mm	New York City: Urban Area	Assumed
Fuel storage tank	labor fraction cost to build	0.131000	proportion (0-1)	USA: Fuel storage tank	RSMeans Building Construction Cost Data 2014: Fuel storage tank
Fuel storage tank	labor fraction cost to demolish	0.894000	proportion (0-1)	USA: Fuel storage tank	RSMeans Building Construction Cost Data 2014: Fuel storage tank
Fuel storage tank	litterfall biomass density	0.000000	kg / m^2	New York City: Urban Area	Assumed
Fuel storage tank	litterfall rate density	0.000000	kg / m^2 / yr	New York City: Urban Area	Assumed
Fuel storage tank	net primary productivity	0.000000	g C / m^2 / year	New York City: Urban Area	Assumed
Fuel storage tank	open water depth	0.000000	mm	New York City: Urban Area	Assumed
Fuel storage tank	pervious (soil) storage capacity	0.000000	mm	New York City: Urban Area	Assumed
Fuel storage tank	plant biomass density	0.000000	kg / m^2	New York City: Urban Area	Assumed
Fuel storage tank	proportion of impervious surface	100.000000	% proportion (0 - 100)	New York City: Urban Area	Assumed
Fuel storage tank	proportion of rainfall intercepted	0.000000	proportion (0-1)	New York City: Urban Area	Assumed
Fuel storage tank	soil organic carbon biomass density	0.000000	kg / m^2	New York City: Urban Area	Assumed
Fuel storage tank	soil respiration rate density	0.000000	kg C / m^2 / yr	New York City: Urban Area	Assumed

Ecosystem	Parameter	Value	Units	Location	Reference
Fuel storage tank	steam production rate density	0.000000	kg steam / m^2 / yr	New York City: Urban Area	Assumed
Fuel storage tank	stormwater drainage capacity	0.950000	unitless coefficient	New York: urban landscape (2012)	NYC DEP 2012- Guidelines for the Design and Construction of Stormwater Management Systems
Fuel storage tank	stream drainage capacity	0.000000	mm	New York City: Urban Area	Assumed
Fuel storage tank	U factor of roof	0.000000	BTU / (h * deg F * ft2)	New York City: Urban Area	Assumed
Fuel storage tank	U factor of walls	0.000000	BTU / (h * deg F * ft2)	New York City: Urban Area	Assumed
Fuel storage tank	wildlife biomass density	0.000000	kg / m^2	New York City: Urban Area	Assumed
High salt marsh	air changes per hour	0.000000	air changes / hour	New York City: Urban Area	Assumed
High salt marsh	construction multiplier	1.540000	unitless coefficient	USA:NYC: All	Barr (in prep.)
High salt marsh	cost to build	16115.000000	$US 2001 / acre	USA: Salt Marsh (2001)	Habitat Restoration The Costs of Environmental Restoration Projects
High salt marsh	demolition cost	6.680000	$NYC 2015 / ft^2	Ohio: High salt marsh (2015)	Weidle Corp. 2015 Sand Price List
High salt marsh	demolition multiplier	1.140000	unitless coefficient	USA: All	Northwest Economic Research Center (2016)
High salt marsh	electricity production rate density	0.000000	kWh / m^2 / yr	New York City: Mannahatta	Assumed
High salt marsh	harvest rate density	0.000000	kg / m^2 / yr	New York City: Mannahatta	Assumed
High salt marsh	herbivory rate density	1.666000	g C / m^2 / year	SW Netherlands Lake Grevelingen: Lagoon (May 1978-May 1979)	Nienhuis & Groenendijk 1986 - Consumption of eelgrass (Zostera marina) by birds and invertebrates: an annual budget

Ecosystem	Parameter	Value	Units	Location	Reference
High salt marsh	impervious storage capacity	0.000000	mm	New York City: Urban Area	Assumed
High salt marsh	labor fraction cost to build	0.600000	proportion (0-1)	USA: High salt marsh	The cost of wetland creation and restoration
High salt marsh	labor fraction cost to demolish	0.601000	proportion (0-1)	USA: High salt marsh	RSMeans Building Construction Cost Data 2014: High salt marsh
High salt marsh	litterfall biomass density	462.000000	g / m^2	Delaware US: Salt marsh	Long Mason 1983 - Saltmarsh Ecology
High salt marsh	litterfall rate density	322.000000	g / m^2 / year	ÃƒÅ½le Verte Quebec Canada: salt marsh (2008)	Yu & Chmura 2010- Soil carbon may be maintained under grazing in a St Lawrence Estuary tidal marsh
High salt marsh	net primary productivity	1790.000000	g / m^2 / year	New York: Salt marsh	Long Mason 1983 - Saltmarsh Ecology
High salt marsh	open water depth	390.140000	mm	England: low and high salt marsh (1939)	Chapman V.J. 1939 Studies in salt-marsh ecology sections I to III
High salt marsh	pervious (soil) storage capacity	0.070000	in / in depth	New York City: Salt Marsh	NYC Soil Survey Staff 2005. NYC Reconnaissance Soil Survey
High salt marsh	plant biomass density	209.000000	g / m^2	Massachusetts U.S.A.: Salt marsh	Long Mason 1983 - Saltmarsh Ecology
High salt marsh	proportion of impervious surface	0.000000	% proportion (0 - 100)	New York City: Mannahatta	Assumed
High salt marsh	proportion of rainfall intercepted	18.100000	% proportion (0 - 100)	Edwards Plateau TX: Midgrass (1984)	Thurow et al. 1987 Rainfall interception by midgrass shortgrass and live oak mottes
High salt marsh	soil organic carbon biomass density	240.000000	g C / m^2 / year	United States: salt marsh (2007)	Craft Christopher 2007 Freshwater input structures soil properties vertical accretion and nutrient accumulation of Georgia and U.S. tidal marshes
High salt marsh	soil respiration rate density	4.390000	Âµmol / m^2 / s	New England: low/high salt marsh (2009)	Wigand Cathleen et al. 2009 Soil respiration rates in coastal marshes subject to increasing watershed nitrogen loads in southern New England USA
High salt marsh	steam production rate density	0.000000	kg steam / m^2 / yr	New York City: Urban Area	Assumed

Ecosystem	Parameter	Value	Units	Location	Reference
High salt marsh	stormwater drainage capacity	0.000000	mm	New York City: Mannahatta	Assumed
High salt marsh	stream drainage capacity	0.000000	mm	New York City: Urban Area	Assumed
High salt marsh	U factor of roof	0.000000	BTU / (h * deg F * ft2)	New York City: Mannahatta	Assumed
High salt marsh	U factor of walls	0.000000	BTU / (h * deg F * ft2)	New York City: Mannahatta	Assumed
High salt marsh	wildlife biomass density	32.000000	g / m^2	Sapelo Island Georgia: Salt marsh (late 1950s - early 1960s)	Teal 1962 Energy Flow in the Salt Marsh Ecosystem of Georgia
Low salt marsh	air changes per hour	0.000000	air changes / hour	New York City: Urban Area	Assumed
Low salt marsh	construction multiplier	1.540000	unitless coefficient	USA:NYC: All	Barr (in prep.)
Low salt marsh	cost to build	16115.000000	$US 2001 / acre	USA: Salt Marsh (2001)	Habitat Restoration The Costs of Environmental Restoration Projects
Low salt marsh	demolition cost	6.680000	$NYC 2015 / ft^2	Ohio: Low salt marsh (2015)	Weidle Corp. 2015 Sand Price List
Low salt marsh	demolition multiplier	1.140000	unitless coefficient	USA: All	Northwest Economic Research Center (2016)
Low salt marsh	electricity production rate density	0.000000	kWh / m^2 / yr	New York City: Mannahatta	Assumed
Low salt marsh	harvest rate density	0.000000	kg / m^2 / yr	New York City: Mannahatta	Assumed
Low salt marsh	herbivory rate density	1.666000	g C / m^2 / year	SW Netherlands Lake Grevelingen: Lagoon (May 1978-May 1979)	Nienhuis & Groenendijk 1986 - Consumption of eelgrass (Zostera marina) by birds and invertebrates: an annual budget
Low salt marsh	impervious storage capacity	0.000000	mm	New York City: Urban Area	Assumed

Ecosystem	Parameter	Value	Units	Location	Reference
Low salt marsh	labor fraction cost to build	0.600000	proportion (0-1)	USA: Low salt marsh	The cost of wetland creation and restoration
Low salt marsh	labor fraction cost to demolish	0.836000	proportion (0-1)	USA: Low salt marsh	RSMeans Building Construction Cost Data 2014:Low salt marsh
Low salt marsh	litterfall biomass density	462.000000	g / m^2	Delaware US: Salt marsh	Long Mason 1983 - Saltmarsh Ecology
Low salt marsh	litterfall rate density	322.000000	g / m^2 / year	ÃƒÅ½le Verte Quebec Canada: salt marsh (2008)	Yu & Chmura 2010- Soil carbon may be maintained under grazing in a St Lawrence Estuary tidal marsh
Low salt marsh	net primary productivity	1790.000000	g / m^2 / year	New York: Salt marsh	Long Mason 1983 - Saltmarsh Ecology
Low salt marsh	open water depth	1063.750000	mm	England: low and high salt marsh (1939)	Chapman V.J. 1939 Studies in salt-marsh ecology sections I to III
Low salt marsh	pervious (soil) storage capacity	0.070000	in / in depth	New York City: Salt Marsh	NYC Soil Survey Staff 2005. NYC Reconnaissance Soil Survey
Low salt marsh	plant biomass density	209.000000	g / m^2	Massachusetts U.S.A.: Salt marsh	Long Mason 1983 - Saltmarsh Ecology
Low salt marsh	proportion of impervious surface	0.000000	% proportion (0 - 100)	New York City: Mannahatta	Assumed
Low salt marsh	proportion of rainfall intercepted	18.100000	% proportion (0 - 100)	Edwards Plateau TX: Midgrass (1984)	Thurow et al. 1987 Rainfall interception by midgrass shortgrass and live oak mottes
Low salt marsh	soil organic carbon biomass density	190.000000	g C / m^2 / year	United States: salt marsh (2007)	Craft Christopher 2007 Freshwater input structures soil properties vertical accretion and nutrient accumulation of Georgia and U.S. tidal marshes
Low salt marsh	soil respiration rate density	1.920000	Âµmol / m^2 / s	New England: low/high salt marsh (2009)	Wigand Cathleen et al. 2009 Soil respiration rates in coastal marshes subject to increasing watershed nitrogen loads in southern New England USA
Low salt marsh	steam production rate density	0.000000	kg steam / m^2 / yr	New York City: Urban Area	Assumed
Low salt marsh	stormwater drainage capacity	0.000000	mm	New York City: Mannahatta	Assumed

Ecosystem	Parameter	Value	Units	Location	Reference
Low salt marsh	stream drainage capacity	0.000000	mm	New York City: Urban Area	Assumed
Low salt marsh	U factor of roof	0.000000	BTU / (h * deg F * ft2)	New York City: Mannahatta	Assumed
Low salt marsh	U factor of walls	0.000000	BTU / (h * deg F * ft2)	New York City: Mannahatta	Assumed
Low salt marsh	wildlife biomass density	32.000000	g / m^2	Sapelo Island Georgia: Salt marsh (late 1950s - early 1960s)	Teal 1962 Energy Flow in the Salt Marsh Ecosystem of Georgia
Pedestrian bridge	air changes per hour	0.000000	air changes / hour	New York City: Urban Area	Assumed
Pedestrian bridge	construction multiplier	1.540000	unitless coefficient	USA:NYC: All	Barr (in prep.)
Pedestrian bridge	cost to build	137.500000	$FL 2014 / ft^2	Florida: Pedestrian bridge (2014)	Florida Department of Transportation 2014 Bridge Costs
Pedestrian bridge	demolition cost	35.000000	$FL 2014 / ft^2	Florida: Pedestrian bridge (2014)	Florida Department of Transportation 2014 Bridge Costs
Pedestrian bridge	demolition multiplier	1.140000	unitless coefficient	USA: All	Northwest Economic Research Center (2016)
Pedestrian bridge	electricity production rate density	0.000000	kWh / m^2 / yr	New York City: Urban Area	Assumed
Pedestrian bridge	harvest rate density	0.000000	kg / m^2 / yr	New York City: Urban Area	Assumed
Pedestrian bridge	herbivory rate density	0.000000	kg / m^2 / yr	New York City: Urban Area	Assumed
Pedestrian bridge	impervious storage capacity	3.000000	mm	New York City: Urban Area	Assumed
Pedestrian bridge	labor fraction cost to build	0.068000	proportion (0-1)	USA: Pedestrian bridge	RSMeans Building Construction Cost Data 2014: Pedestrian bridge
Pedestrian bridge	labor fraction cost to demolish	0.546000	proportion (0-1)	USA: Pedestrian bridge	RSMeans Site Work & Landscape Cost Data 2014: Pedestrian bridge

Ecosystem	Parameter	Value	Units	Location	Reference
Pedestrian bridge	litterfall biomass density	0.000000	kg / m^2	New York City: Urban Area	Assumed
Pedestrian bridge	litterfall rate density	0.000000	g C / m^2 / year	New York City: Urban Area	Assumed
Pedestrian bridge	net primary productivity	0.000000	g C / m^2 / year	New York City: Urban Area	Assumed
Pedestrian bridge	open water depth	0.000000	mm	New York City: Urban Area	Assumed
Pedestrian bridge	pervious (soil) storage capacity	0.000000	in / ft of depth	New York City: Urban Area	Assumed
Pedestrian bridge	plant biomass density	0.000000	kg / m^2	New York City: Urban Area	Assumed
Pedestrian bridge	proportion of impervious surface	100.000000	% proportion (0 - 100)	New York City: Urban Area	Assumed
Pedestrian bridge	proportion of rainfall intercepted	0.000000	proportion (0-1)	New York City: Urban Area	Assumed
Pedestrian bridge	soil organic carbon biomass density	0.000000	kg / m^2	New York City: Mannahatta	Assumed
Pedestrian bridge	soil respiration rate density	0.000000	kg C / m^2 / yr	New York City: Urban Area	Assumed
Pedestrian bridge	steam production rate density	0.000000	kg steam / m^2 / yr	New York City: Urban Area	Assumed
Pedestrian bridge	stormwater drainage capacity	0.850000	unitless coefficient	New York: urban landscape (2012)	NYC DEP 2012- Guidelines for the Design and Construction of Stormwater Management Systems
Pedestrian bridge	stream drainage capacity	0.000000	mm	New York City: Urban Area	Assumed
Pedestrian bridge	U factor of roof	0.000000	BTU / (h * deg F * ft2)	New York City: Urban Area	Assumed
Pedestrian bridge	U factor of walls	0.000000	BTU / (h * deg F * ft2)	New York City: Urban Area	Assumed

Ecosystem	Parameter	Value	Units	Location	Reference
Pedestrian bridge	wildlife biomass density	0.000000	kg / ha	New York City: Urban Area	Assumed

Appendix 2. Costs to build parameters incorporated in Visionmaker Jamaica Bay.

Full references are available online at https://visionmaker.us/nyc/jamaicabay/ and www.zotero.org/groups/mannahatta_2409

Apendix 2 Table A. Costs to build parameters incorporated in Visionmaker Jamaica Bay.

Ecosystem	Value	Units	Location	Reference
Trail	1.330000	$PA 2005 / ft^2	Pennsylvania: Trail (2005)	Chester County Board of Commissioners 2007 Trail & Path Planning: A Guide for Municipalities
Photovoltaic panels	7.794000	$US 2013 / ft^2	USA: Photovoltaic Panels (2013)	NREL 2013 Distributed Generation Renewable Energy Estimate of Costs
Solar heating panels	141.000000	$US 2013 / ft^2	USA: Solar Heating Panels (2013)	NREL 2013 Distributed Generation Renewable Energy Estimate of Costs
Freshwater marsh	16115.000000	$US 2001 / acre	USA: Salt Marsh (2001)	Habitat Restoration The Costs of Environmental Restoration Projects
Street trees	0.380000	$NYC 2015 / ft^2	New York City: Street trees (2015)	NYC Parks Dept. 2015 Tree Fund
Cliffs and rock outcrops	36.110000	$US 2008 / ft^2	United States: Cliffs and rock outcrops (2008)	Rockwerx 2008 Rock Wall FAQ
Shrub land	1010.930000	$US 2015 / acre	Connecticut: Shrub land (2015)	Department of energy and environmental protection 2014 Connecticuts Young Forest and Shrubland Initiative
School or university	189.600000	$US 2014 / ft^2	United States: School or university (2014)	RSMeans 2013 Square Foot Costs
Mixed use: retail / office building	183.000000	$US 2014 / ft^2	United States: Mixed use: retail / office building (2014)	RSMeans 2013 Square Foot Costs
Hardwood swamp	6630.000000	$US 2015 / acre	Michigan: Hardwood swamp (2014)	Michigan State University 2014 Michigan's Natural Communities: Northern Hardwood Swamp
Orchard	0.098324	$CA 2001 / ft^2	CA: Orchard (2001)	Caprile et al. 2001 Sample Costs to Establish an Apple Orchard
Single family home	127.350000	$US 2014 / ft^2	United States: Single family home (2014)	RSMeans 2013 Square Foot Costs

Ecosystem	Value	Units	Location	Reference
Hotel	204.700000	$US 2014 / ft^2	United States: Hotel (2014)	RSMeans 2013 Square Foot Costs
Light rail line	40000000.000000	$US 2006 / mile of railway	USA: Light rail line (2006)	reconnectingamerica 2006 Transit Technologies Worksheet
Estuary	300000.000000	$US 2003 / acre	US: Estuary (2003)	Evergreen Funding Consultants 2003 estuary:A Primer on Habitat Project Costs
Pond	23200.000000	$US 1997 / acre	USA: Pond (2014)	EPA 2014 Pond cost
Water treatment plant	1452380.950000	$AK 2008 / acre	Arkansas: Waste Treatment Plant (2008)	McGood Williams & Yates 2008 Wastewater treatment
Graywater recycling	3.970000	$CA 2014 / ft^2	CALIFORNIA: Graywater recycling (2014)	Univ. of California 2014 Cost-Benefit Analysis of Onsite Residential Graywater Recycling
Lawn	0.750000	$US 2015 / ft^2	US: Lawn (2015)	Landscaping network 2015 Cost of Lawn and Artificial Turf
Sewage treatment plant	1452380.950000	$AK 2008 / acre	Arkansas: Waste Treatment Plant (2008)	McGood Williams & Yates 2008 Wastewater treatment
Waste energy power plant	6347345.460000	$OK 2013 / acre	Oklahoma: Waste Energy Power Plant (2013)	EIA 2013 Capital Cost for Electricity Plants
Tidal energy facility	1428571.430000	$NYC 2012 / acre	NYC: Tidal energy facility (2012)	FERC 2012 ISSUING PILOT PROJECT LICENSE
Utility yard	3.110000	$NYC 2015 / ft^2	New York City: Utility yard (2015)	BuildingJournal.com 2015 Asphalt Driveway Calculator
Airfield	20.000000	$FL 2011 / ft^2	Florida: Airfield (2011)	Florida Department of Transportation 2011 Airport Costs
Greenhouse / vertical farm	19.000000	$US 2011 / ft^2	USA: Green house (2011)	University of Kentucky 2011 Greenhouses and Similar Structures an Overview
Eelgrass meadow	45000.000000	$US 2001 / acre	USA: Eelgrass meadow (2001)	Habitat Restoration The Costs of Environmental Restoration Projects
Green roof	17.500000	$US 2013 / ft^2	USA: Green Roof (2013)	EPA 2013 Green Roofs
Streetcar line	17500000.000000	$US 2006 / mile of railway	US: Streetcar line (2006)	Reconnectingamerica 2006 Transit Technologies Worksheet

Ecosystem	Value	Units	Location	Reference
Compost bin	65.000000	$NYC 2014 / compost bin	NYC: Compost Bin (2014)	NYC Compost project 2014 Low-Cost Composting Equipment
Beach	5.000000	$NYC 2015 / ft^2	OHIO: Beach (2015)	Weidle Corp. 2015 Sand Price List
Geothermal pump	9.000000	$US 2008 / ft^2	US: Geothermal pump (2008)	Energy Environmental: solargeothermal radiant wind 2008 Installation
Bioswale	0.500000	$US 2005 / ft^2	USA: Bioswale (2004)	Clark et al. 2008 Florida Field Guide to Low Impact Development
Oak hickory forest	102838.670000	$US 2015 / acre	Michigan: oak- hickory forest types (2013)	Michigan State University 2013 oak hickory forest types
Disturbed Land	4.200000	$NYC 2015 / ft^2	Upper West Side: Disturbed land (2015)	Homewyse 2015 Cost to Grade Lot
Office building	183.000000	$US 2014 / ft^2	United States: Office building (2014)	RSMeans 2013 Square Foot Costs
Apartment building	230.450000	$US 2014 / ft^2	United States: Apartment building (2014)	RSMeans 2013 Square Foot Costs
Retail building	144.600000	$US 2014 / ft^2	United States: Retail building (2014)	RSMeans 2013 Square Foot Costs
Cottages / Mobile home	38.360000	$US 2013 / ft^2	United States: Cottages / Mobile home (2013)	U.S. Census Bureau 2014 Manufactured Homes Survey
Hospital	340.800000	$US 2014 / ft^2	United States: Hospital (2014)	RSMeans 2013 Square Foot Costs
Computer data center	305.100000	$US 2014 / ft^2	United States: Computer data center (2014)	RSMeans 2013 Square Foot Costs
Stadium	471.920000	$TX 2014 / ft^2	Texas: Stadium (2014)	University of Nevada 2014 Review of Stadium Tours Estimated Building Costs
Stream	246.000000	$NC 2008 / lf	North Carolina: Stream (2008)	Estimation and Analysis of Expenses of Design-Bid-Build Projects for Stream Mitigation in North Carolina
Bike lane	10.060000	$US 2013 / ft^2	USA: Bike Lane (2013)	Bushell et al. 2013 Costs for Pedestrian and Bicyclist Infrastructure Improvements

Ecosystem	Value	Units	Location	Reference
Meadow	2777.777778	$NV 2012 / acre	Nevada: Meadow (2012)	Stillwater Sciences 2012 An Economic Analysis of Sierra Meadow Restoration
Derelict structures	108.000000	$US 2014 / ft^2	United States: Warehouse (2014)	RSMeans 2013 Square Foot Costs
Hemlock northern hardwood forest	21360.500000	$US 2015 / acre	US: Hemlock-northern hardwood forest (2015)	New York Natural Heritage Program 2015 Hemlock-Northern Hardwood Forest
Parking lot	3.110000	$NYC 2015 / ft^2	New York City: Parking lot (2015)	BuildingJournal.com 2015 Asphalt Driveway Calculator
Factory	135.300000	$US 2014 / ft^2	United States: Factory (2014)	RSMeans 2013 Square Foot Costs
Mixed use: retail / residential building	230.450000	$US 2014 / ft^2	United States: Mixed use: retail / residential building (2014)	RSMeans 2013 Square Foot Costs
Mixed use: office / residential building	202.950000	$US 2014 / ft^2	United States: Mixed use: office / residential building (2014)	RSMeans 2013 Square Foot Costs
Public assembly hall	184.900000	$US 2014 / ft^2	United States: Public assembly hall (2014)	RSMeans 2013 Square Foot Costs
Street (collector)	5069743.000000	$FL 2014 / mile	Florida: Street (2015)	Florida Department of Transportation 2015 Transportation Costs
Swimming pool	180.000000	$US 2010 / ft^2	United States: Swimming pool (2010)	USA Swimming 2010 25 yard compared to 50 meter
Paved ball field/court	5.680000	$CA 2003 / ft^2	COLORADO: Park (2003)	RPI Consulting inc. 2003 STATE OF COLORADO Small Community Park & Recreation Planning Standards
Cemetery	0.750000	$US 2015 / ft^2	US: Lawn (2015)	landscaping network 2015 Cost of Lawn and Artificial Turf
Camp	0.750000	$US 2015 / ft^2	USA: Camp (2015)	landscaping network 2015 Cost of Lawn and Artificial Turf
Cistern / rain barrels	87.500000	$CT 2009 / unit	Connecticut: Cistern/Rain Barrels (2009)	Connecticut Department of Energy and Environmental Protection 2009 Rain Barrels: Rainfall as a Resource
Elevated train	888.510000	$NYC 1991 / mile of elevated train	NYC: Elevated Train (1991)	San JosÃ© State 2012 University CASE STUDY REPORT: JOHN F. KENNEDY INTERNATIONAL AIRPORT AIRTRAIN

Ecosystem	Value	Units	Location	Reference
Subway	3000000000.000000	$NYC 2012 / mile of subway	NYC: Subway (2012)	CNN Money 2012 Short subway line $4.5 billion price tag
Pier	210.000000	$FL 2010 / ft^2	Florida: Pier (2010)	Moffatt & Nichol 2010 Pier Advisory Report
Pedestrian street / plaza	5066666.667000	$WA 2012 / acre	Washington: Plaza (2011)	LOTT Clean Water Alliance 2012 East Bay Public Plaza
Solid waste transfer plant	42039.330000	$OK 2015 / acre	Oklahoma: Solid Waste Transfer Plant (2015)	Oklahoma State University 2015 Solid Waste Transfer Stations for Rural Oklahoma
Heavy rail line	150000000.000000	$US 2006 / mile of railway	USA: Heavy rail line (2006)	reconnectingamerica 2006 Transit Technologies Worksheet
Ornamental garden	6.000000	$TX 2012 / ft^2	Texas: Garden (2012)	Texas A & M 2012 Stormwater Management: Rain Gardens
Warehouse	108.000000	$US 2014 / ft^2	United States: Warehouse (2014)	RSMeans 2013 Square Foot Costs
Garage	64.900000	$US 2014 / ft^2	United States: Garage (2014)	RSMeans 2013 Square Foot Costs
Natural gas power plant	84.400000	$TX 2013 / ft^2	Texas: Natural Gas Power Plant (2013)	EIA 2013 Capital Cost for Electricity Plants
Solar energy facility	340426.000000	$CA 2013 / acre	California: Solar Energy Facility (2013)	CleanEnergy Action Project 2012 Solar PV| Photovoltaic Solar Power Case Studies
Landfill	350000.000000	$US 2015 / acre	USA: Landfill (2015)	ForesterDailyNews 2015 Landfill Economics Part 2: Getting Down to Business
Alley	3.110000	$NYC 2015 / ft^2	New York City: Alley (2015)	BuildingJournal.com 2015 Asphalt Driveway Calculator
Boulevard (arterial)	12634475.000000	$FL 2014 / mile	Florida: Boulevard (2015)	Florida Department of Transportation 2015 Transportation Costs
Highway	8242976.000000	$FL 2014 / mile	Florida: Street (2015)	Florida Department of Transportation 2015 Transportation Costs
Sidewalk	59.000000	$VT 2010 / ft^2	VT: Sidewalk (2010)	Vermont Agency of Transportation 2010 Report on Shared and Sidewalk Unit Costs
Traffic slowed street	15.625000	$MT 2007 / ft^2	Montana: Traffic Slowed Street (2007)	Robert Peccia & Associates 2007 GREATER BOZEMAN AREA TRANSPORTATION PLAN

Ecosystem	Value	Units	Location	Reference
Agricultural field / vegetable garden	473.770000	$CA 2013 / acre	CA: Agricultural Field (2013)	Long et al. 2013 Sample costs to grow organic alfalfa
Diesel power plant	282.420000	$TX 2013 / ft^2	Texas: Natural Gas Power Plant (2013)	EIA 2013 Capital Cost for Electricity Plants
Wind farm	0.740000	$CA 2011 / ft^2	CALIFORNIA: wind farm (2011)	SFGATE 2006 New windmills near delta fuel state's global warming fight
Cogeneration plant	1000.000000	$NY 2011 / ft^2	NY: Cogeneration (2011)	Covanta 2015 cogeneration:Albany Medical Center
Gas station	227.050000	$US 2014 / ft^2	United States: Gas Station (2014)	RSMeans 2013 Square Foot Costs
Tunnel	925272727.300000	$NYC 2014 / mile of tunnel	New York City: Tunnel (2014)	MTA 2014 East Side Access
Bridge	152.500000	$FL 2014 / ft^2	Florida: Bridge (2014)	Florida Department of Transportation 2014 Bridge Costs
Fuel storage tank	401.810000	$FL 2011 / ft^2	Florida: Fuel storage tank (2011)	Florida Department of Transportation 2011 Airport Costs
Water/wastewater storage tank	72.040000	$MI 2003 / ft^2	State of Michigan: Water/wastewater storage tank (2003)	State of Michigan 2003 tanks
Pedestrian bridge	137.500000	$FL 2014 / ft^2	Florida: Pedestrian bridge (2014)	Florida Department of Transportation 2014 Bridge Costs
Park savanna	0.750000	$US 2015 / ft^2	US: Lawn (2015)	landscaping network 2015 Cost of Lawn and Artificial Turf
Airport terminal	250.000000	$FL 2011 / ft^2	Florida: Airport terminal (2011)	Florida Department of Transportation 2011 Airport Costs
Restaurant	219.850000	$US 2014 / ft^2	United States: Restaurant (2014)	RSMeans 2013 Square Foot Costs
Mixed use: restaurant / retail building	148.560500	$US 2014 / ft^2	United States: Mixed use: restaurant / retail building (2014)	RSMeans 2013 Square Foot Costs
Mixed use: restaurant / residential building	230.450000	$US 2014 / ft^2	United States: Mixed use: restaurant / retail building (2014)	RSMeans 2013 Square Foot Costs

Ecosystem	Value	Units	Location	Reference
Mixed use: restaurant / office building	192.212500	$US 2014 / ft^2	United States: Mixed use: restaurant / office building (2014)	RSMeans 2013 Square Foot Costs
Deep water estuary	442000.000000	$US 2003 / acre	USA: Deep water Estuary (2003)	Evergreen Funding Consultants 2003 estuary:A Primer on Habitat Project Costs
High salt marsh	16115.000000	$US 2001 / acre	USA: Salt Marsh (2001)	Habitat Restoration The Costs of Environmental Restoration Projects
Low salt marsh	16115.000000	$US 2001 / acre	USA: Salt Marsh (2001)	Habitat Restoration The Costs of Environmental Restoration Projects
Permeable pavers	7.330000	$US 2010 / ft^2	USA: Permeable pavers (2014)	University of Maryland 2016 Permeable Pavement Fact Sheet

Appendix 3. Demolition cost parameters incorporated in Visionmaker Jamaica Bay.

Full references are available online at https://visionmaker.us/nyc/jamaicabay/ and www.zotero.org/groups/mannahatta_2409

Appendix 3 Table A. Demolition cost parameters incorporated in Visionmaker Jamaica Bay.

Ecosystem	Value	Units	Location	Reference
Trail	4.350000	$NYC 2015 / ft^2	Upper West Side: Trail (2015)	Homewyse 2015 Cost to Grade Lot
Photovoltaic panels	0.000000	$NYC 2015 / ft^2	New York City: Urban Area	Assumed
Solar heating panels	0.000000	$NYC 2015 / ft^2	New York City: Urban Area	Assumed
Freshwater marsh	6.680000	$NYC 2015 / ft^2	Ohio: Freshwater marsh (2015)	Weidle Corp. 2015 Sand Price List
Street trees	4.350000	$NYC 2015 / ft^2	Upper West Side: Street trees (2015)	Homewyse 2015 Cost to Grade Lot
Cliffs and rock outcrops	132.200000	$NYC 2015 / $yard^3$	Demolition Costs: Cliffs and rock outcrops (2015)	Homewyse 2015 Cost to Excavate Land
Shrub land	4.350000	$NYC 2015 / ft^2	Upper West Side: Shrub land (2015)	Homewyse 2015 Cost to Grade Lot
Hardwood swamp	6.680000	$NYC 2015 / ft^2	Ohio: Hardwood swamp (2015)	Weidle Corp. 2015 Sand Price List
Orchard	4.350000	$NYC 2015 / ft^2	Upper West Side: Orchard (2015)	Homewyse 2015 Cost to Grade Lot
Light rail line	9.050000	$US 2015 / foot of railway	United States: Light rail line (2015)	b2-Consultants LLC 2015 Railroad Track Removal
Estuary	14.160000	$NYC 2015 / ft^2	Ohio: Estuary (2015)	Weidle Corp. 2015 Sand Price List
Pond	9.180000	$NYC 2015 / ft^2	Ohio: Pond (2015)	Weidle Corp. 2015 Sand Price List
Water treatment plant	1.370000	$NYC 2015 / ft^2	New York City: Water treatment plant (2015)	BuildingJournal.com 2015 Demolition Cost Calculator
Graywater recycling	0.000000	$NYC 2015 / ft^2	New York City: Urban Area	Assumed
Lawn	2.550000	$NYC 2015 / ft^2	Upper West Side: Lawn (2015)	Homewyse 2015 Cost to Grade Lot
Sewage treatment plant	1.370000	$NYC 2015 / ft^2	New York City: Sewage treatment plant (2015)	BuildingJournal.com 2015 Demolition Cost Calculator
Waste energy power plant	1.370000	$NYC 2015 / ft^2	New York City: Waste energy power plant (2015)	BuildingJournal.com 2015 Demolition Cost Calculator
Tidal energy facility	1.980000	$NYC 2015 / ft^2	New York City: Tidal energy facility (2015)	BuildingJournal.com 2015 Demolition Cost Calculator

Ecosystem	Value	Units	Location	Reference
Utility yard	4.350000	$NYC 2015 / ft^2	Upper West Side: Utility yard (2015)	Homewyse 2015 Cost to Grade Lot
Greenhouse / vertical farm	1.480000	$NYC 2015 / ft^2	New York City: Greenhouse / vertical farm (2015)	BuildingJournal.com 2015 Demolition Cost Calculator
Eelgrass meadow	6.680000	$NYC 2015 / ft^2	Ohio: Eelgrass meadow (2015)	Weidle Corp. 2015 Sand Price List
Green roof	0.000000	$NYC 2015 / ft^2	New York City: Urban Area	Assumed
Streetcar line	9.050000	$US 2015 / foot of railway	United States: Streetcar line (2015)	b2-Consultants LLC 2015 Railroad Track Removal
Compost bin	0.000000	$NYC 2015 / ft^2	New York City: Urban Area	Assumed
Beach	4.350000	$NYC 2015 / ft^2	Upper West Side: Beach (2015)	Homewyse 2015 Cost to Grade Lot
Geothermal pump	0.000000	$NYC 2015 / ft^2	New York City: Urban Area	Assumed
Bioswale	2.410000	$NYC 2015 / ft^2	Upper West Side: Bioswale (2015)	Homewyse 2015 Cost to Grade Lot
Disturbed Land	4.350000	$NYC 2015 / ft^2	Upper West Side: Disturbed land (2015)	Homewyse 2015 Cost to Grade Lot
Cottages / Mobile home	0.970000	$NYC 2015 / ft^2	New York City: Cottages / Mobile home (2015)	BuildingJournal.com 2015 Demolition Cost Calculator
Computer data center	1.980000	$NYC 2015 / ft^2	New York City: Computer data center (2015)	BuildingJournal.com 2015 Demolition Cost Calculator
Stream	4.900000	$NYC 2015 / ft^2	Ohio: Stream (2015)	Weidle Corp. 2015 Sand Price List
Bike lane	4.350000	$NYC 2015 / ft^2	Upper West Side: Bike lane (2015)	Homewyse 2015 Cost to Grade Lot
Meadow	2.550000	$NYC 2015 / ft^2	Upper West Side: Meadow (2015)	Homewyse 2015 Cost to Grade Lot
Derelict structures	0.770000	$NYC 2015 / ft^2	New York City: Derelict structures (2015)	BuildingJournal.com 2015 Demolition Cost Calculator
Hemlock northern hardwood forest	4.350000	$NYC 2015 / ft^2	Upper West Side: Hemlock northern hardwood forest (2015)	Homewyse 2015 Cost to Grade Lot
Parking lot	4.350000	$NYC 2015 / ft^2	Upper West Side: Parking lot (2015)	Homewyse 2015 Cost to Grade Lot
Factory	1.410000	$NYC 2015 / ft^2	New York City: Factory (2015)	BuildingJournal.com 2015 Demolition Cost Calculator
Street (collector)	4.350000	$NYC 2015 / ft^2	Upper West Side: Street (collector) (2015)	Homewyse 2015 Cost to Grade Lot
Swimming pool	21.690000	$NYC 2015 / ft^2	Upper West Side: Swimming pool (2015)	Homewyse 2015 Cost to Remove Pool
Paved ball field/court	4.350000	$NYC 2015 / ft^2	Upper West Side: Paved ball field/court (2015)	Homewyse 2015 Cost to Grade Lot

Ecosystem	Value	Units	Location	Reference
Cemetery	4.200000	$NYC 2015 / ft^2	Upper West Side: Cemetary (2015)	Homewyse 2015 Cost to Grade Lot
Camp	4.350000	$NYC 2015 / ft^2	Upper West Side: Camp (2015)	Homewyse 2015 Cost to Grade Lot
Cistern / rain barrels	0.000000	$NYC 2015 / ft^2	New York City: Urban Area	Assumed
Elevated train	47.500000	$FL 2014 / ft^2	Florida: Elevated train (2014)	Florida Department of Transportation 2014 Bridge Costs
Subway	14.200000	$NYC 2015 / ft^2	Ohio: Subway (2015)	Weidle Corp. 2015 Sand Price List
Pier	97.170000	$WA 2015 / ft^2	Tacoma: Pier (2015)	Port of Tacoma 2015 Pier Removal
Pedestrian street / plaza	4.350000	$NYC 2015 / ft^2	Upper West Side: Pedestrian street / plaza (2015)	Homewyse 2015 Cost to Grade Lot
Heavy rail line	9.050000	$US 2015 / foot of railway	United States: Heavy rail line (2015)	b2-Consultants LLC 2015 Railroad Track Removal
Ornamental garden	2.410000	$NYC 2015 / ft^2	Upper West Side: Ornamental garden (2015)	Homewyse 2015 Cost to Grade Lot
Garage	0.650000	$NYC 2015 / ft^2	New York City: Garage (2015)	BuildingJournal.com 2015 Demolition Cost Calculator
Landfill	4.350000	$NYC 2015 / ft^2	Upper West Side: Landfill (2015)	Homewyse 2015 Cost to Grade Lot
Alley	4.350000	$NYC 2015 / ft^2	Upper West Side: Alley (2015)	Homewyse 2015 Cost to Grade Lot
Boulevard (arterial)	4.350000	$NYC 2015 / ft^2	Upper West Side: Boulevard (arterial) (2015)	Homewyse 2015 Cost to Grade Lot
Highway	4.350000	$NYC 2015 / ft^2	Upper West Side: Highway (2015)	Homewyse 2015 Cost to Grade Lot
Sidewalk	4.350000	$NYC 2015 / ft^2	Upper West Side: Sidewalk (2015)	Homewyse 2015 Cost to Grade Lot
Traffic slowed street	4.350000	$NYC 2015 / ft^2	Upper West Side: Traffic slowed street (2015)	Homewyse 2015 Cost to Grade Lot
Agricultural field / vegetable garden	2.410000	$NYC 2015 / ft^2	Upper West Side: Agricultural field / vegetable garden (2015)	Homewyse 2015 Cost to Grade Lot
Wind farm	0.064296	$IL 2014 / ft^2	Illinois: Wind farm (2014)	Energy Ventures Analysis 2015 Decommissiong Estimate
Cogeneration plant	1.980000	$NYC 2015 / ft^2	New York City: Cogeneration plant (2015)	BuildingJournal.com 2015 Demolition Cost Calculator
Gas station	1.400000	$NYC 2015 / ft^2	New York City: Gas Station (2015)	BuildingJournal.com 2015 Demolition Cost Calculator

Ecosystem	Value	Units	Location	Reference
Tunnel	14.160000	$NYC 2015 / ft^2	Ohio: Tunnel (2015)	Weidle Corp. 2015 Sand Price List
Bridge	47.500000	$FL 2014 / ft^2	Florida: Bridge (2014)	Florida Department of Transportation 2014 Bridge Costs
Fuel storage tank	0.920000	$NYC 2015 / ft^2	New York City: Fuel storage tank (2015)	BuildingJournal.com 2015 Demolition Cost Calculator
Water / wastewater storage tank	0.000000	$NYC 2015 / ft^2	New York City: Urban Area	Assumed
Pedestrian bridge	35.000000	$FL 2014 / ft^2	Florida: Pedestrian bridge (2014)	Florida Department of Transportation 2014 Bridge Costs
Park savanna	4.350000	$NYC 2015 / ft^2	Upper West Side: Park savanna (2015)	Homewyse 2015 Cost to Grade Lot
Deep water estuary	24.120000	$NYC 2015 / ft^2	Ohio: Deep water estuary (2015)	Weidle Corp. 2015 Sand Price List
High salt marsh	6.680000	$NYC 2015 / ft^2	Ohio: High salt marsh (2015)	Weidle Corp. 2015 Sand Price List
Low salt marsh	6.680000	$NYC 2015 / ft^2	Ohio: Low salt marsh (2015)	Weidle Corp. 2015 Sand Price List
Permeable pavers	0.000000	$NYC 2015 / ft^2	New York City: Urban Area	Assumed
Oak hickory forest	4.350000	$NYC 2015 / ft^2	Upper West Side: Oak hickory forest (2015)	Homewyse 2015 Cost to Grade Lot
Apartment building	20.000000	$NYC 2013 / ft^2	New York City: Apartment building (2013)	HR&A Advisors 2013 Cost to Rehab
Airfield	9.699044	$CA 2012 / ft^2	Los Angeles: Airfield (2012)	LAWA 2012 Appendix G LAX Cost Estimates
Airport terminal	55.980000	$CT 2014 / ft^2	Connecticut: Airport terminal (2014)	The Airport News 2014 Bradley Terminal B Demolition
Hospital	13.700000	$CT 2014 / ft^2	Pennsylvania: Hospital (2014)	Rotenberg C. 2015 Demolition of Montgomery Hospital in Norristown proceeds through freezing cold
Single family home	8.160000	$US 2015 / ft^2	United States: Single family home (2015)	b2-Consultants LLC 2015 Wood Frame Building Demolition
Warehouse	2.500000	$CA 2004 / ft^2	California: Warehouse (2004)	Mavrogenes H. S. 2004 Bellevue Ave Demolition Project
Stadium	15.380000	$NYC 2010 / ft^2	New York City: Stadium (2010)	DEMCO 2010 Yankee Stadium Demolition
Hotel	20.000000	$NYC 2013 / ft^2	New York City: Hotel (2013)	HR&A Advisors 2013 Cost to Rehab
Mixed use: office / residential building	20.000000	$NYC 2013 / ft^2	New York City: Mixed use: office / residential building (2013)	HR&A Advisors 2013 Cost to Rehab

Ecosystem	Value	Units	Location	Reference
Office building	20.000000	$NYC 2013 / ft^2	New York City: Office building (2013)	HR&A Advisors 2013 Cost to Rehab
Natural gas power plant	3541666.670000	$MA 2011 / acre	Massachusetts: Natural gas power plant (2011)	Salem et al. 2011 Salem Harbor Power Station Site Assessment Study
Solar energy facility	7500.000000	$MD 2013 / acre	Maryland: Solar energy facility (2013)	Maryland Solar 2013 Maryland Solar Project Facility Decommissioning Plan
Diesel power plant	3541666.670000	$MA 2011 / acre	Massachusetts: Diesel power plant (2011)	Salem et al. 2011 Salem Harbor Power Station Site Assessment Study
School or university	20.000000	$NYC 2013 / ft^2	New York City: School or university (2013)	HR&A Advisors 2013 Cost to Rehab
Mixed use: retail / office building	20.000000	$NYC 2013 / ft^2	New York City: Mixed use: retail / office building (2013)	HR&A Advisors 2013 Cost to Rehab
Mixed use: restaurant / retail building	20.000000	$NYC 2013 / ft^2	New York City: Mixed use: restaurant / retail building (2013)	HR&A Advisors 2013 Cost to Rehab
Mixed use: restaurant / residential building	20.000000	$NYC 2013 / ft^2	New York City: Mixed use: restaurant / residential building (2013)	HR&A Advisors 2013 Cost to Rehab
Mixed use: restaurant / office building	20.000000	$NYC 2013 / ft^2	New York City: Mixed use: restaurant / office building (2013)	HR&A Advisors 2013 Cost to Rehab
Mixed use: retail / residential building	20.000000	$NYC 2013 / ft^2	New York City: Mixed use: retail / residential building (2013)	HR&A Advisors 2013 Cost to Rehab
Public assembly hall	20.000000	$NYC 2013 / ft^2	New York City: Public assembly hall (2013)	HR&A Advisors 2013 Cost to Rehab
Restaurant	20.000000	$NYC 2013 / ft^2	New York City: Restaurant (2013)	HR&A Advisors 2013 Cost to Rehab
Retail building	20.000000	$NYC 2013 / ft^2	New York City: Retail building (2013)	HR&A Advisors 2013 Cost to Rehab
Solid waste transfer plant	20.000000	$NYC 2013 / ft^2	New York City: Solid waste transfer plant (2013)	HR&A Advisors 2013 Cost to Rehab

Appendix 4. Data used for creation of species-area curves.

Appendix 4 Table A. Data used for creation of species-area curves (excluding marine fish).

Place Name	Land Area (sq km)	Watered Area (sq km)	Latitude (decimal degrees)	Amphibians	Birds	Freshwater Fish	Mammals	Plants	Reptiles	Source
Abraham Lincoln Birthplace National Historic Site	1.37	–	37.53	16	131	–	38	572	21	IRMA 2015
Acadia National Park	156.98	20.473	44.34	11	215	33	37	866	7	IRMA 2015
Allegheny Portage Railroad National Historic Site	4.33	0.952	40.45	19	116	15	31	589	12	IRMA 2015
Anacostia Park	4.86	–	38.87	10	223	–	9	249	8	IRMA 2015
Antietam National Battlefield	13.17	0.790	39.46	7	137	41	36	691	11	IRMA 2015
Apostle Islands National Lakeshore	278.21	121.576	46.93	17	–	44	42	–	6	IRMA 2015
Appomattox Court House National Historical Park	7.20	0.050	37.38	19	93	30	26	344	14	IRMA 2015
Arctic Meadows	0.31	–	41.13	1	–	–	–	57	1	Stillwater township 2015
Assateague Island National Seashore	197.23	166.135	38.25	8	294	135	50	660	18	IRMA 2015
Bennet Bogs Nature Conservancy preserve	0.13	–	38.99	–	–	–	–	119	–	E. Creveling, Personal communication 2015
Big Cypress National Preserve	2952.25	1520.974	25.90	–	–	–	–	–	48	IRMA 2015

Place Name	Land Area (sq km)	Watered Area (sq km)	Latitude (decimal degrees)	Amphibians	Birds	Freshwater Fish	Mammals	Plants	Reptiles	Source
Big South Fork National River and Recreation Area	495.76	7.584	36.47	28	168	94	57	1094	30	IRMA 2015
Biscayne National Park	710.60	708.678	25.48	–	230	–	–	–	34	IRMA 2015
Blair Creek Nature Conservancy preserve	1.97	–	41.06	17	71	–	7	314	4	E. Creveling, Personal communication 2015
Bluestone National Scenic River	17.56	0.517	37.57	28	106	41	43	825	11	IRMA 2015
Canaveral National Seashore	236.58	182.563	28.79	22	273	156	25	750	55	IRMA 2015
Cape Cod National Seashore	164.08	60.725	41.97	12	–	73	52	915	18	IRMA 2015
Cape Hatteras National Seashore	125.83	78.955	35.30	12	–	–	34	1149	44	IRMA 2015
Cape Island Creek Nature Conservancy preserve	0.74	–	38.95	3	–	–	–	33	–	E. Creveling, Personal communication 2015
Cape Lookout National Seashore	113.09	84.245	34.61	10	275	–	18	610	30	IRMA 2015
Cape May Bird Refuge Nature Conservancy preserve	0.88	–	38.93	10	–	–	–	240	7	E. Creveling, Personal communication 2015
Carl Sandburg Home National Historic Site	1.10	0.008	35.27	22	102	15	35	611	22	IRMA 2015
Carolina Beach State Park	3.10	–	34.05	18	241	–	22	395	40	North Carolina Division of Parks 2015

Place Name	Land Area (sq km)	Watered Area (sq km)	Latitude (decimal degrees)	Amphibians	Birds	Freshwater Fish	Mammals	Plants	Reptiles	Source
Castillo de San Marcos National Monument	0.08	0.003	29.90	4	84	–	–	147	2	IRMA 2015
Catoctin Mountain Park	24.90	–	39.65	17	134	–	42	727	13	IRMA 2015
Charles Pinckney National Historic Site	0.13	0.011	32.85	3	–	–	16	77	5	IRMA 2015
Chattahoochee River National Recreation Area	35.19	5.402	33.99	25	192	59	37	948	41	IRMA 2015
Chesapeake and Ohio Canal National Historic Park	85.33	–	38.90	20	181	–	37	679	21	IRMA 2015
Chickamauga and Chattanooga National Military Park	33.30	0.076	34.94	23	175	19	50	966	22	IRMA 2015
Colonial National Historical Park	38.08	6.587	37.22	28	262	88	33	1018	34	IRMA 2015
Congaree National Park	98.13	0.748	33.78	34	191	60	37	855	45	IRMA 2015
Cowpens National Battlefield	3.45	–	35.14	23	104	–	22	554	32	IRMA 2015
Cumberland Gap National Historical Park	100.59	0.726	36.60	26	156	29	49	977	16	IRMA 2015
Cumberland Island National Seashore	147.43	78.457	30.83	19	323	89	31	782	42	IRMA 2015
Cuyahoga Valley National Park	135.21	8.755	41.24	19	241	65	37	1167	22	IRMA 2015
Delaware Water Gap National Recreation Area	277.65	–	41.15	23	236	–	49	1407	26	IRMA 2015
Dismal Swamp State Park	58.40	–	36.51	19	170	–	34	357	29	North Carolina Division of Parks 2015

Place Name	Land Area (sq km)	Watered Area (sq km)	Latitude (decimal degrees)	Amphibians	Birds	Freshwater Fish	Mammals	Plants	Reptiles	Source
Dry Tortugas National Park	265.39	253.111	24.63	–	289	–	–	–	–	IRMA 2015
Eisenhower National Historic Site	2.83	0.001	39.79	7	111	31	11	237	3	IRMA 2015
Eldora Nature Nature Conservancy preserve	3.84	–	39.22	10	–	–	–	116	13	E. Creveling, Personal communication 2015
Eleanor Roosevelt National Historic Site	0.66	0.194	41.76	12	49	6	3	338	10	IRMA 2015
Everglades National Park	6226.63	6047.030	25.32	–	357	221	–	–	56	IRMA 2015
Fire Island National Seashore	79.55	56.528	40.70	2	–	50	37	389	12	IRMA 2015
Fork River Mountain Nature Conservancy preserve	12.56	–	39.81	10	46	–	11	326	15	E. Creveling, Personal communication 2015
Fort Caroline National Memorial	0.57	0.081	30.39	10	181	–	13	610	19	IRMA 2015
Fort Donelson National Battlefield	2.21	0.044	36.49	21	177	13	36	784	29	IRMA 2015
Fort Dupont Park	1.62	–	38.88	–	–	–	3	–	–	IRMA 2015
Fort Fisher State Recreation Area	1.16	–	33.95	9	227	–	18	92	18	North Carolina Division of Parks 2015
Fort Frederica National Monument	1.14	0.687	31.22	8	98	21	14	263	15	IRMA 2015
Fort Macon State Park	1.72	–	34.70	9	299	–	30	323	22	North Carolina Division of Parks 2015

Place Name	Land Area (sq km)	Watered Area (sq km)	Latitude (decimal degrees)	Amphibians	Birds	Freshwater Fish	Mammals	Plants	Reptiles	Source
Fort Matanzas National Monument	1.21	0.435	29.72	9	175	80	22	234	25	IRMA 2015
Fort Necessity National Battlefield	3.74	0.377	39.82	22	145	4	32	451	14	IRMA 2015
Fort Pulaski National Monument	22.43	20.480	32.03	7	216	42	19	306	17	IRMA 2015
Fort Sumter National Monument	0.94	0.549	32.75	4	204	133	9	275	4	IRMA 2015
Franklin Delano Roosevelt National Memorial	0.03	–	38.88	–	12	–	–	–	–	IRMA 2015
Frederick Douglass National Historic Site	0.03	–	38.86	–	20	–	–	–	–	IRMA 2015
Fredericksburg and Spotsylvania National Military Park	42.00	0.200	38.29	22	159	41	26	371	18	IRMA 2015
Gandy's Beach Nature Conservancy preserve	0.74	–	39.30	2	–	–	1	–	–	E. Creveling, Personal communication 2015
Gateway National Recreation Area	109.19	–	40.45	4	–	–	34	920	18	IRMA 2015
Gauley River National Recreation Area	45.16	7.444	38.22	26	148	36	43	810	18	IRMA 2015
Gettysburg National Military Park	24.13	0.013	39.81	15	157	18	25	784	13	IRMA 2015
Goose Creek State Park	6.77	–	35.48	20	184	–	24	299	35	North Carolina Division of Parks 2015
Great Falls Park	3.24	–	38.99	8	177	–	16	20	18	IRMA 2015

Place Name	Land Area (sq km)	Watered Area (sq km)	Latitude (decimal degrees)	Amphibians	Birds	Freshwater Fish	Mammals	Plants	Reptiles	Source
Great Smoky Mountains National Park	2098.24	53.636	35.68	41	–	71	–	1618	39	IRMA 2015
Great Swamp National Wildlife Refuge	14.81	–	40.71	19	223	–	31	–	24	US Fish and Wildlife Service 2015
Greenbelt Park	4.76	–	38.99	3	127	–	10	20	–	IRMA 2015
Guilford Courthouse National Military Park	0.87	–	36.13	19	76	–	21	431	27	IRMA 2015
Gulf Islands National Seashore	487.56	424.623	30.36	–	316	–	43	–	59	IRMA 2015
Hackensack Meadowlands Proper	83.00	–	40.78	10	260	–	45	145	14	Kiviat and MacDonald 2004
Hammocks Beach State Park	5.84	–	34.64	9	196	–	33	279	25	North Carolina Division of Parks 2015
Hand's Landing Nature Conservancy preserve	0.69	–	39.11	2	–	–	1	–	–	E. Creveling, Personal communication 2015
Harmony Hall	0.26	–	38.75	–	123	–	3	–	–	IRMA 2015
Harpers Ferry National Historical Park	15.02	–	39.32	16	120	–	27	686	19	IRMA 2015
High Mountain Park Nature Conservancy preserve	5.10	–	40.97	12	76	–	19	135	4	E. Creveling, Personal communication 2015
Hirst Ponds Nature Conservancy preserve	1.48	–	39.49	–	30	–	–	34	–	E. Creveling, Personal communication 2015

Place Name	Land Area (sq km)	Watered Area (sq km)	Latitude (decimal degrees)	Amphibians	Birds	Freshwater Fish	Mammals	Plants	Reptiles	Source
Home of Franklin D. Roosevelt National Historic Site	3.64	0.317	41.77	9	54	11	10	400	9	IRMA 2015
Hopewell Culture National Historical Park	4.52	0.176	39.38	21	274	15	40	457	26	IRMA 2015
Hopewell Furnace National Historic Site	3.43	0.001	40.20	16	139	18	19	741	15	IRMA 2015
Horseshoe Bend National Military Park	8.30	0.530	32.98	32	119	26	33	431	37	IRMA 2015
Hutcheson Memorial Forest	2.02	–	40.50	4	84	–	18	351	5	HMF, Personal communication 2015
Huyck Preserve	0.41	–	42.52	18	194	–	40	–	9	Huyck preserve 2015
Indian Trail Swamp	2.93	–	39.13	15	155	–	10	341	14	E. Creveling, Personal communication 2015
Indiana Dunes National Lakeshore	64.19	10.306	41.65	18	301	71	46	–	23	IRMA 2015
Johnsonburg Swamp Nature Conservancy preserve	2.89	–	40.98	14	180	–	4	272	5	E. Creveling, Personal communication 2015
Johnstown Flood National Memorial	0.69	0.145	40.35	16	112	6	22	382	8	IRMA 2015
Kenilworth Park and Aquatic Gardens	2.83	–	38.91	15	223	–	20	436	13	IRMA 2015
Kennesaw Mountain National Battlefield Park	11.74	0.010	33.98	24	207	11	19	844	22	IRMA 2015

Place Name	Land Area (sq km)	Watered Area (sq km)	Latitude (decimal degrees)	Amphibians	Birds	Freshwater Fish	Mammals	Plants	Reptiles	Source
Kings Mountain National Military Park	16.02	0.001	35.14	22	122	22	30	686	34	IRMA 2015
Lincoln Boyhood National Memorial	0.80	0.004	38.12	13	224	–	38	332	13	IRMA 2015
Little Flatbrook Nature Conservancy preserve	0.36	–	41.28	–	35	–	2	97	–	E. Creveling, Personal communication 2015
Little River Canyon National Preserve	55.34	0.779	34.44	28	147	40	35	995	28	IRMA 2015
Lizard Tail Swamp Nature Conservancy preserve	1.68	–	39.12	10	130	–	4	297	8	E. Creveling, Personal communication 2015
Lummis Ponds Nature Conservancy preserve	0.51	–	39.36	–	118	–	1	–	–	E. Creveling, Personal communication 2015
Mammoth Cave National Park	207.80	3.372	37.18	28	167	79	48	1270	33	IRMA 2015
Manassas National Battlefield Park	20.74	0.006	38.81	23	159	37	26	744	24	IRMA 2015
Manumuskin River Nature Conservancy preserve	14.86	–	39.34	17	115	–	31	115	23	E. Creveling, Personal communication 2015
Marsh-Billings-Rockefeller National Historical Park	2.58	0.089	43.63	13	74	2	34	525	5	IRMA 2015
Martin Van Buren National Historic Site	0.11	–	42.37	12	84	–	15	455	2	IRMA 2015

Place Name	Land Area (sq km)	Watered Area (sq km)	Latitude (decimal degrees)	Amphibians	Birds	Freshwater Fish	Mammals	Plants	Reptiles	Source
Mashipacong Bogs Nature Conservancy preserve	4.03	–	41.27	6	104	–	6	208	–	E. Creveling, Personal communication 2015
Maurice River Bluffs Nature Conservancy preserve	2.17	–	39.36	6	138	–	14	325	10	E. Creveling, Personal communication 2015
Medoc Mountain State Park	15.75	–	36.26	28	132	–	17	551	31	North Carolina Division of Parks 2015
Menantico Creek Nature Conservancy preserve	2.43	–	39.38	–	20	–	4	–	2	E. Creveling, Personal communication 2015
Minisink Valley Nature Conservancy preserve	0.76	–	41.35	–	10	–	3	322	1	E. Creveling, Personal communication 2015
Minute Man National Historical Park	3.87	0.350	42.45	17	113	13	40	908	13	IRMA 2015
Mississippi National River and Recreation Area	217.84	68.222	44.87	14	293	100	51	1369	22	IRMA 2015
Monocacy National Battlefield	6.56	0.311	39.37	9	102	43	24	553	9	IRMA 2015
Montague Woods Nature Conservancy preserve	0.08	–	41.34	3	10	–	–	159	–	E. Creveling, Personal communication 2015
Moores Creek National Battlefield	0.40	0.008	34.46	24	105	12	24	653	25	IRMA 2015

Place Name	Land Area (sq km)	Watered Area (sq km)	Latitude (decimal degrees)	Amphibians	Birds	Freshwater Fish	Mammals	Plants	Reptiles	Source
Morristown National Historical Park	6.91	0.002	40.77	14	130	15	15	494	8	IRMA 2015
Muckshaw Ponds Nature Conservancy preserve	2.15	–	41.03	10	109	–	4	353	4	E. Creveling, Personal communication 2015
National Capital Parks-East	26.49	–	38.88	15	241	–	25	–	22	IRMA 2015
National Mall and Memorial Parks	26.49	–	38.89	–	26	–	–	–	–	IRMA 2015
New River Gorge National River	284.85	17.150	37.96	30	192	55	51	–	20	IRMA 2015
Ninety Six National Historic Site	3.90	0.113	34.15	21	149	22	25	440	39	IRMA 2015
Nocella Nature Nature Conservancy preserve	0.77	–	41.23	–	46	–	1	–	–	E. Creveling, Personal communication 2015
Obed Wild and Scenic River	21.55	1.138	36.04	28	159	54	50	758	32	IRMA 2015
Ocmulgee National Monument	2.79	0.065	32.84	26	172	31	32	406	35	IRMA 2015
Oswego River Lowlands Nature Conservancy preserve	2.13	–	39.76	6	35	–	1	142	3	E. Creveling, Personal communication 2015
Oxon Run National Parkway	0.45	0.113	38.80	3	173	–	7	100	4	IRMA 2015
Petersburg National Battlefield	13.56	0.079	37.22	21	130	22	34	345	26	IRMA 2015

Place Name	Land Area (sq km)	Watered Area (sq km)	Latitude (decimal degrees)	Amphibians	Birds	Freshwater Fish	Mammals	Plants	Reptiles	Source
Pettigrew State Park	23.60	–	35.89	17	189	–	26	275	29	North Carolina Division of Parks 2015
Pictured Rocks National Lakeshore	298.16	71.218	46.56	13	–	73	52	–	9	IRMA 2015
Piscataway Park	18.64	1.497	38.68	16	215	2	28	639	19	IRMA 2015
President's Park	0.07	–	38.90	–	–	–	3	44	–	IRMA 2015
Prince William Forest Park	44.89	0.039	38.59	22	129	26	36	924	25	IRMA 2015
Richmond National Battlefield Park	6.13	0.035	37.43	23	137	30	24	795	24	IRMA 2015
Rock Creek Park	7.10	–	38.96	11	182	–	30	731	13	IRMA 2015
Russell Cave National Monument	1.29	–	34.97	17	130	–	35	543	14	IRMA 2015
Sagamore Hill National Historic Site	0.29	0.026	40.89	4	136	49	13	316	5	IRMA 2015
Saint Croix National Scenic River	395.50	99.391	45.39	19	269	95	57	1457	24	IRMA 2015
Saint-Gaudens National Historic Site	0.58	0.014	43.50	13	52	12	27	432	4	IRMA 2015
Saratoga National Historical Park	11.64	1.413	43.00	14	–	13	37	916	10	IRMA 2015
Shenandoah National Park	782.16	0.005	38.53	24	196	41	57	1406	–	IRMA 2015
Shiloh National Battlefield	16.52	0.249	35.14	26	186	51	46	809	28	IRMA 2015
Sleeping Bear Dunes National Lakeshore	284.19	63.789	44.91	20	238	92	54	1138	18	IRMA 2015
Stones River National Battlefield	2.87	0.072	35.88	13	152	46	35	633	21	IRMA 2015

Place Name	Land Area (sq km)	Watered Area (sq km)	Latitude (decimal degrees)	Amphibians	Birds	Freshwater Fish	Mammals	Plants	Reptiles	Source
Stonybrook-Millstone watershed	3.76	–	40.37	7	89	–	13	320	8	Stonybrook-Millstone watershed 2015
Sussex Swamp Nature Conservancy preserve	1.08	–	41.04	10	94	–	1	349	1	E. Creveling, Personal communication 2015
Theodore Roosevelt Island National Memorial	0.41	0.050	38.90	1	70	–	3	–	6	IRMA 2015
Thomas Stone National Historic Site	1.29	0.011	38.53	14	112	17	14	377	8	IRMA 2015
Timucaun Ecological and Historical Preserve	184.92	142.361	30.45	23	–	136	25	610	43	IRMA 2015
Valley Forge National Historical Park	13.97	0.423	40.10	17	173	28	27	936	19	IRMA 2015
Vanderbilt Mansion National Historic Site	0.85	0.046	41.80	6	62	10	2	470	7	IRMA 2015
Vicksburg National Military Park	6.67	0.022	32.34	27	190	18	39	306	42	IRMA 2015
Weir Farm National Historic Site	0.22	0.032	41.26	12	51	3	4	471	8	IRMA 2015
White Lake Nature Conservancy preserve	1.59	–	41.00	8	93	–	8	524	4	E. Creveling, Personal communication 2015
Willow Grove Lake Nature Conservancy preserve	7.23	–	39.55	6	115	–	22	80	15	E. Creveling, Personal communication 2015
Wolf Trap National Park for the Performing Arts	0.54	–	38.94	12	79	–	17	196	9	IRMA 2015

Appendix 4 Table B. Marine data used for species-area curves.

Estuary Name	Watered Area (sq km)	Latitude (decimal degrees)	Species Richness (marine fish)	Source
Blue Hill Bay	297.85	44.31	42	Jury et al. 1994
Boston Harbor	129.50	42.34	42	Jury et al. 1994
Buzzards Bay	585.34	41.50	51	Estuarine Living Marine Resources Database 2016
Cape Fear River Estuary	128.50	33.90	30	Estuarine Living Marine Resources Database 2016
Casco Bay Estuary	398.86	43.67	44	Jury et al. 1994
Charleston Harbor	20.70	32.77	30	Estuarine Living Marine Resources Database 2016
Chesapeake Bay	9919.65	37.72	140	Caroline County 2007
Chincoteague Bay	354.83	38.04	51	Estuarine Living Marine Resources Database 2016
Choptank River Estuary	300.00	38.64	39	Caroline County 2007
Cobscook Bay	103.60	44.91	34	Jensen 2013
Delaware Bay	1989.11	39.18	89	NJDEP 2016
Englishman/Machias Bay	202.02	44.58	41	Jury et al. 1994
Gardiners Bay	510.23	41.11	51	Estuarine Living Marine Resources Database 2016
Great Bay	38.85	43.07	40	Jury et al. 1994
Great Hudson River Estuary	771.82	41.20	35	NYDEC 2016
Great South Bay	391.09	40.70	43	USFWS 2016
James River Estuary	611.24	36.92	51	Estuarine Living Marine Resources Database 2016
Massachusetts Bay	178.71	42.38	42	Jury et al. 1994
Merrimack River Estuary	15.54	43.05	39	Jury et al. 1994
Muscongus Bay	186.48	43.90	43	Jury et al. 1994
Narraguagus Bay	181.30	44.51	41	Jury et al. 1994
Neuse River Estuary	1070.60	35.05	95	US Army Corps of Engineers 2016
Passamaquoddy Bay	406.63	45.10	45	Estuarine Living Marine Resources Database 2016
Penobscot Bay	934.99	44.20	42	Jury et al. 1994
Plum Island Sound	35.00	42.73	34	Buchsbaum et al. 2000
Potomac River Estuary	1279.45	38.06	64	Aijrand 1978

Estuary Name	Watered Area (sq km)	Latitude (decimal degrees)	Species Richness (marine fish)	Source
Rappahannock River Estuary	375.55	37.64	51	Estuarine Living Marine Resources Database 2016
Saco Bay	44.03	43.50	44	Jury et al. 1994
Sheepscot Bay	266.77	43.79	44	Jury et al. 1994
Tangier/Pocomoke Sounds	445.00	37.91	51	Estuarine Living Marine Resources Database 2016
York River Estuary	191.66	37.23	51	Estuarine Living Marine Resources Database 2016

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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