National Park Service
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Natural Resource Stewardship and Science

Natural Resource Condition Assessment

Gateway National Recreation Area

Natural Resource Report NPS/GATE/NRR—2018/1774



ON THE COVER
East Pond at the Wildlife Refuge. Jamaica Bay Unit of Gateway National Recreation Area.
National Park Service.

Natural Resource Condition Assessment

Gateway National Recreation Area

Natural Resource Report NPS/GATE/NRR—2018/1774

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Contents

Page

Figures....vii

Tables....xiii

Executive Summary....xv

Background....xv

Natural Resource Condition Assessment....xv

Acknowledgments....xxi

List of Abbreviations....xxiii

1. NRCA Background Information....1

2. Introduction and Resource Setting....5

2.1 History and enabling legislation....5

2.1.1 Geographic setting....6

2.1.2 Land use....15

2.1.3 Road density....19

2.1.4 Population....22

2.1.5 Climate....24

2.1.6 Visitation statistics....24

2.2 Natural resources....25

2.2.1 Geology....25

2.2.2 Soils....26

2.2.3 Shorelines....30

2.2.4 Watersheds....30

2.2.5 Habitats, flora, and fauna....31

2.2.6 Deer populations....35

2.2.7 Soundscapes....36

2.2.8 Lightscapes....38

2.3 Resource condition threats and stressors....38

2.3.1 Air quality 39
2.3.2 Non-native species 39
2.3.3 Adverse recreational use 39
2.3.4 Water pollution 40
2.3.5 Inland erosion 41
2.3.6 Sediment contamination and accumulation 41
2.3.7 Climate change 41
2.4 Resource stewardship 45
2.4.1 Management directive and planning guidance 45
2.4.2 Status of supporting science 47
3. Study Scoping and Design 49
3.1 Preliminary scoping 49
3.2 Study design 50
3.2.1 Assessment framework 50
3.2.2 Reporting areas 51
3.2.3 General approach and methods 52
4. Natural Resource Conditions 55
4.1 Air quality 55
4.1.1 Nitrogen and sulfur wet deposition 57
4.1.2 Mercury atmospheric deposition 61
4.1.3 Ozone 62
4.1.4 Atmospheric visibility 67
4.2 Water resources 69
4.2.1 Water resources summary 69
4.2.2 Dissolved oxygen 75
4.2.3 Water clarity (secchi depth) 76
4.2.4 Chlorophyll a 78
4.2.5 Total nitrogen and total phosphorus 79

4.2.6 pH 82
4.2.7 Enterococcus 84
4.3 Biological integrity 87
4.3.1 Seabeach amaranth abundance 88
4.3.2 Piping plover 90
4.3.3 Diamondback terrapin 93
4.3.4 American holly 94
4.3.5 Horseshoe crab 97
4.4 Landscapes dynamics 100
4.4.1 Landscape dynamics summary 100
4.4.2 Saltmarsh elevation 101
4.4.3 Impervious surface 109
4.4.4 Shoreline erosion and accretion 114
5. Discussion 121
5.1 Air resource summary 121
5.2 Water resources summary 123
5.3 Biological integrity summary 125
5.4 Landscape dynamics summary 127
Literature Cited 131

Figures

Page

Figure 2-1. Location of Gateway National Recreation Area in the Northeast Region of the United States. 7

Figure 2-2. Gateway National Recreation Area park units (Adapted from NPS). 8

Figure 2-3. Jamaica Bay Unit of Gateway National Recreation Area (Source: NPS). 9

Figure 2-4. Staten Island Unit of Gateway National Recreation Area (Source: NPS) 11

Figure 2-5. The Sandy Hook Unit of Gateway National Recreation Area (Source: NPS). 13

Figure 2-6. Land use surrounding the Jamaica Bay Unit of Gateway National Recreation Area (Source: NLCD 2011). 16

Figure 2-7. Land use surrounding the Staten Island Unit of Gateway National Recreation Area (Source: NLCD 2011). 17

Figure 2-8. Land use surrounding the Sandy Hook Unit of Gateway National Recreation Area (Source: NLCD 2011). 18

Figure 2-9. Roads located within the Jamaica Bay Unit of Gateway National Recreation Area (Source: NPS) 19

Figure 2-10. Roads located within the Staten Island Unit of Gateway National Recreation Area (Source: NPS) 20

Figure 2-11. Roads located within the Sandy Hook Unit of Gateway National Recreation Area (Source: NPS) 21

Figure 2-12. Population density surrounding Gateway National Recreation Area (Source: NPScape Landscape Monitoring Project found here: https://science.nature.nps.gov/im/monitor/npscape/). 23

Figure 2-13. Visitors to Gateway National Recreation Area by month (Source: NPS). 25

Figure 2-14. Annual visitors to Gateway National Recreation Area by park unit (Source: NPS). 25

Figure 2-15. Soil types within the Jamaica Bay Unit, Gateway National Recreation Area (Source: USDA NRCS). 27

Figure 2-16. Soil types within the Staten Island Unit, Gateway National Recreation Area (Source: USDA NRCS). 28

Figure 2-17. Soil types within the Sandy Hook Unit, Gateway National Recreation Area (Source: USDA NRCS). 29

Figures (continued)

Page

Figure 2-18. Conceptual diagram illustrating the major habitat types present in Gateway National Recreation Area. 31

Figure 2-19. Deer sightings sorted by group size in the Staten Island Unit, Gateway National Recreation Area (NYC Department of Parks and Recreation 2016). 36

Figure 2-20. Median existing sound pressure levels for Gateway National Recreation Area (NPS 2016f). 37

Figure 2-21. Jamaica Bay Unit geomorphic units pre- (top), and post- (bottom) Hurricane Sandy, Gateway National Recreation Area. Source: Psuty et al. 2017. 42

Figure 2-22. Staten Island Unit geomorphic units pre- (top), and post- (bottom) Hurricane Sandy, Gateway National Recreation Area. Source: Psuty et al. 2017. 43

Figure 2-23. Sandy Hook Unit geomorphic units pre- (top), and post- (bottom) Hurricane Sandy, Gateway National Recreation Area. Source: Psuty et al. 2017. 44

Figure 4-1. Air quality monitors near Gateway National Recreation Area (Source: NPS Air Resources Division). 56

Figure 4-2. Total wet deposition of sulfate as SO_4^{2-} (kg/ha) for the continental United States in 2015 (Source: NADP/NTN 2016). 58

Figure 4-3. Total wet deposition of nitrate and ammonium (N) (kg/ha) for the continental United States in 2015 (Source: NADP/NTN 2016). 58

Figure 4-4. Application of the percent attainment categories to the wet nitrogen deposition value categories 60

Figure 4-5. Application of the percent attainment categories to the wet sulfur deposition value categories 60

Figure 4-6. Total mercury wet deposition across the United States in 2015 (Source: NADP/MDN 2016). 61

Figure 4-7. Interpolated ozone at Gateway National Recreation Area was 76.4 ppb, which results in 0% attainment of the reference condition for human health. 65

Figure 4-8. Interpolated ozone W126 at Gateway National Recreation Area was 11.1 ppb, which results in 30% attainment of the reference condition. 66

Figure 4-9. Long term trend in ozone concentration (ppb) for Gateway National Recreation Area for 2006-2015 66

Figures (continued)

Page

Figure 4-10. Long term trend in W126 ozone exposure index for vegetation for Gateway National Recreation Area for 2006-2015 67

Figure 4-11. Application of percent attainment categories to the visibility value categories 69

Figure 4-12. Water quality monitoring sites used in the assessment of water resources within the Jamaica Bay Unit of Gateway National Recreation Area. 72

Figure 4-13. Water quality monitoring sites used in the assessment of water resources within the Staten Island Unit of Gateway National Recreation Area. 73

Figure 4-14. Water quality monitoring sites used in the assessment of water resources within the Sandy Hook Unit of Gateway National Recreation Area. 74

Figure 4-15. Annual median dissolved oxygen values from 2003 to 2015 for Jamaica Bay Unit of Gateway National Recreation Area 76

Figure 4-16 Annual median Secchi depth (ft) values from 2003 to 2015 for the Jamaica Bay Unit of Gateway National Recreation Area 77

Figure 4-17. Annual median chlorophyll a values from 2005 to 2015 for the Jamaica Bay Unit of Gateway National Recreation Area 79

Figure 4-18. Annual median total nitrogen values from 2005 to 2015 for the Jamaica Bay Unit of Gateway National Recreation Area. 82

Figure 4-19. Annual median total phosphorus values from 2005 to 2015 for the Jamaica Bay Unit of Gateway National Recreation Area. 82

Figure 4-20. Annual pH median values from 2005 to 2015 for the Jamaica Bay Unit of Gateway National Recreation Area 83

Figure 4-21 Annual median *Enterococcus* values from 2005 to 2015 for the Jamaica Bay, Sandy Hook, and Staten Island Units of GATE 85

Figure 4-22. Abundance of individual seabeach amaranth (Amaranthus pumilus) plants in the Jamaica Bay Unit of Gateway National Recreation Area between 2005 and 2015 89

Figure 4-23. Abundance of individual seabeach amaranth (*Amaranthus pumilus*) plants in the Sandy Hook Unit of Gateway National Recreation Area between 2005 and 2015. 90

Figure 4-24. Piping plover productivity at Breezy Point, Jamaica Bay Unit of Gateway National Recreation Area between 2011 and 2015 92

Figures (continued)

Page

Figure 4-25. Piping plover productivity in the Sandy Hook Unit of Gateway National Recreation Area between 2005 and 2015 92

Figure 4-26. Abundance of female terrapin individuals at Ruler's Bar Hassock (Jamaica Bay Unit of Gateway National Recreation Area) between 2005 and 2015 (Source: R. Burke, Hofstra University)..... 94

Figure 4-27. Maritime holly forest extent throughout the Sandy Hook Unit, Gateway National Recreation Area, with the section used in the assessment of biological integrity shown in dark green 96

Figure 4-28. Mean Index of Spawning Activity for Plumb Beach (Jamaica Bay Unit of Gateway National Recreation Area) between 2009 and 2016 (Source: Cornell Cooperative Extension)..... 99

Figure 4-29. Mean Index of Spawning Activity for Breezy Point (Jamaica Bay Unit of Gateway National Recreation Area) between 2009 and 2016 (Source: NPS). 99

Figure 4-30. Mean Index of Spawning Activity for Great Kills (Staten Island Unit of Gateway National Recreation Area) for years 2015 and 2016 (Source: Cornell Cooperative Extension)..... 100

Figure 4-31. Mean Index of Spawning Activity for Plumb Island (Sandy Hook Unit of Gateway National Recreation Area) between years 2009 and 2015 (Source: NPS)..... 100

Figure 4-32. Marsh elevation surveys and tidal datum gauging stations in Jamaica Bay of Gateway National Recreation Area..... 102

Figure 4-33. Marsh elevation surveys and tidal datum gauging stations at Sandy Hook Unit of Gateway National Recreation Area. 103

Figure 4-34. Conversion of saltmarsh elevation (in relation to tidal range between Mean Tide Level (MTL) and Mean High Water (MHW) to a percentage score for Jamaica Bay (left) and Sandy Hook (right), Gateway National Recreation Area..... 105

Figure 4-35. Frequency distribution of marsh elevation measurements in Jamaica Bay of Gateway National Recreation Area in 2014 106

Figure 4-36. Frequency distribution of marsh elevation measurements in Sandy Hook of Gateway National Recreation Area in 2014. 107

Figure 4-37. Conversion of impervious surface to percentage score (based on <10% impervious surface threshold)..... 109

Figures (continued)

Page

Figure 4-38. Impervious surfaces throughout the Jamaica Bay Unit of Gateway National Recreation Area. 111

Figure 4-39. Impervious surfaces throughout the Staten Island Unit of Gateway National Recreation Area. 112

Figure 4-40. Impervious surfaces throughout the Sandy Hook Unit of Gateway National Recreation Area. 113

Figure 4-41. Relationship of 1983-2001 tidal epoch water levels to the North American Vertical Datum of 1988, to the 1929 National Geodetic Vertical Datum, and to a representative beach profile at Sandy Hook, Gateway National Recreation Area. 115

Figure 4-42. Location of 16 monuments and their accompanying azimuths at Sandy Hook Unit, Gateway National Recreation Area, used in recording the 2D beach/dune profiles collected as part of the Northeast Coastal and Barrier Network monitoring program 116

Figure 4-43. Location of 11 monuments and their accompanying azimuths on Breezy Point, Jamaica Bay Unit, Gateway National Recreation Area, used in running the 2D beach/dune profiles. Orthophotography provided by NOAA Office for Coastal Management Digital Coast Partnership, 2014 117

Figure 4-44. Location of five monuments and their accompanying azimuths at Plumb Beach, Jamaica Bay Unit, Gateway National Recreation Area, used in running the 2D beach/dune profiles 118

Figure 4-45. Location of nine monuments and their accompanying azimuths at Great Kills, Staten Island Unit, Gateway National Recreation Area, used in running the 2D beach/dune profiles 119

Tables

Page

Table E.1. Condition assessment of resources within Gateway National Recreation Area. xvii

Table 3-1. Vital signs indicators and associated metrics chosen for the Natural Resource Condition Assessment of Gateway National Recreation Area. 51

Table 3-2. Indicator symbols used to indicate condition, trend, and confidence in the assessment. 52

Table 3-3. Example indicator symbols and descriptions of how to interpret them in WCS tables. 53

Table 4-1. Vital signs indicators chosen for the Natural Resource Condition Assessment of air resources within Gateway National Recreation Area. 56

Table 4-2. Air quality metrics, data availability, reference conditions, and condition assessment categories used in the natural resources assessment of Gateway National Recreation Area. 57

Table 4-3. Plant species sensitive to ozone in Gateway National Recreation Area (NPS ARD 2004). 63

Table 4-4. Indicators, metrics, and data sources used to assess water resources of Gateway National Recreation Area 71

Table 4-5. Chlorophyll a criteria for the assessment in Gateway National Recreation Area. 78

Table 4-6. Total nitrogen and total phosphorus multiple threshold criteria used for the assessment of Gateway National Recreation Area (EcoCheck 2011). 81

Table 4-7. Indicators, metrics, and data sources used to assess biological integrity of Gateway National Recreation Area 87

Table 4-8. Indicators, metrics, and data sources used to assess Landscapes dynamics of Gateway National Recreation Area 101

Table 4-9. Locations of tidal datum gauging stations and tidal measurements at Jamaica Bay Unit and Sandy Hook Unit of Gateway National Recreation Area, including mean values for Mean Tide Level (MTL) and Mean High Water (MHW) for each park unit. 104

Table 4-10. Tidal elevation scoring categories for marsh elevation at Jamaica Bay and Sandy Hook, Gateway National Recreation Area. 105

Tables (continued)

Page

Table 4-11. Number of elevation measurements at each site (n), average elevation, average scores, and condition of saltmarshes in Jamaica Bay and Sandy Hook of Gateway National Recreation Area based on elevation between Mean Tide Level (MTL) and Mean High Water (MHW). 108

Table 4-12. Impervious surface area (by surface type), attainment score, and condition for each park unit and overall for Gateway National Recreation Area. 110

Table 4-13. Condition and percent change in distances from monitoring monuments and NAVD88 benchmark at SH3, BP3, PB2, and GK2 from spring 2010 to spring 2016. 120

Table 5-1. Condition assessment of air quality resources within Gateway National Recreation Area. 122

Table 5-2. Key findings, management implications, and recommended next steps for air quality in Gateway National Recreation Area. 123

Table 5-3. Condition assessment of water resources within Gateway National Recreation Area. 124

Table 5-4. Key findings, management implications, and recommended next steps for water resources in Gateway National Recreation Area. 125

Table 5-5. Condition assessment of biological integrity resources within Gateway National Recreation Area. 126

Table 5-6. Key findings, management implications, and recommended next steps for biological integrity in Gateway National Recreation Area. 127

Table 5-7. Condition assessment of landscape dynamics indicators within Gateway National Recreation Area. 128

Table 5-8. Key findings, management implications, and recommended next steps for landscape dynamics in Gateway National Recreation Area. 129

Executive Summary

Background

Bordering the greater New York and New Jersey metropolitan region, Gateway National Recreation Area (GATE) encompasses some of the last remaining open space surrounding New York Harbor. GATE is a complex urban park, preserving approximately 27,025 acres of land and sea across two states, and three New York City boroughs. GATE contains three administrative units: Jamaica Bay, Sandy Hook, and Staten Island. Habitats stretch across open bays, ocean, marsh islands, shorelines, dunes, maritime and successional forests, grasslands, mudflats, and other open spaces. The park includes marinas, greenways, campgrounds, trails, beaches, and picnic grounds within historic landscapes, the remains of important coastal defense works, rare structures from U.S. aviation history, and the oldest continuously operating lighthouse in the United States. Each year, millions come to experience the recreational, natural, and cultural opportunities that stretch throughout the coastline of three New York City boroughs and into northern New Jersey.

It is widely recognized that GATE adds critical open space in an increasingly urbanized region, provides refuge for many species, serves as a migration stop for wildlife, and is an important cultural landscape in the country's history. Despite being surrounded by human development, the park supports a wide variety of animals, including mammals, birds, reptiles, amphibians, and a large diversity of invertebrates. The park is located adjacent to the confluence of the New York Bight and New York Bay, and is the turning point of the primarily east-west oriented coastline of New England and Long Island, and the north-south oriented coastline of the mid-Atlantic coast. This geographic location acts to concentrate marine and estuarine species migrating between the New York Bight portion of the north Atlantic and the Hudson-Raritan Estuary. GATE contains a diverse array of terrestrial and aquatic habitats, including beach, dune and swale, forests, grasslands, shrublands, saltmarshes and mudflats, and brackish and tidal waters.

Natural Resource Condition Assessment

Natural Resource Condition Assessments (NRCAs) are an effort to assess and report on park resource conditions and are meant to complement traditional issue and threat-based resource assessments. NRCAs report on current conditions, trends, critical data gaps, and general level of confidence for a subset of park natural resource indicators. This analysis is designed to help park managers as they think about near-term workload priorities, frame data, and study needs for important park resources, and communicate messages about park natural resources to various audiences. The goal of this report is to deliver science-based information that is credible and has practical uses for a variety of park decision-making, planning, and partnership activities.

Assessment of natural resource condition within GATE was carried out using the Inventory and Monitoring Program Vital Signs ecological monitoring framework. Twenty one metrics were synthesized in four categories: Air Quality, Water Resources, Biological Integrity, and Landscape Dynamics. The assessment of condition was based on the comparison of available data collected between 2010 and 2015 to justified ecological threshold values. When data were not available to

support peer-reviewed ecological thresholds, regulatory and management-based thresholds were used.

Final condition scores for each of the four vital signs categories were calculated based on the percentage of sites or samples that met or exceeded threshold values for each indicator. An indicator attainment score of 100% reflected that the indicator at all sites and at all times met the threshold identified to maintain natural resources. The overall score for the vital sign was determined using the average of each of the metrics use to assess condition. An overall park score could be determined by averaging the score for Air Quality, Water Resources, Biological Integrity, and Landscape Dynamics. Due to a lack of park specific historical data, trends were not assessed within this document.

Overall, the natural resources of Gateway National Recreation Area were in moderate condition.

Air quality was identified as the most highly degraded resource, warranting significant concern. Degraded air quality is a problem throughout the eastern United States and while the causes of degraded air quality are out of the park's control, the specific implications to the habitats and species in the park are less well known. Gaining a better understanding of how reduced air quality is impacting sensitive habitats and species within the park would help prioritize management efforts. Park management efforts to directly improve regional air quality are likely to have minimal impacts, however the park can play a leading role in regional education of the causes and effects of air pollution.

The condition of water resources for the park was assessed as being of moderate concern. Because many of the water resources within the park originate outside of park boundaries, and due to a lack of water quality data for the Staten Island and Sandy Hook Units, it is difficult to identify and manage environmental impacts from pollution within GATE. The park should aim to work collaboratively with local, state, and federal partners to undertake a comprehensive water quality monitoring program.

Biological integrity was assessed as being of moderate concern. American Holly forest extent had a condition of moderate concern. Overall, piping plover, seabeach amaranth, and diamondback terrapin were assessed as significant concern. A fifth indicator, horseshoe crab Index of Spawning Activity was not scored due to a lack of established reference criteria or sufficient long-term historical data, and was included for informational purposes only. Due to a lack of spatial monitoring across all park units, these indicators are all presented with low confidence. Future recommendations involve establishing a standard biological inventory, and selecting species and habitats that are important to park management goals.

Landscape dynamics in the park were assessed as being of moderate concern. Confidence in the assessment was moderate, and would be increased by developing a time-series of high-resolution, classified land cover imagery specific to the park. Data collection priorities also could include the implementation of a noise and light pollution monitoring protocol.

The condition status for each of the 21 metrics evaluated in this report is summarized in the following table (Table E.1.). Red, yellow, and green respectively indicate significant concern, moderate concern, and good condition.

Table E.1. Condition assessment of resources within Gateway National Recreation Area.

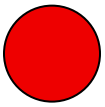
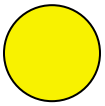
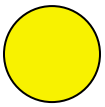
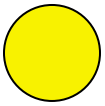
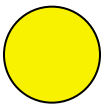
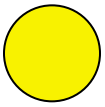
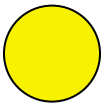
Resource	Indicator	Status	Rationale and Reference Conditions
Air quality	Total sulfur (wet deposition in kg/ha/yr)		Estimated sulfur wet deposition was 2.7 kg/ha/yr (2008-12); condition elevated to significant concern due to sensitive ecosystems; NPS ARD advises against using interpolated values for trends (Data Source: NADP-NTN via AirAtlas)
	Total nitrogen (wet deposition in kg/ha/yr)		Estimated nitrogen wet deposition was 2.9 kg/ha/yr (2008-12); moderate sensitivity to nutrient-enrichment effects; NPS ARD advises against using interpolated values for trend (Data Source: NADP-NTN via AirAtlas)
	Mercury deposition		Mercury/toxics deposition warrants moderate concern. Given that landscape factors influence the uptake of mercury in the ecosystem, the status is based on estimated wet mercury deposition and predicted levels of methylmercury in surface waters. The 2011-2013 estimated wet mercury deposition is moderate at the park, ranging from 8.0 to 8.7 micrograms per square meter and predicted methylmercury concentrations in surface waters is high, ranging from 0.068 to 0.079 nanogram per liter.
	Ozone (ppb)		Interpolated fourth-highest daily maximum eight-hour ozone concentration between 2009 and 2013 for GATE was 76.4 ppb, which resulted in 0% attainment of reference condition.
	Ozone W126		Interpolated W126 value between 2009 and 2013 for GATE was 11.1 ppm-hours, which resulted in 30% attainment of the reference condition, or a condition of moderate condition.
	Atmospheric visibility		Interpolated haze index between 2009 and 2013 for GATE was 6.2 dv, which resulted in 25% attainment of the reference condition, or a condition of moderate concern.
Water resources	Dissolved oxygen		The condition of dissolved oxygen within bottom waters in GATE was very good with 95% attainment of the reference condition.
	Water clarity (secchi depth)		Water clarity condition within GATE is of moderate concern with 65% attainment of the reference condition.

Table E.1 (continued). Condition assessment of resources within Gateway National Recreation Area.

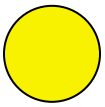
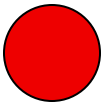
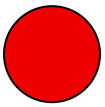
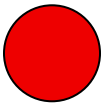
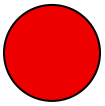
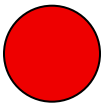
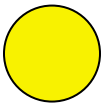
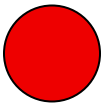
Resource	Indicator	Status	Rationale and Reference Conditions
Water Resources (continued)	Chlorophyll *a*		Chlorophyll *a* is in moderate condition, with 54% attainment of the reference condition. The discharge of several large wastewater treatment plants and high nutrient inputs, in conjunction with long residence times, allows for the proliferation of phytoplankton populations.
	Total nitrogen		Total nitrogen had a score of 19% attainment of reference condition, a condition of significant concern.
	Total phosphorus		Total phosphorus had a score of 7% attainment of reference condition, a condition of significant concern.
	pH		Condition of pH within GATE was good with 98% of data points attaining the reference condition.
	Enterococcus		Current condition of *Enterococcus* parkwide for 2010-2015 is good condition, with 94% attainment of reference condition over all samples.
Biological integrity	Seabeach amaranth abundance		Condition of seabeach amaranth within GATE was assessed as a significant concern. Sites in Jamaica Bay attained the reference condition in zero of six (0%) sampled years (2010-2015). In Sandy Hook, there was a 33.3% attainment of the reference condition, with two of six years attaining the reference condition. Note that abundances are much higher in the Sandy Hook Unit (median of 1220.5) than in the Jamaica Bay Unit (median of 63.5).
	Piping plover		Overall piping plover productivity within GATE had a 16.5% attainment of the reference condition, or a condition of significant concern. At Breezy Point, productivity was below the conservation goal of 1.5 in all years sampled. In the Sandy Hook Unit, productivity two of the six years (2010 and 2011) above the conservation goal.
	Diamondback terrapin		Condition of the diamondback terrapin population within the Jamaica Bay unit of GATE was assessed as being of significant concern, as all sampling years between 2010 and 2015 failed to attain the reference condition (0% attainment). Over the past 10 years of survey data, the population of nesting female diamondback terrapins has decreased by almost 50% (Figure 4.22).

Table E.1 (continued). Condition assessment of resources within Gateway National Recreation Area.

Resource	Indicator	Status	Rationale and Reference Conditions
Biological integrity (continued)	American Holly		Holly forest in Sandy Hook has been assessed at 91% of the historic state, or good condition. It is important to note that the current condition of whole forest is unknown, as only the portion studied by Stalter and McArthur could be assessed in this report.
Landscape dynamics	Surface elevation table (SET)		• Sandy Hook - Average marsh elevation was 0.45 m in 2014 in comparison to the reference tidal datum mean high water elevation of 0.776 m and mean tidal level of 0.249 m, resulting in a 58% attainment score. • Jamaica Bay - Average marsh elevation was 0.55 m in 2014 in comparison to the reference tidal datum mean high water elevation of 0.886 m and mean tidal elevation of 0.886 m and mean tidal level of 0.078 m, resulting in a 58% attainment score.
	% impervious surfaces		Percent impervious surfaces was 14.8, a condition of significant concern.
	% shoreline change		• Sandy Hook - Moderate Condition - Shoreline distance from benchmark in 2016 was 66% of distance in 2011 (net erosion). • Jamaica Bay - Good Condition - Shoreline distance from benchmark in 2016 was >100% of distance in 2011 (net accretion). • Staten Island - Good Condition - Shoreline distance from benchmark in 2016 was 89% of distance in 2011 (net erosion).

Acknowledgments

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List of Abbreviations

ARD—National Park Service Air Resources Division
EPA—United States Environmental Protection Agency
cfu—colony forming unit
CSO—combined sewer overflow
dBA—decibels
dv—deciview
ft—feet
GATE—Gateway National Recreation Area
GIS—geographic information systems
ha—hectare
I&M Program—National Park Service Inventory and Monitoring Program
IAN—Integration & Application Program
kg—kilogram
km—kilometer
km^2—square kilometer
L—liter
m—meter
m^2—square meter
mi—mile
mg—milligram
NAAQS—National Ambient Air Quality Standards
NADP—National Atmospheric Deposition Program
NCBN—Northeast Coastal and Barrier Network
na—nanogram
NLDC—National Land Cover Database
NPS—National Park Service
NRA—National Recreation Area
NRCA—Natural Resource Condition Assessment
NRCS—Natural Resources Conservation Service
NTN—National Trends Network
NYCDEP—New York City Department of Environmental Protection
NYNHP—New York Natural Heritage Program
NYS—New York State
PCB— Polychlorinated biphenyl
PM—particulate matter
ppb—parts per billion
ppm—parts per million
RSS—Resource Stewardship Strategy
UMCES—University of Maryland Center for Environmental Science
U.S.—United States

USFWS—United States Fish and Wildlife Service
USDA—United States Department of Agriculture
USGS—United States Geological Survey
yr—year
μ—micron
μg—microgram

1. NRCA Background Information

Natural Resource Condition Assessments (NRCAs) evaluate current conditions for a subset of natural resources and resource indicators in national park units, hereafter "parks." NRCAs also report on trends in resource condition (when possible), identify critical data gaps, and characterize a general level of confidence for study findings. The resources and indicators emphasized in a given project depend on the park's resource setting, status of resource stewardship planning and science in identifying high-priority indicators, and availability of data and expertise to assess current conditions for a variety of potential study resources and indicators.

NRCAs Strive to Provide…

- *Credible condition reporting for a subset of important park natural resources and indicators*
- *Useful condition summaries by broader resource categories or topics, and by park areas*

NRCAs represent a relatively new approach to assessing and reporting on park resource conditions. They are meant to complement—not replace—traditional issue-and threat-based resource assessments. As distinguishing characteristics, all NRCAs:

- Are multi-disciplinary in scope;[1]
- Employ hierarchical indicator frameworks;[2]
- Identify or develop reference conditions/values for comparison against current conditions;[3]
- Emphasize spatial evaluation of conditions and GIS (map) products; [4]
- Summarize key findings by park areas; and [5]
- Follow national NRCA guidelines and standards for study design and reporting products.

Although the primary objective of NRCAs is to report on current conditions relative to logical forms of reference conditions and values, NRCAs also report on trends, when appropriate (i.e., when the underlying data and methods support such reporting), as well as influences on resource conditions. These influences may include past activities or conditions that provide a helpful context for

[1] The breadth of natural resources and number/type of indicators evaluated will vary by park.

[2] Frameworks help guide a multi-disciplinary selection of indicators and subsequent "roll up" and reporting of data for measures ⇨ conditions for indicators ⇨ condition summaries by broader topics and park areas

[3] NRCAs must consider ecologically-based reference conditions, must also consider applicable legal and regulatory standards, and can consider other management-specified condition objectives or targets; each study indicator can be evaluated against one or more types of logical reference conditions. Reference values can be expressed in qualitative to quantitative terms, as a single value or range of values; they represent desirable resource conditions or, alternatively, condition states that we wish to avoid or that require a follow-up response (e.g., ecological thresholds or management "triggers").

[4] As possible and appropriate, NRCAs describe condition gradients or differences across a park for important natural resources and study indicators through a set of GIS coverages and map products.

[5] In addition to reporting on indicator-level conditions, investigators are asked to take a bigger picture (more holistic) view and summarize overall findings and provide suggestions to managers on an area-by-area basis: 1) by park ecosystem/habitat types or watersheds, and 2) for other park areas as requested.

understanding current conditions, and/or present-day threats and stressors that are best interpreted at park, watershed, or landscape scales (though NRCAs do not report on condition status for land areas and natural resources beyond park boundaries). Intensive cause-and-effect analyses of threats and stressors, and development of detailed treatment options, are outside the scope of NRCAs.
Due to their modest funding, relatively quick timeframe for completion, and reliance on existing data and information, NRCAs are not intended to be exhaustive. Their methodology typically involves an informal synthesis of scientific data and information from multiple and diverse sources. Level of rigor and statistical repeatability will vary by resource or indicator, reflecting differences in existing data and knowledge bases across the varied study components.

The credibility of NRCA results is derived from the data, methods, and reference values used in the project work, which are designed to be appropriate for the stated purpose of the project, as well as adequately documented. For each study indicator for which current condition or trend is reported, we will identify critical data gaps and describe the level of confidence in at least qualitative terms. Involvement of park staff and National Park Service (NPS) subject-matter experts at critical points during the project timeline is also important. These staff will be asked to assist with the selection of study indicators; recommend data sets, methods, and reference conditions and values; and help provide a multi-disciplinary review of draft study findings and products.

NRCAs can yield new insights about current park resource conditions, but, in many cases, their greatest value may be the development of useful documentation regarding known or suspected resource conditions within parks. Reporting products can help park managers as they think about near-term workload priorities, frame data and study needs for important park resources, and communicate messages about current park resource conditions to various audiences. A successful NRCA delivers science-based information that is both credible and has practical uses for a variety of park decision making, planning, and partnership activities.

Important NRCA Success Factors

- *Obtaining good input from park staff and other NPS subject-matter experts at critical points in the project timeline*
- *Using study frameworks that accommodate meaningful condition reporting at multiple levels (measures ⇨ indicators ⇨ broader resource topics and park areas)*
- *Building credibility by clearly documenting the data and methods used, critical data gaps, and level of confidence for indicator-level condition findings*

However, it is important to note that NRCAs do not establish management targets for study indicators. That process must occur through park planning and management activities. What an NRCA can do is deliver science-based information that will assist park managers in their ongoing, long-term efforts to describe and quantify a park's desired resource conditions and management

targets. In the near term, NRCA findings assist strategic park resource planning[6] and help parks to report on government accountability measures.[7] In addition, although in-depth analysis of the effects of climate change on park natural resources is outside the scope of NRCAs, the condition analyses and data sets developed for NRCAs will be useful for park-level climate-change studies and planning efforts.

NRCAs also provide a useful complement to rigorous NPS science support programs, such as the NPS Natural Resources Inventory & Monitoring (I&M) Program.[8] For example, NRCAs can provide current condition estimates and help establish reference conditions, or baseline values, for some of a park's vital signs monitoring indicators. They can also draw upon non-NPS data to help evaluate current conditions for those same vital signs. In some cases, I&M data sets are incorporated into NRCA analyses and reporting products.

NRCA Reporting Products…

Provide a credible, snapshot-in-time evaluation for a subset of important park natural resources and indicators, to help park managers:

- *Direct limited staff and funding resources to park areas and natural resources that represent high need and/or high opportunity situations* ***(near-term operational planning and management)***
- *Improve understanding and quantification for desired conditions for the park's "fundamental" and "other important" natural resources and values* ***(longer-term strategic planning)***
- *Communicate succinct messages regarding current resource conditions to government program managers, to Congress, and to the general public* ***("resource condition status" reporting)***

Over the next several years, the NPS plans to fund an NRCA project for each of the approximately 270 parks served by the NPS I&M Program. For more information visit the NRCA Program website.

[6] An NRCA can be useful during the development of a park's Resource Stewardship Strategy (RSS) and can also be tailored to act as a post-RSS project.

[7] While accountability reporting measures are subject to change, the spatial and reference-based condition data provided by NRCAs will be useful for most forms of "resource condition status" reporting as may be required by the NPS, the Department of the Interior, or the Office of Management and Budget.

[8] The I&M program consists of 32 networks nationwide that are implementing "vital signs" monitoring in order to assess the condition of park ecosystems and develop a stronger scientific basis for stewardship and management of natural resources across the National Park System. "Vital signs" are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values.

2. Introduction and Resource Setting

2.1 History and enabling legislation

Gateway National Recreation Area (GATE) is a complex urban park, preserving 27,025 acres of land and sea across two states and three New York City boroughs. The park was established

> *…in order to preserve and protect for the use and enjoyment of present and future generations an area possessing outstanding natural and recreational features.*

The park's establishing legislation was signed into law in October 1972, and signified the culmination of years of effort by citizens, planners, activists, the National Park Service (NPS), and members of Congress. A "national recreation area" was a reflection of an ongoing evolution of the national park concept, from a system of parks preserving the natural wonders and scenic masterpieces in relatively remote and secluded areas, to a system that included the development of several urban-edge parks, balancing natural and cultural resources with recreational opportunities. The political climate of the 1960s recognized that the majority of the nation was living in urban areas, where many outdoor recreation opportunities were too distant for regular use. The ability to bring "parks to people" was assisted by a shift in federal policy allowing for federal money to acquire shoreline area for park designation. Within the National Park System, there are 17 designated National Recreation Areas (NRAs). Five of these NRAs, including GATE, are located near major population centers. Such urban parks combine scarce open spaces with the preservation of historic resources and important natural areas in locations that can provide outdoor recreation for large numbers of people (NPS 2016).

GATE was established by an act of Congress and the legislation defined the original scope and vision for the park (NPS 2016b). Congress envisioned GATE as a ring of green space and shoreline around the New York outer harbor for water-based outdoor recreation. The majority of recreation opportunities would focus on beach activities, primarily sunbathing and swimming. The park was created from public lands including United States Army and Navy installations, New York City parks, and New Jersey state lands. The Park's enabling legislation in concert with the Organic Act of 1916 are the guiding legislation for GATE.

The Organic Act that established the National Park Service (NPS) on August 25, 1916 provides the primary mandate NPS has for natural resource protection within all national parks. It states,

"the Service thus established shall promote and regulate the use of the Federal areas known as national parks, monuments, and reservations… by such means and measures as conform to the fundamental purpose of the said parks, monuments, and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wildlife 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."

Gateway National Recreation Area was established in U.S. Code Title 16, Chapter 1, Subchapter 87 (LXXXVII) dated May, 1972. The legislation states,

“In order to preserve and protect for the use and enjoyment of present and future generations an area possessing outstanding natural and recreational features, the Gateway National Recreation Area (hereinafter referred to as the “recreation area”) is hereby established.”

This piece of legislation established the composition and boundaries of GATE as four units: Jamaica Bay Unit, Staten Island Unit, Sandy Hook Unit, and Breezy Point Unit. The Breezy Point Unit was later combined with the Jamaica Bay Unit, resulting in the three units as they exist today. Bordering the greater New York and New Jersey metropolitan region, GATE encompasses some of the last remaining open space surrounding New York Harbor (NPS 1976). Park access via public transportation was an important element in the formation of the park, and it was estimated that 10% of the U.S. population lived within a 2-hour drive from a GATE site (NPS 2015b). The original vision for GATE included a ferry service that would link park sites, and affordable rates to ensure that the parks are accessible to low-income residents of the region and attractive to large numbers of visitors. Some of the public transportation and water access goals originally outlined in the park plan have yet to be realized.

Today, GATE is primarily composed of open bays, ocean, marsh islands, shoreline, dunes, maritime and successional forests, grasslands, mudflats, and other open spaces. The park includes marinas, greenways, campgrounds, trails, beaches, and picnic grounds within historic landscapes, the remains of important coastal defense works, rare structures from U.S. aviation history, and the oldest continuously operating lighthouse in the United States. Each year millions come to experience the recreational, natural, and cultural opportunities that stretch throughout the coastline of three New York City boroughs and into northern New Jersey.

2.1.1 Geographic setting

Park description

Gateway National Recreation Area is located in the Northeast Region of the National Parks Service, a NPS region that ranges from the northern border of Maine to the southern border of Virginia (NPS 2016) (Figure 2-1). GATE contains three administrative units: Jamaica Bay, Sandy Hook, and Staten Island (Figure 2-2). The park has historically attracted close to 10 million visitors each year to see its historic monuments, beautiful beaches, and thriving wildlife populations (NYHP 2016b). Established in 1972, GATE overlaps two states and includes units in three New York City boroughs: Queens, Brooklyn and Staten Island (NPS 2016a).

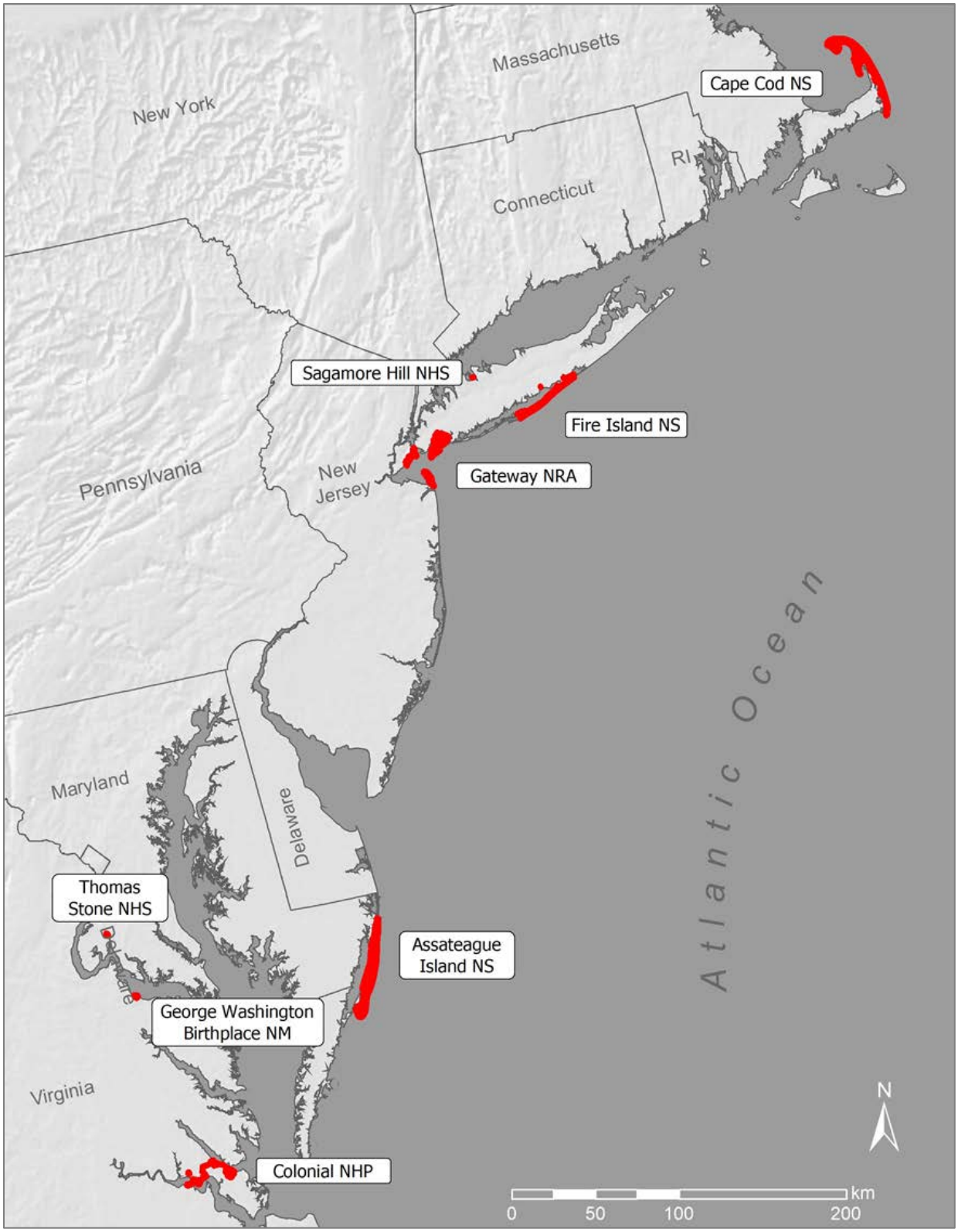


Figure 2-1. Location of Gateway National Recreation Area in the Northeast Region of the United States. Red denotes park boundaries of National Park Units included in the Northeast Coastal and Barrier Network Inventory and Monitoring Network (Source: NPS NCBN).



Figure 2-2. Gateway National Recreation Area park units (Adapted from NPS).

Within the legislative boundary, GATE includes approximately 27,025 acres and extends into adjacent waters, including the Atlantic Ocean, Jamaica Bay, Raritan Bay, and Upper and Lower New York Bay. The park manages 21,680 acres of land and waters, the additional 5,345 acres are either managed by other federal agencies, owned by New York City, or privately held by entities such as Breezy Point Cooperative, Broad Channel, and Roxbury. These three distinct geographic areas are linked together by similar types of resources and recreation uses, yet retain distinctive characteristics that make them special (NPS 2014c).

Jamaica Bay

The Jamaica Bay Unit is the largest of the three units and is one of the largest expanses of open-space in the region, consisting of over 19,000 acres of land, bay, estuarine, and ocean waters within two boroughs of New York: Brooklyn, and Queens (Figure 2.3).

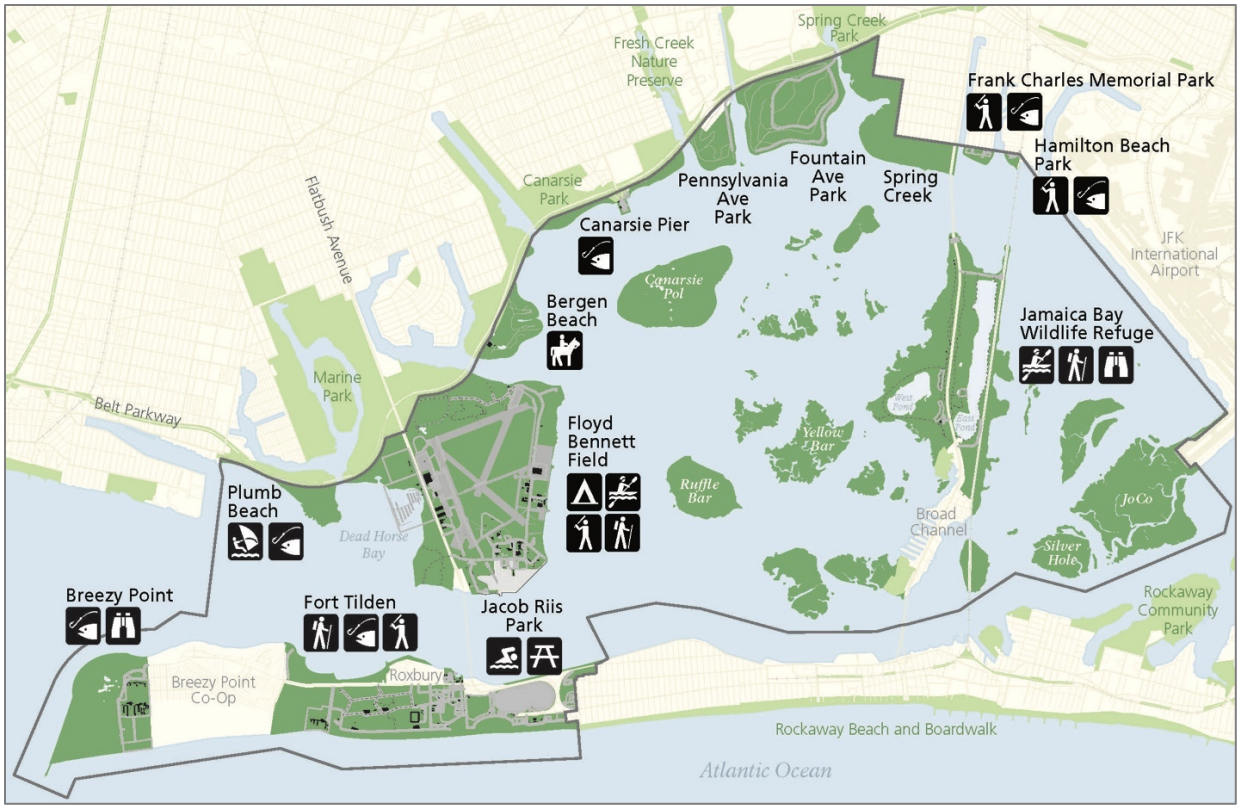


Figure 2-3. Jamaica Bay Unit of Gateway National Recreation Area (Source: NPS).

Until the late 1800's Jamaica Bay was primarily a wilderness area, supporting a prosperous shellfish and fishing industry. In 1879, the Secretary of War, together with the city government of New York, petitioned to establish Jamaica Bay as a major seaport. As a result, broad shipping channels were dredged, and dredge spoils were used to fill in marsh and create land for docks and piers. In 1943, the marsh was further filled as construction for Idlewild Airport (now John F. Kennedy International Airport) began (USGS 2015). Jamaica Bay became part of GATE in 1974, two years after its establishment as a National Recreation Area. The unit includes: ***Plumb Beach***, ***Floyd Bennett Field***, ***Bergen Beach***, ***Canarsie Pier***, ***Pennsylvania Avenue*** and ***Fountain Avenue Parks***, ***Frank Charles Memorial Park***, ***Hamilton Beach***, ***Spring Creek***, ***Jacob Riis Park***, ***Fort Tilden***, ***Breezy Point Tip***, and the ***Jamaica Bay Wildlife Refuge*** (NPS 2014c):

- ***Plumb Beach*** is a stretch of shoreline, tidal mudflats, low saltmarsh areas, a tidal lagoon, a dune system, and woodland thickets at the entrance to Gerritsen Creek adjacent to the Belt Parkway. This area is a popular location for wind-related activities such as windsurfing and kiteboarding and provides important habitat for horseshoe crabs and shorebirds (NPS 2014c).
- ***Floyd Bennett Field*** was New York City's first municipal airport; later it became a World War II naval air station. Today this area includes over 1,300 acres of grassland, saltmarshes, tidal mudflats, a marina, and the former airfield, including a control tower and terminal that is now the William Fitts Ryan Visitor Center (Ryan Visitor Center). The open fields provide important habitat for many grassland bird species, including Grasshopper sparrows

(*Ammodramus savannarum*), Meadowlarks (*Sturnella*), American kestrels (*Falco sparverius*), and Northern harriers (*Circus cyaneus*) (NPS 2014c). The northern-most corner of Floyd Bennett Field, known as the North 40, includes a wooded trail system and several ponds, which were built with taxpayer funds designated to "Return-a-Gift-to-Wildlife" (NPS 2004). Floyd Bennett Field hosts a variety of recreational opportunities, including an urban camping program, as well as biking, jogging and running along the Jamaica Bay Greenway, a multi-use path. In addition, several privately owned concessionaires of the Department of the Interior provide additional recreational opportunities: Aviator Sports Events operates a multipurpose use field house with ice arenas, a gymnastics center and other indoor sports, as well as outdoor sports fields and event spaces: Jamaica Bay Riding Academy, and Brooklyn Golf Center (NPS 2014c).

- ***Canarsie Pier***, which extends into Jamaica Bay, includes a historic pier used for fishing, picnicking, and community events. The protected shoreline surrounding the pier supports valuable saltmarsh habitat (NPS 2004), and the adjacent natural area provides access to the bay for kayaking and boating (NPS 2014c).
- ***Bergen Beach***, extends east from Floyd Bennett Field to Canarsie Pier. Historically the area housed an amusement park, but today, it is a natural soft-sand beach surrounded by low saltmarsh. Included on the property is the Jamaica Bay Riding Academy, a concession that provides visitors with the opportunity to ride horses in a riding arena, on trails, and along the beach (NPS 2014c; NPS 2004).
- The ***Pennsylvania Avenue*** and ***Fountain Avenue Parks*** are capped and sealed landfills that are undergoing transformation into natural areas (NPS 2014c). These two Parks total 407 acres of native grasses (*Andropogon gerardii* or bluestem) and plantings of cedars, oak and pine (RPA 2012). Their transformation from eyesores into natural areas has been a collaboration between New York City and the National Park Service, and creating trails and viewing platforms may allow public access in the future (RPA 2012).
- ***Spring Creek*** is an undeveloped upland, wetland and marsh area that is dominated by *Phragmites australis* (NPS 2014c). The Spring Creek South Storm Resilience and Ecosystem Restoration Project is in the planning phase. This project will restore over 225 acres of wetland and coastal forest and create a protective berm to reduce the risk of storm damage and flooding in the adjacent community (NY DEC 2017c).
- ***Jamaica Bay Wildlife Refuge*** is the only wildlife refuge administered by the National Park Service. All other national refuges fall under the administration of the United States Fish & Wildlife Service. Jamaica Bay Wildlife Refuge is 9,155 acres of one of the most significant bird sanctuaries in the Northeastern United States and has seen more than 330 species of birds visit in the past twenty-five years (NYHP 2016a). The varied natural habitats of Jamaica Bay include a saltmarsh, upland field and woods, several fresh and brackish water ponds, and an expanse of bay that support not only a diverse bird community, but also populations of native reptiles, amphibians, and over 60 species of butterflies.

- ***Frank Charles Memorial Park*** and ***Hamilton Beach*** were originally created as municipal parks and include playgrounds and ball fields along with shoreline access for fishing, as well as some sensitive marshlands (NPS 2014c).
- ***Jacob Riis Park Historic District*** is a cultural landscape that includes beaches for swimming and sunbathing, basketball courts, paddle tennis, playgrounds, a golf course, a historic bathhouse, and a mile-long cement boardwalk (NPS 2014c).
- ***Fort Tilden Historic District*** is a former military site that overlooks the approach to New York Harbor and today includes athletic fields, hiking trails, an arts center, a theater, and an observatory deck on a historic battery offering spectacular views of Jamaica Bay, New York Harbor, and the Manhattan skyline. Dunes, a maritime forest, freshwater ponds, and coastal defense resources including Battery Harris and the Nike Missile Launch Site are also found here (NPS 2014c).

Staten Island

Located in Staten Island, New York, the Staten Island Unit contains 6.7 miles of National Park Service protected coastline and a total 2,100 acres of protected land (NPS 2013b, NPS 2013c) (Figure 2-4).



Figure 2-4. Staten Island Unit of Gateway National Recreation Area (Source: NPS).

The Staten Island Unit ecompasses bay waters, shoreline, and several multi-use areas including ***Great Kills Park***, ***World War Veterans Park*** at Miller Field, ***Fort Wadsworth***, ***Swinburne Island*** and ***Hoffman Island*** (NPS 2014c):

- ***Great Kills Park*** (Great Kills being dutch for "many creeks") is an ecologically diverse open space for visitors to view the harbor and boaters and fisherman to enjoy a piece of the wild. Great Kills Park occupies 523 acres in the vicinity of the Raritan and Lower bays of Great Kills Harbor and has a seasonal swimming beach, a multi-use path, and boat launch and marina (NPS 2015c).
- ***Miller Army Airfield Historic District*** was operated by the Army from 1919 to 1969 as the only Air Coast Defense Station on the east coast. The park now provides open space for picnicking, fields for sports, and contains a community garden (NPS 2015c).
- ***Fort Wadsworth Historic District*** was a prime location for defending New York Harbor due to it's location at Verrazano Narrows - the thinnest waterway that ships are required to traverse in order to enter New York Harbor. The site occupies 226 acres of rocky beach, turf, vines and successional woodlands on the northeastern shore of Staten Island and offers urban camping sites and is a popular destination for birding and fishing (NPS, 2008, NPS 2015c).
- ***Swinburne Island and Hoffman Island*** are both man-made islands in lower New York Bay. Historically, the islands housed hospitals where immigrants were quarantined prior to entering into the port of New York, but are now off limits to visitors. The islands provide bird nesting habitat, and harbor seals (*Phoca vitulina*) have been wintering on and around the islands (NPS 2014c).



Fort Wadsworth in the Staten Island Unit. Photo: Peter Miller.

Sandy Hook

The Sandy Hook Unit (4,688 acres) consists of the ***Fort Hancock and Sandy Hook Proving Ground National Historic Landmark District*** and includes natural areas and shorelines adjacent to the Atlantic Ocean and Sandy Hook Bay in Monmouth County, New Jersey (NPS 2014c) (Figure 2-5).



Figure 2-5. The Sandy Hook Unit of Gateway National Recreation Area (Source: NPS).

The Sandy Hook peninsula encompasses 6.1 miles of National Park Service protected coastline and includes miles of beaches and trails, a globally rare maritime holly forest, saltmarshes, and opportunities for swimming, fishing, biking, windsurfing, observing wildlife, and other educational and recreational activities (NPS 2014c). Today, over 100 buildings and fortifications remain from the long-term military installations. Historic coastal defense features include multiple historic batteries and the Nike Missile Radar and Launch Sites. The unit is also the site of the historic Spermaceti Cove Life Saving Station and the Sandy Hook Lighthouse, which is the nation's oldest continually operated lighthouse - it has been guiding ships into the harbor since 1764 (NPS 2014c).

As a natural barrier to New York Harbor, Sandy Hook has a long military history. The armed fortifications of Fort Hancock were built at the end of the 19th century following the Spanish American War, and provided coastal defense for New York Harbor from 1895 until 1974. The open space around the Fort was also used as a Proving Ground from 1874 and 1919.Fort Hancock was the site of Nike nuclear missile batteries built in the 1950s. In 1974, the Fort was decommissioned and given to the National Park Service for inclusion into GATE (USGS 2015). Today, both the National Park Service and the United States Coast Guard manage areas of the peninsula (NPS 2014c).

The three park units, although geographically separate from each other, share similarities. Sandy Hook, Jamaica Bay, and Staten Island all contain a large portion of shoreline directly connected to New York Harbor and also house historic buildings, landscapes, and archeological sites that are monuments to America's coastal defenses from the Revolutionary War to the Cold War (NPCA 2016a). Although similar in many ways, the park units are also distinct and therefore provide a diversity of experience and settings within GATE.



The Sandy Hook lighthouse, the nation’s oldest continually operating lighthouse. Photo: Jim Lukach.

2.1.2 Land use

Gateway National Recreation Area is in the middle of the New York - New Jersey metropolitan area. The uplands around the Jamaica Bay Unit, including much of the Rockaway Peninsula, are dominated by urban-residential, commercial and industrial development. Jamaica bay itself has been altered by dredging, filling, and development, including the construction of Floyd Bennett Field and John F. Kennedy Airport. About 18.75 acres (equivalent to 75% of the original 25 square miles) of wetlands in Jamaica Bay have been filled, mostly around the perimeter of the bay, and extensive areas of the bay have been dredged for navigation channels and to provide fill for the airports and other construction projects (U.S. FWS 1997) (Figure 2-6). The Staten Island Unit, although not as heavily developed as the Jamaica Bay Unit, is surrounded by medium intensity development (NLCD 2011) (Figure 2-7). The Sandy Hook Unit is surrounded by the least development, although the surrounding areas are still densely populated (NLCD, 2011) (Figure 2-8).

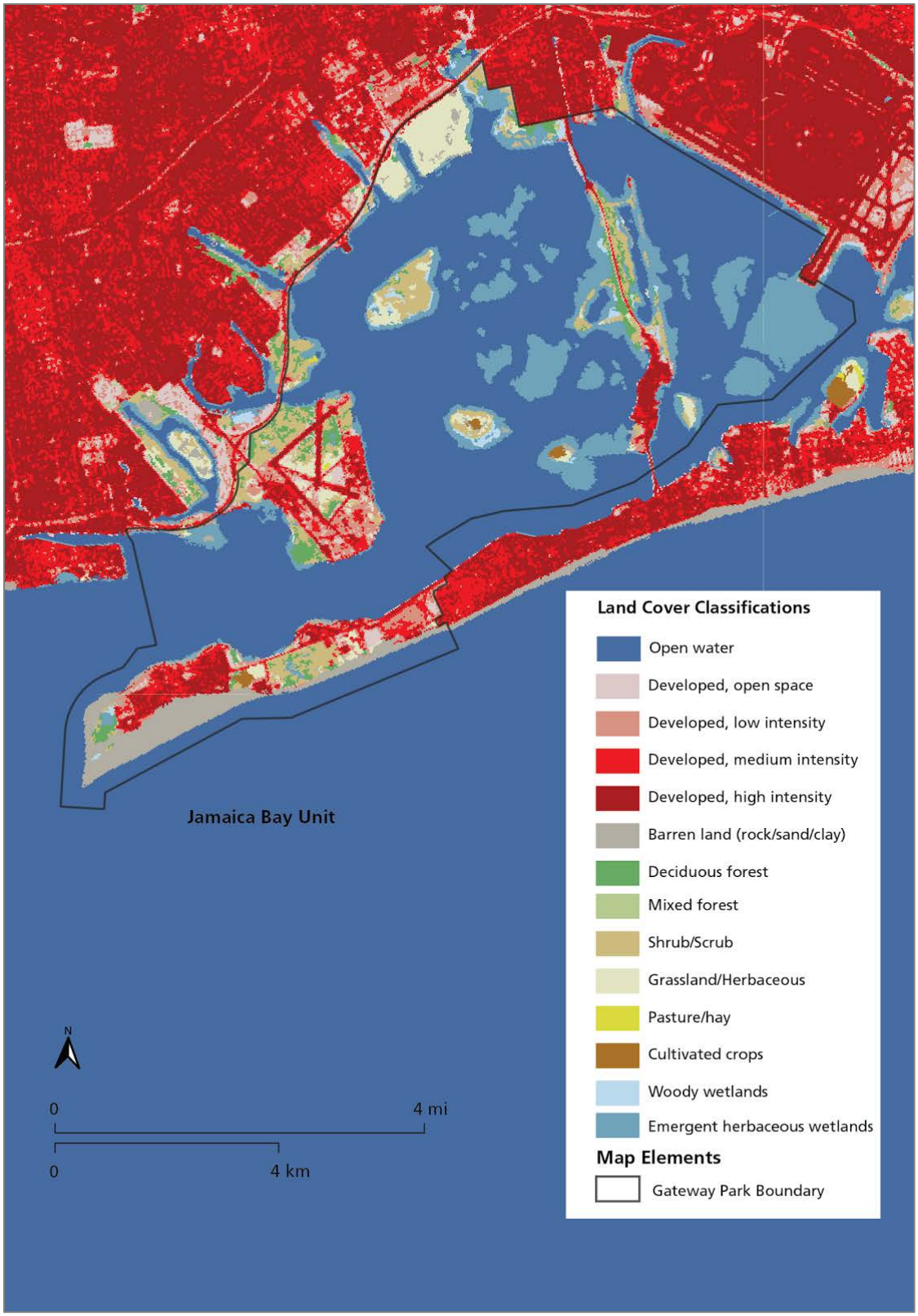


Figure 2-6. Land use surrounding the Jamaica Bay Unit of Gateway National Recreation Area (Source: NLCD 2011).

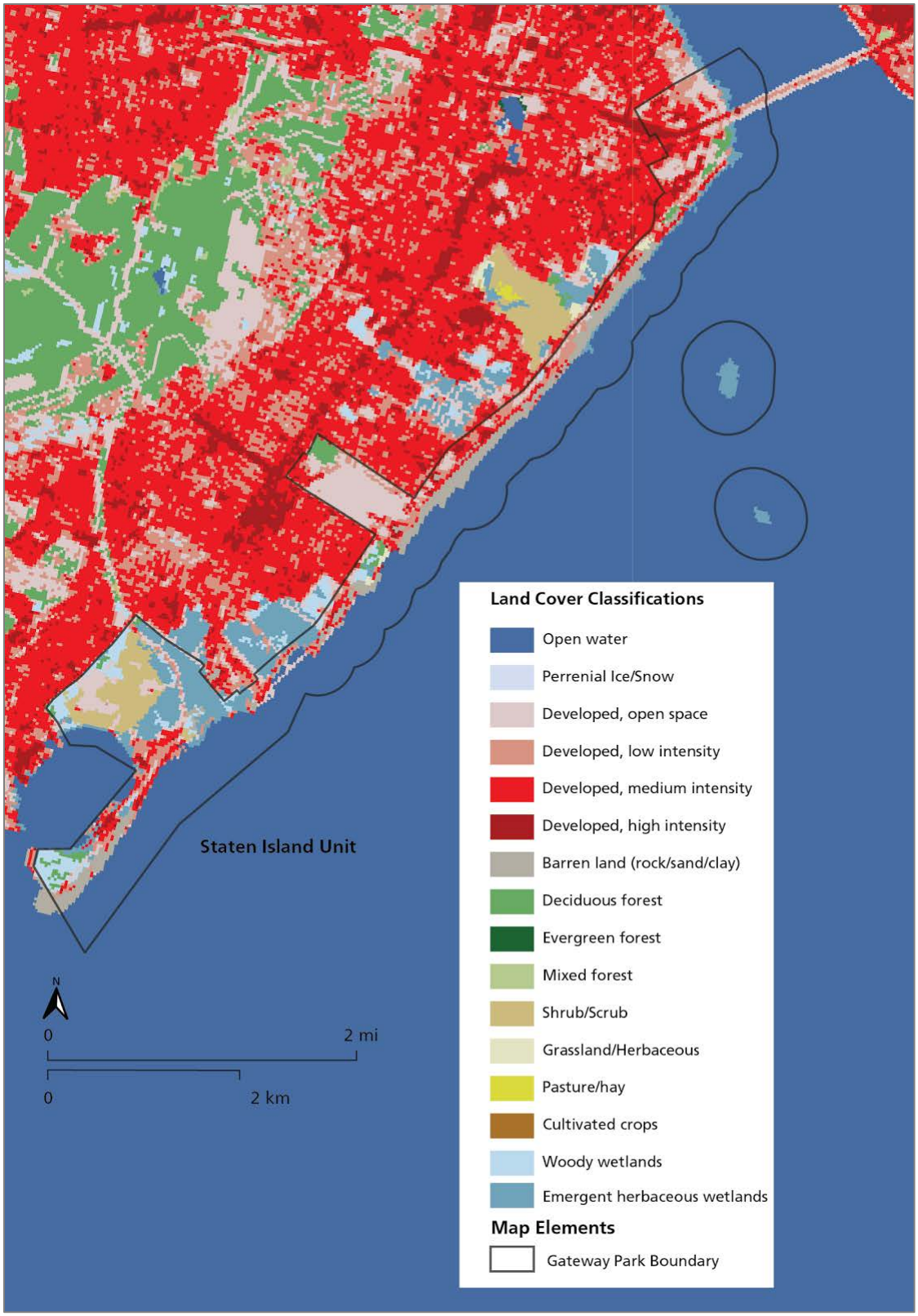


Figure 2-7. Land use surrounding the Staten Island Unit of Gateway National Recreation Area (Source: NLCD 2011).

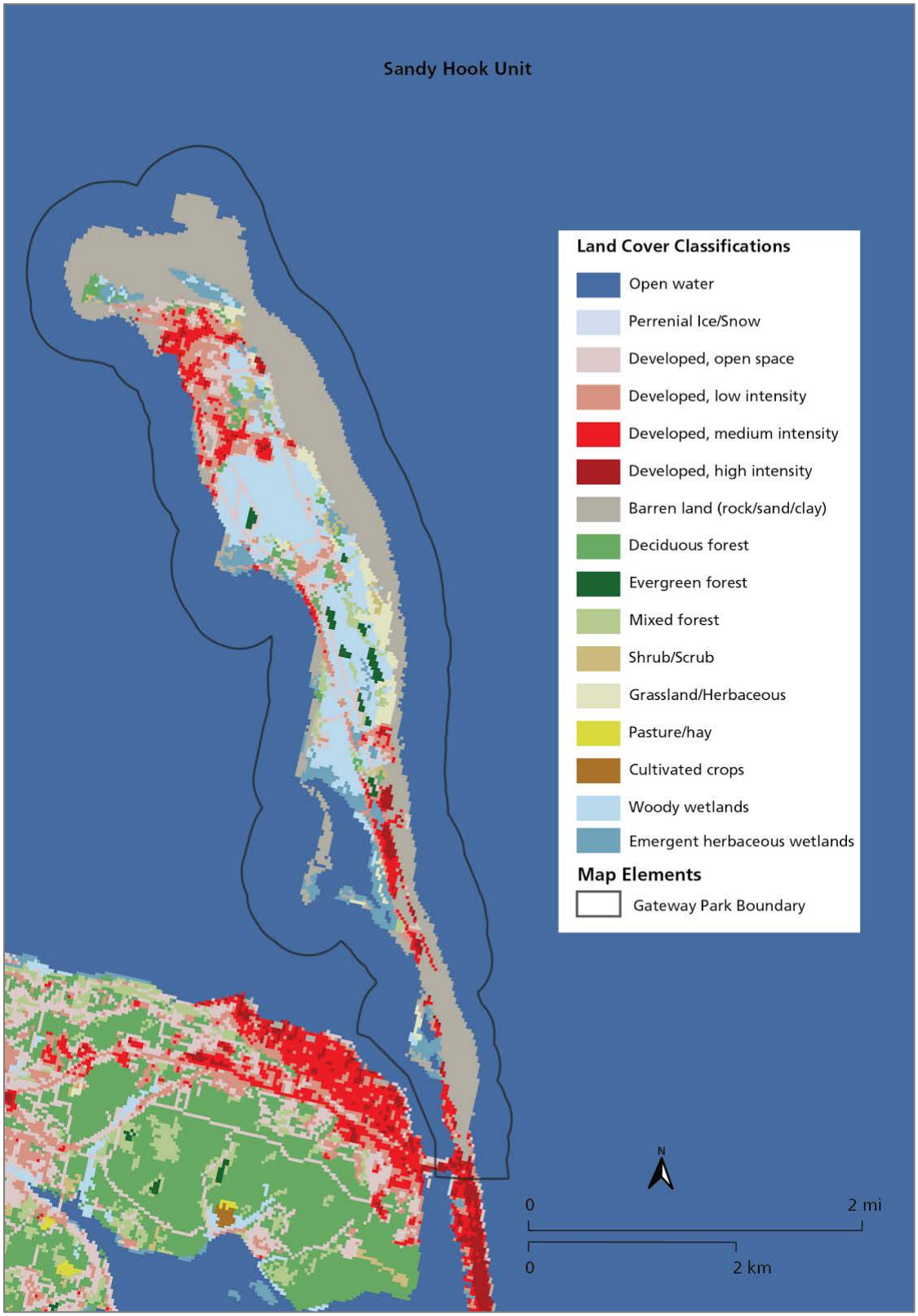


Figure 2-8. Land use surrounding the Sandy Hook Unit of Gateway National Recreation Area (Source: NLCD 2011).

2.1.3 Road density

Not only is GATE surrounded by development, all park units are very dense with roads. Roads and other habitat-dividing cuts, such as utility corridors, can act as barriers to wildlife movement, increase habitat fragmentation, and contribute to percent impervious surface within the park. High road density, or the presence of a large roadway, can decrease the quality of wildlife habitat by fragmenting it, and increases the risk of wildlife mortality by vehicle strike (Forman *et al.* 1995). Studies have shown the existence of roads alone has a greater effect on species, habitat, water and soil than vehicle use on the roads (Forman and Hersperger 1996). Road densities higher than 1.5 km/km^2 have been shown to impact turtle populations, while densities higher than 0.6 km/km^2 can impact natural populations of large vertebrates (Forman *et al.* 1995; Gibbs and Shriver 2002; Steen and Gibbs 2004). Road density inside GATE is currently 5.2 km/km^2 (analysis performed for this assessment). Figures 2-9 through 2-11 show roads inside each individual park unit. Although road density was not evaluated as an indicator, it was included in analysis of impervious surfaces in Chapter 4.



Figure 2-9. Roads located within the Jamaica Bay Unit of Gateway National Recreation Area (Source: NPS).



Figure 2-10. Roads located within the Staten Island Unit of Gateway National Recreation Area (Source: NPS).

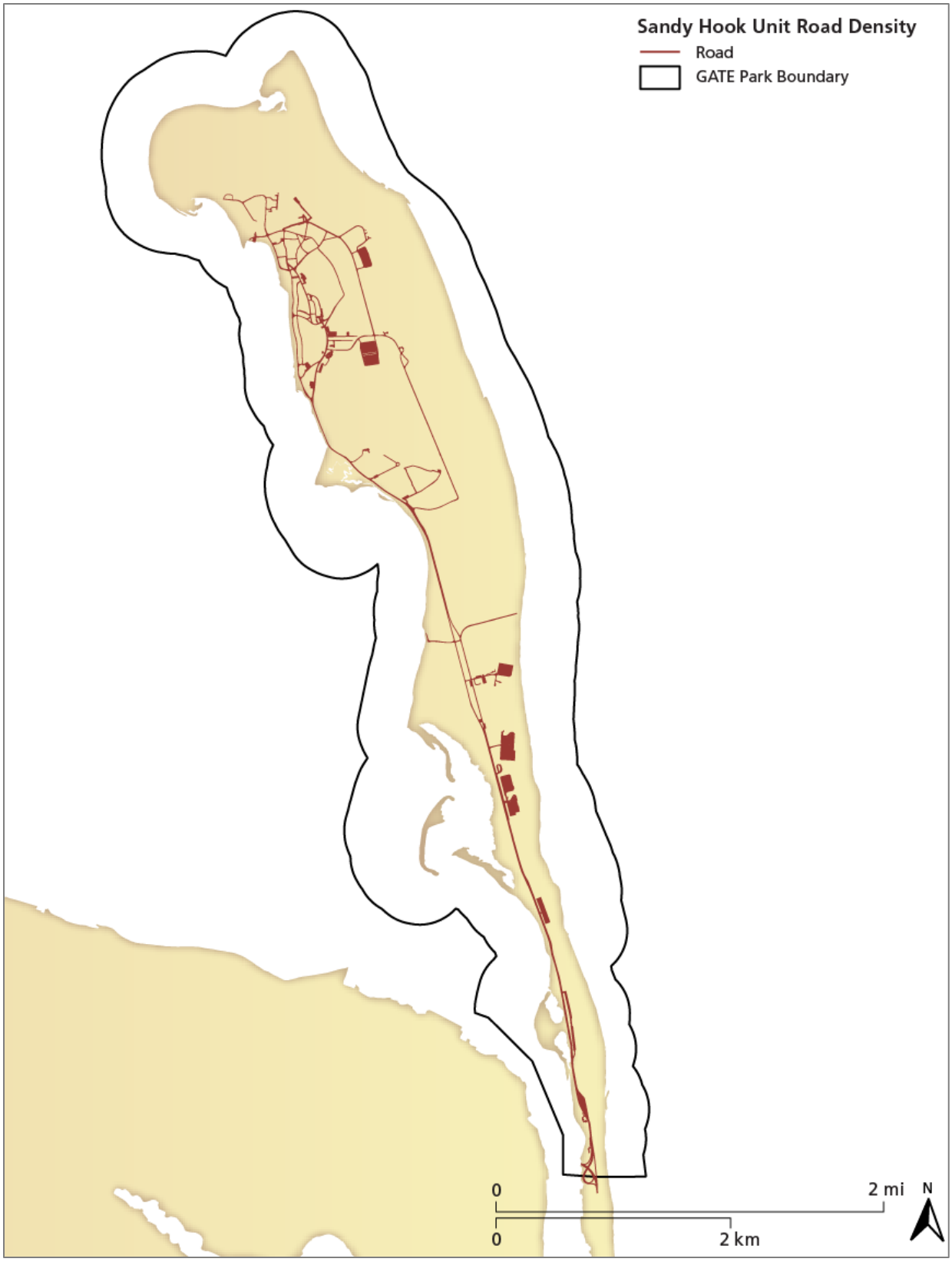


Figure 2-11. Roads located within the Sandy Hook Unit of Gateway National Recreation Area (Source: NPS).

2.1.4 Population

GATE was established by the U.S. Congress to preserve and protect the resources within its boundaries, but also to provide natural areas and recreational opportunities to the large percentage of the nation's population living near the park. GATE lies within the New York Metropolitan Area, the most populous city in the United States, and it is estimated that 10% of the U.S. population lives within a 2-hour drive from a GATE site (NPS 1976). As of July 2015, the U.S. Census Bureau had estimated New York City's population at 8,550,405. This was an increase of 375,300 residents (4.6%), since the April 2010 census. The city had not experienced such a high pace of growth since the 1920s (NYC Department of Planning 2013). Since GATE was established in 1972, New York City's population has fluctuated, although the city's metropolitan population steadily grew from 17.1 million to 20.2 million people in this time period (U.S. Census 2015). Population density directly adjoining GATE is varied, although is almost always greater than 2,000 people per kilometer squared and sometimes as high as 10,000 people per kilometer squared (Figure 2-12). Figure 2.12 shows population density not directly adjoining GATE, but just 3 miles away in Queens can sometimes be higher than 40,000 people per kilometer squared. Park units are located within four counties: Richmond County, Queens County and Kings County in New York State, and Monmouth County in New Jersey. Each of these counties are highly populated and continue to grow annually. From 2000 to 2010, Richmond county grew by 5.36% to a total population of 474,558 (U.S. Census 2016). Queens County grew by 0.27% to 2,230,722; Kings county grew 1.54% to 2,504,700, and Monmouth County grew 2.45% to 630,380 (U.S. Census 2016).

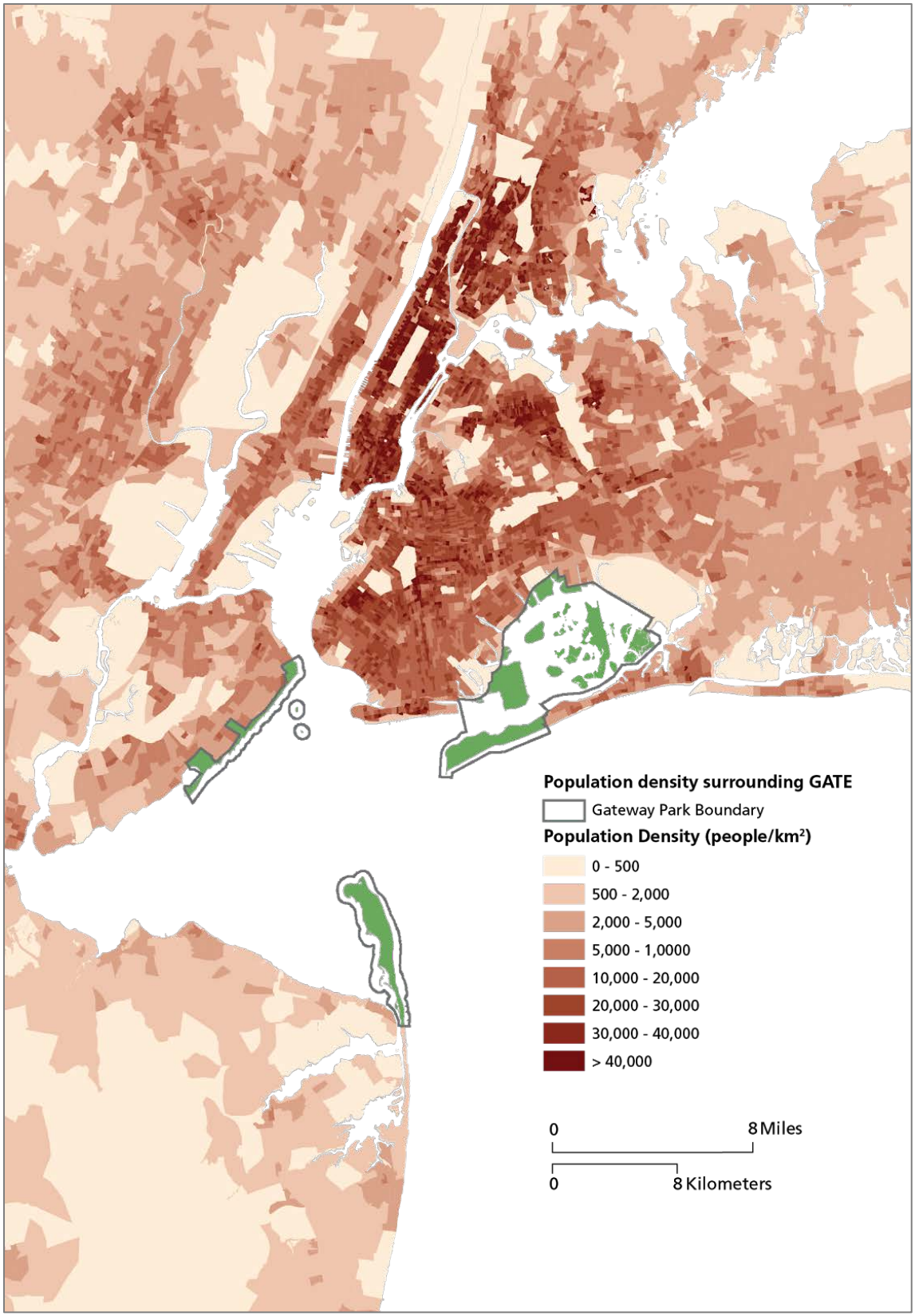


Figure 2-12. Population density surrounding Gateway National Recreation Area (Source: NPScape Landscape Monitoring Project found here: https://science.nature.nps.gov/im/monitor/npscape/).

2.1.5 Climate

Weather and climate are key drivers of ecological structure and function, and global and regional scale climate variations can have major impacts on natural systems (Chapin et al. 1996; Schlesinger 1997; Jacobson et al. 2000; Bonan 2002). These variations can influence the fundamental properties of ecological systems, such as soil-water relationships, plant-soil processes, and nutrient cycling, as well as disturbances rates and intensity (Davey et al. 2006). GATE experiences a humid continental climate moderated by its proximity to the Atlantic Ocean. Temperatures are moderate in the spring and fall, but range from the high 90's in the summer to snow and sleet in winter. There are no distinct dry or wet seasons in the region, but minimum precipitation occurs in the winter season (monthly average of 3.5 inches), and average highs within the summer (4 inch monthly average) (U.S. Climate Data 2017). Monthly winter snow accumulations range between 3 to 10 inches, however these amounts may occasionally exceed 20 inches as a result of recurring coastal nor'easters. Tropical storms and hurricanes occasionally introduce large-scale disturbances within GATE (Davey et al. 2006), and park resources are subject to tidal flooding during storm surges from winds (NYCDEP 2007).

Significant positive trends in temperature and precipitation have been reported over the region. Future climate change models in the eastern U.S. are expected to influence the intensity and frequency of ice storms, tropical cyclones, and other extreme storm events in the region (Rosenzweig and Solecki 2015).

2.1.6 Visitation statistics

GATE was the third most visited unit in the National Park Service system in the late 2000's (Thornberry-Ehrlich, 2011), but in the past 5 years (2011-2015) recreational visits to GATE have averaged 6,287,787 people per year which leaves it as the 6th most visited park unit (Figure 2-13 and Figure 2-14) (NPS 2016e) (NPS 2014c). Visitation to the park is highest from May to September, reflecting warmer weather during the spring and summer months and the ample recreation opportunities offered at GATE. Visitation during 2012 was most likely down due to Superstorm Sandy effecting park hours and the public's ability to visit. Many visitors to GATE engage in traditional beach activities such as swimming, sunbathing, and sport fishing.

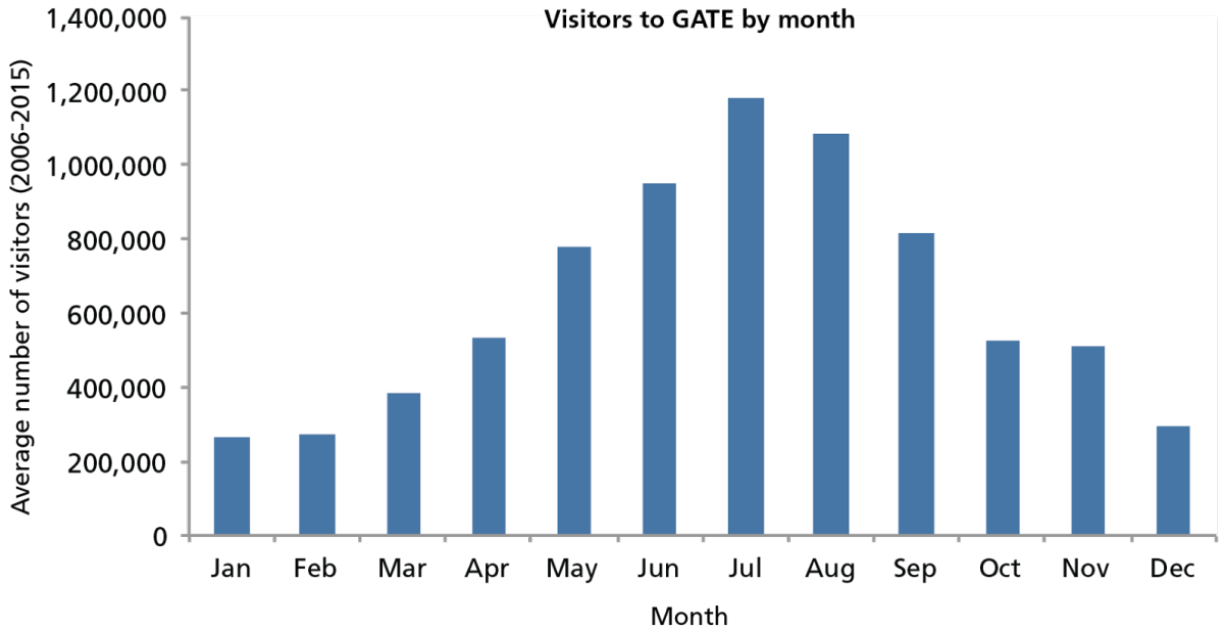


Figure 2-13. Visitors to Gateway National Recreation Area by month (Source: NPS).

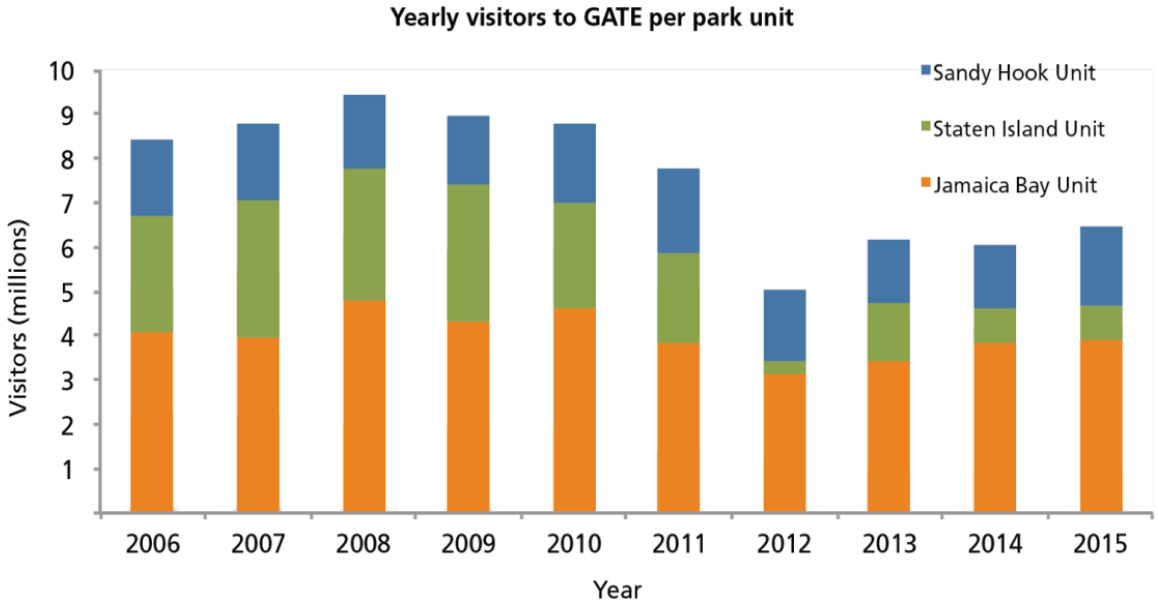


Figure 2-14. Annual visitors to Gateway National Recreation Area by park unit (Source: NPS).

2.2 Natural resources

2.2.1 Geology

The New York Bight, which surrounds and includes GATE, is part of the Atlantic coastal plain physiographic province. The Atlantic Coastal Plain encompasses Long Island, part of Staten Island, and southern New Jersey (USGS 2015). The Highland Region includes the upland portions of New Jersey and the Hudson Highlands Region of southern New York (Manhattan, the Bronx, parts of Brooklyn and Staten Island). These are the highest headlands along the Atlantic Coast south of

Maine and are comprised of rugged, hilly to mountainous terrain, with rocky outcrops visible on hillsides and along streambanks (Stoffer and Messina, 1996). In New Jersey, the Navesink River separates Sandy Hook from the Highland Region.

The park is located near the maximum extent of Pleistocene glacial advance in New York and New Jersey, and glacial moraine and unconsolidated deposits make up the underlying bedrock in portions of the park. The Coastal Plain section of New York City was glaciated, whereas Sandy Hook and points south are unglaciated (USDA NRCS 2001). Bedrock for the Jamaica Bay and Staten Island units includes Cretaceous and Tertiary sedimentary units of the Raritan Formation, the Monmouth Group, the Matawan Group, and the Magothy Formation (Fisher *et al*. 1970). The coastal parks of GATE contain young, Holocene sands derived from glacial deposits, continental formations, and offshore shoals (Thornberry-Ehrlich, 2011). The surficial geology of the Sandy Hook Unit is holocene age beach and nearshore marine sand (Stanford 2000).

2.2.2 Soils

Human influenced soils are extensive and are of major importance to the use and management of GATE. Recognizing the need for more soil-specific information, twenty-two new soil series and interpretation records have been made for the drastically human-influenced soils which carry relatively narrowly defined ranges of characteristics and soil interpretations for urban land use.

Jamaica Bay soils are mapped as the Ipswich soil series (Figure 2-15). The Ipswich series is comprised of very deep, poorly drained soils formed in thick organic deposits. They are on level tidal marshes subjected to inundation by salt water twice daily. The bay and barrier beach sediments within Jamaica Bay are composed predominantly of sand and gravel derived from glacial outwash and marine sources (US FWS 1997). Also present within Jamaica Bay are numerous landfill areas where park soils include the extensive use of artificial fill material. Throughout Jamaica Bay, dredging projects to create navigational channels and to obtain fill have been completed. The largest dredging project provided fill for Idlewild (now JFK international airport). Fill was used to create land at Floyd Bennett Field, Cross Bay Boulevard, and parts of Rockaway Beach (NPS 1976).

Soils within the Staten Island unit are primarily recent beach sands and organic silts and clays (Figure 2-16). Some park areas have been altered by filling with dredged materials or refuse fill, and much of the area near Great Kills Harbor was once a landfill (NPS 1976, USDA 2001). Of significant interest to humans in the Staten Island Unit is the red sand of the Great Kills Park beaches, which has been a popular attraction for many years (USDA, 2001).

In Sandy Hook, soils are predominantly clay, sand, and gravel of the quaternary age, mainly dominated by the Hooksan soil series (Figure 2-17). Soils on Sandy Hook were formed in a mantle of eolian marine washed sand and can readily change with each coastal storm (USDA, 2001).

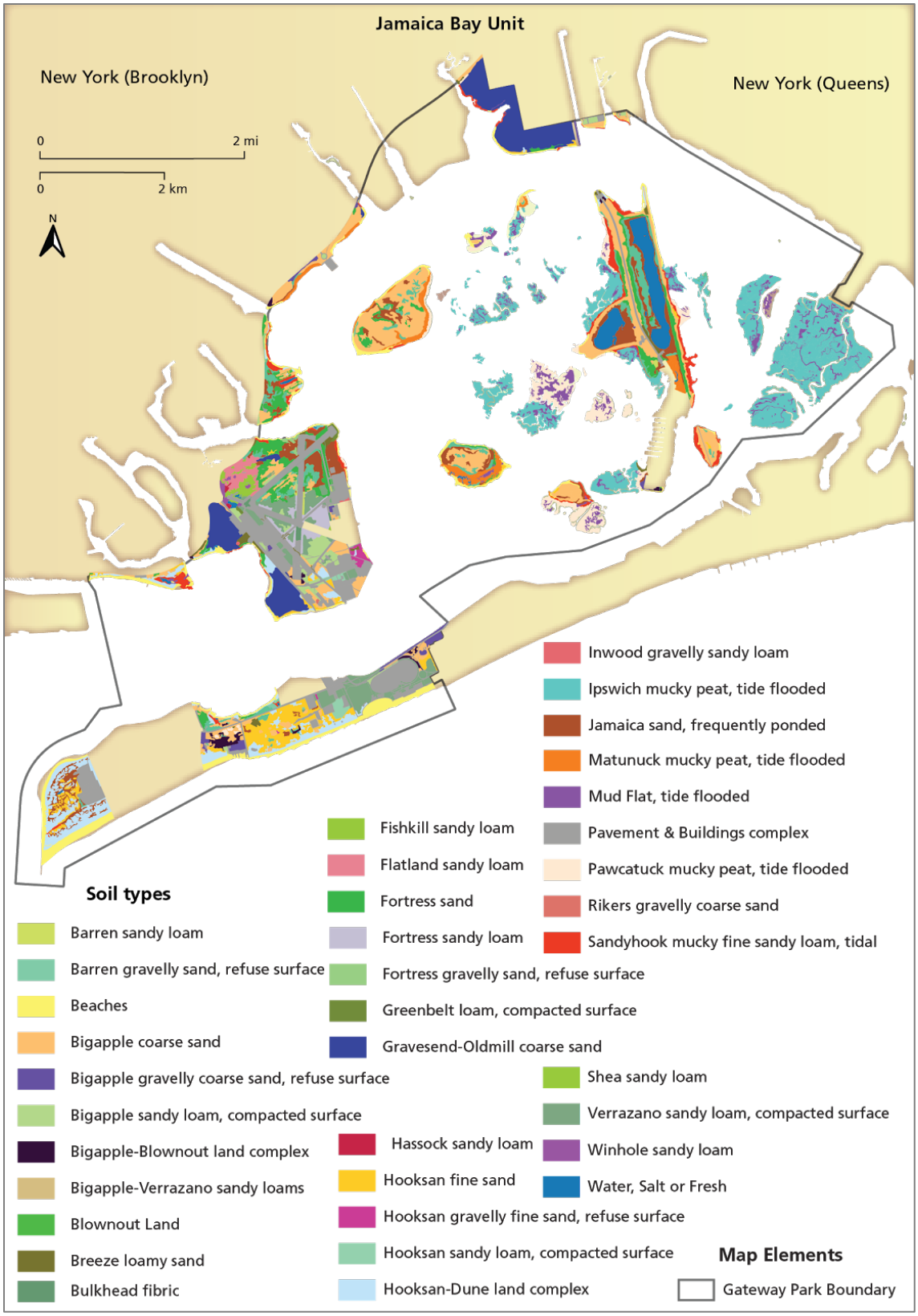


Figure 2-15. Soil types within the Jamaica Bay Unit, Gateway National Recreation Area (Source: USDA NRCS).

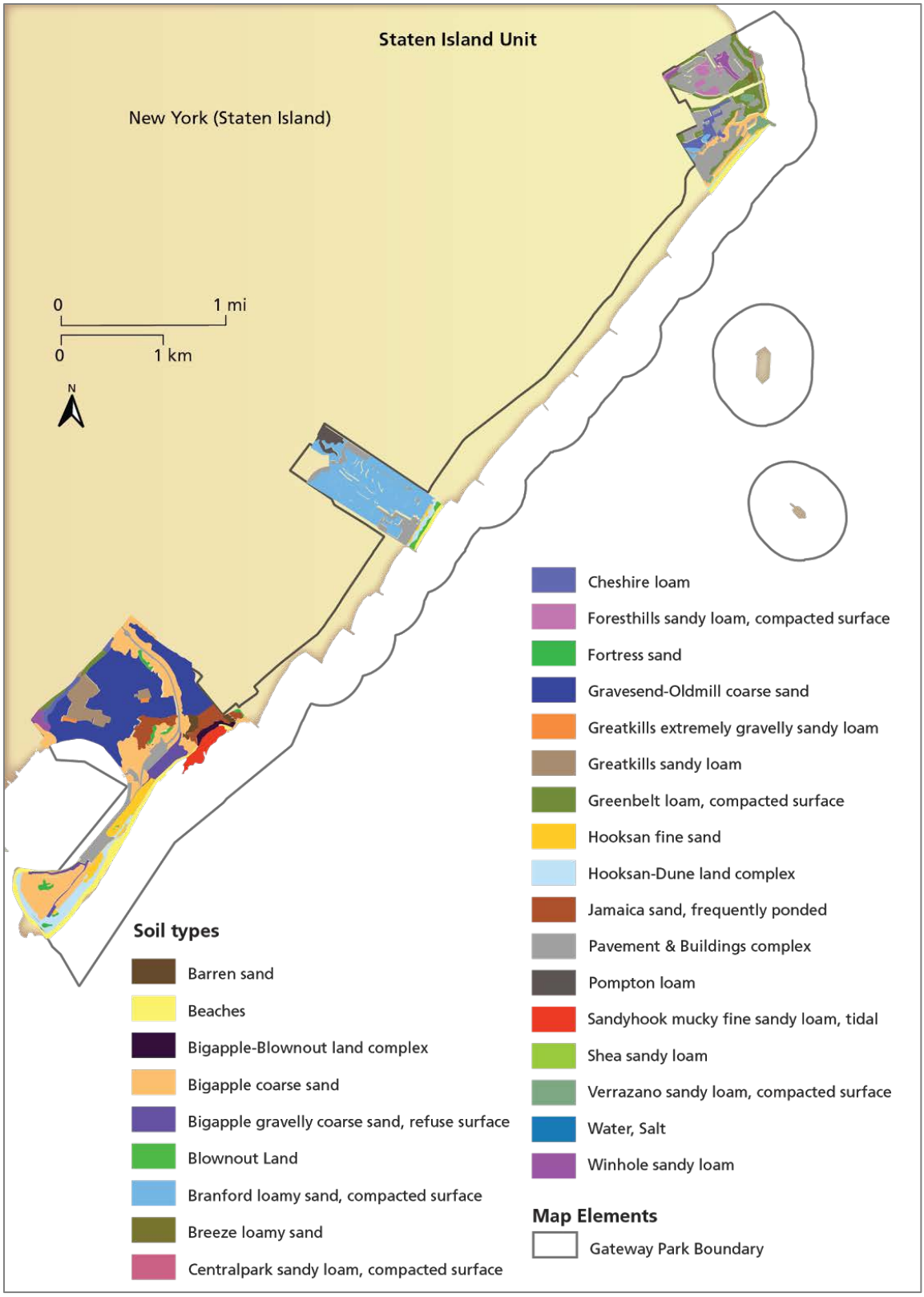


Figure 2-16. Soil types within the Staten Island Unit, Gateway National Recreation Area (Source: USDA NRCS).

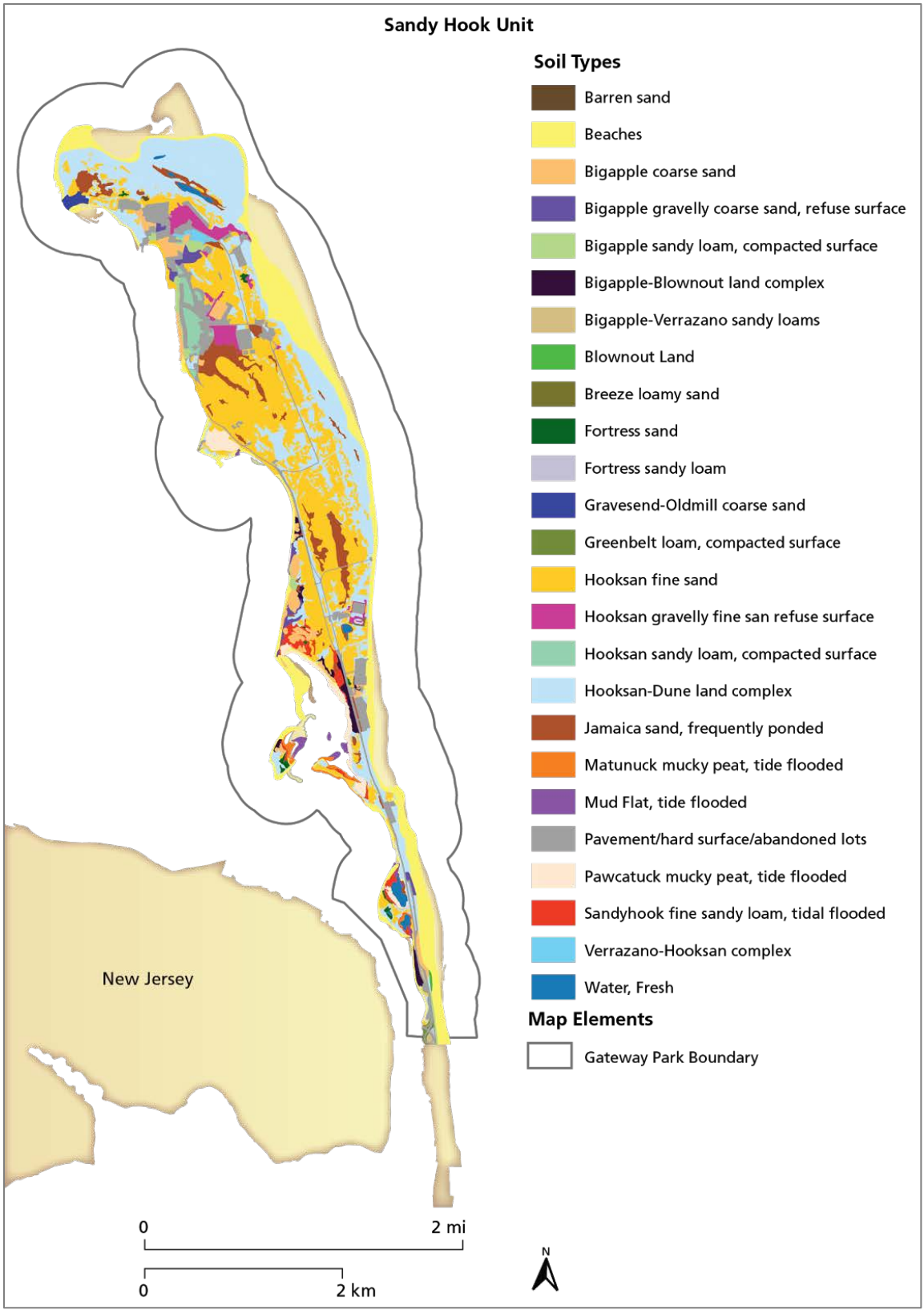


Figure 2-17. Soil types within the Sandy Hook Unit, Gateway National Recreation Area (Source: USDA NRCS).

2.2.3 Shorelines

There are several types of shorelines present within GATE. Jamaica Bay is composed of saltmarsh islands within a tidal estuary. The Jamaica Bay Unit's Breezy Point and Fort Tilden are a barrier complex separated from the Long Island mainland by a tidal lagoon. The south shore of Staten Island consist of long, straight, sand beaches, and the Sandy Hook shoreline is a recurved barrier spit formed by littoral drift moving north into New York Bay.

The coastline of GATE is constantly changing. Two major factors influencing shoreline geomorphological evolution are sea level change and sediment supply. The primary geomorphological components of the GATE ocean shoreline are the Sandy Hook peninsula and Breezy Point/Riis Park of Rockaway barrier spit that extends into New York Harbor (Psuty et al. 2016). Under natural conditions, ocean spits like Sandy Hook and Rockaway Peninsula are dynamic and subject to considerable changes associated with overwash, breaching, and creation and migration of inlets. Sandy Hook is currently attached to the barrier to the south, but has historically been an island, and at one time was also attached to the mainland at the town of Highlands, New Jersey (Nordstrom and Jackson 2016). The southern beaches at Sandy Hook are undergoing severe erosion. This erosion is both natural and often accelerated by human activities. Implementation of large scale beach nourishment projects, combined with the construction of numerous groins, bulkheads, and jetties have greatly restricted shoreline change (Nordstrom and Jackson 2016). While there has not been any direct placement of sediment on the beaches of GATE, there have been episodes of beach nourishment updrift from the south for Sandy Hook and updrift from the east for Breezy Point that contributed sediment to the shorelines in the park. This material adds to the local sediment supply and partially offsets the negative effects of storm erosion (Psuty et al. 2016).

The Staten Island shore is exposed to ocean waves entering the opening between Sandy Hook and Breezy Point. Net longshore transport is from northeast to southwest along most of the shoreline (Nordstrom and Jackson 2016). The construction of groins has resulted in sediment starved beaches, and erosion has resulted in the need for more structures to be added. Flooding is an issue in the low-lying land south of the groins, and during Superstorm Sandy, considerable damage occurred in these areas (Nordstrom and Jackson 2016).

2.2.4 Watersheds

The Jamaica Bay watershed occupies 142 square miles, and includes portions of Kings, Queens, and Nassau Counties. The watershed is situated at the south-western tip of Long Island and is located primarily within the Boroughs of Brooklyn and Queens, New York City. A relatively small portion of the Bay is located in the Town of Hempstead, Nassau County, New York. Elevations within the watershed range from sea level to a maximum of approximately 250 feet, to the west of Queens and Nassau County border near the Cross Island Parkway (NYCDEP 2007). Jamaica Bay is a saline to brackish, eutrophic (nutrient-rich) estuary covering about 10,118 hectares (25,000 acres), with a mean depth of 4 meters (13 feet), a semidiurnal tidal range averaging 1.5 meters (5 feet) (NPS 2016). Eight tributaries feed into Jamaica Bay: Sheepshead Bay, Paerdegat Basin, Fresh Creek, Hendrix Creek, Spring Creek, Shellbank Basin, Bergen Basin and Thurston Basin. All of the Jamaica Bay tributaries have been highly altered over the years through channelization and have little to no

remaining natural freshwater flow. The Jamaica Bay estuary connects with Lower New York Bay to the west through Rockaway Inlet. Jamaica Bay has evolved from a landscape of grasslands, woodlands, freshwater streams, and saltmarsh wetlands to one of the most densely urbanized areas in the United States. Land uses in the Jamaica Bay watershed include residential, commercial and industrial lands, landfills, as well as vacant, undeveloped lands, marshes, wetlands, parks, and the John F. Kennedy International Airport (NYCDEP 2007).

The Sandy Hook/Staten Island watershed that drains into lower New York Bay occupies 554 square miles, and ranges in elevation from -7 to 646 feet above sea level. The highest elevations are in the most northern portion of the watershed. The watershed is predominately urban (96.8%), as it includes the New York City area. Agricultural areas are small, with the majority of farms in the Monmouth County, New Jersey, portion (USDA NRCS 2011).

2.2.5 Habitats, flora, and fauna

Despite being surrounded by human development, GATE supports a wide variety of animals, including mammals, birds, reptiles, amphibians, fish, and a large diversity of invertebrates. The park is located adjacent to the confluence of the New York Bight and New York Bay, and is at the turning point of the primarily east-west oriented coastline of New England and Long Island and the north-south oriented coastline of the mid-Atlantic coast. This geographic location acts to concentrate marine and estuarine species migrating between the New York Bight portion of the North Atlantic and the Hudson-Raritan Estuary (NPS 2016f). GATE contains a diverse array of terrestrial and aquatic habitats, including beach, dune and swale, forests, grasslands, shrublands, saltmarshes and mudflats, freshwater ponds, and brackish and tidal waters (Figure 2-18).

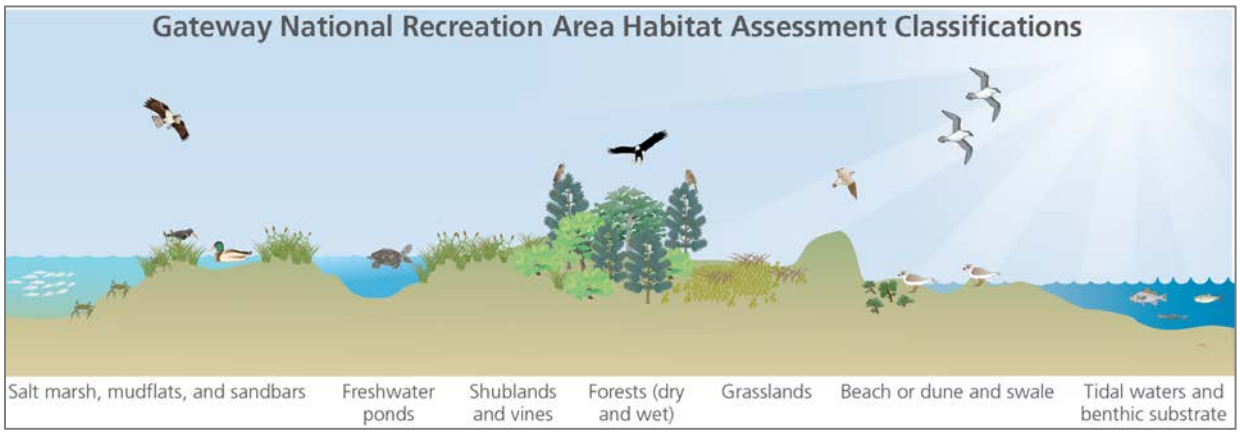


Figure 2-18. Conceptual diagram illustrating the major habitat types present in Gateway National Recreation Area.

Jamaica Bay is one of the largest coastal wetland systems in the northeast United States, and provides habitat and breeding ground for many species of birds, mammals, amphibians, and fish. GATE has over 325 species of birds that are known to primarily use Jamaica Bay as stopover, foraging, and/or breeding habitat, while visiting as they migrate along the Atlantic Flyway (NPS 2016, Waldman 2008). Some of these bird species, such as the piping plover (*Charadrius melodus*), are threatened or

endangered. They find food, shelter, and protection within the borders of this national park. Bald eagles (*Haliaeetus leucocephalus*), tiny Ruby-throated Hummingbirds (*Archilochus colubris*), and great blue herons (*Ardea herodias*), all breed, rest, or feed in the park's extensive wetlands, woodlands, and shorelines. But the park protects habitat for far more than birds. Many reptiles and amphibians also reside in the park. In spring, tree frogs such as spring peepers (*Pseudacris*) and gray tree frogs (*Hyla versicolor*) breed in shallow pools, while snakes such as the black racer (*Coluber constrictor priapus*), garter snake (*Thamnophis*), and brown snake (*Pseudonaja textilis*) hunt the park woodlands. Mammals also prosper here, with evenings being the best time to observe raccoons, opossums, and muskrats on their nightly forays. Nearby, dragonflies, damselflies, butterflies, and crickets lead. Fish are too often overlooked when considering park animals, but striped bass (*Morone saxitallis*), bluefish (*Pomatomus saltatrix*), and even seahorses swim the extensive marshlands and open waters of Jamaica Bay (NPS 2016).

Tidal waters and benthic substrates

Jamaica Bay's depth ranges from just a few inches to over sixty feet, with most of the main channels ranging from 25 to 45 feet deep. The smaller channels in the center of the Bay range from 10 to 20 feet. The rest of the bay consists of shallow sandy bottom waters and saltmarshes, many of which are exposed at low tide, but covered by several inches to several feet of water at high tide. (NPS 2016)

Estuaries are noted for their high productivity and importance as a spawning, nursery, and feeding ground for juvenile fish. Eighty-one species of finfish have been caught in Jamaica Bay waters. Some, including bay anchovy (*Anchoa mitchilli*), naked goby (*Gobiosoma bosc*), white perch (*Morone americana*), and winter flounder (*Pseudopleuronectes americanus*) are considered inhabitants of the bay, while others, such as summer flounder (*Paralichthys dentatus*), are seasonal visitors (NPS 1976). Beds of eastern oyster (*Crassostrea virginica*) provide considerable ecosystem services such as water filtration, and habitat for many species. Oysters were once plentiful in Jamaica Bay, and at its peak, the Bay produced 700,000 bushels of oysters per year (Franz 1982) but today are almost absent (O'Neil et al., 2016). Jamaica bay continues to hold a large hard clam (*Mercenaria mercenaria*) population and fisherman harvest ribbed mussel (*Aulacomya atra*) for bait and chum use (Waldman 2008).

Despite historically existing in the area, the eelgrass (*Zostera marina*, a type of seagrass) is not presently found in Jamaica Bay (Waldman 2008). Eelgrass suffered major declines between 1930 and 1933 along the East coast due to wasting disease, and only partially recovered in many places (Waldman 2008). Eelgrass is a type of submerged aquatic vegetation that grows in estuaries and shallow bays. It is important for fish and shellfish as habitat. Eelgrass plants form meadows on the bay bottom, where aquatic creatures such as shellfish take shelter among the leaves. They also stabilize sediments, reduce erosion and remove nitrogen from the water. There have been several pilot studies throughout Jamaica Bay to plant eelgrass and evaluate restoration potential, however, none have been successful in reestablishing the species inside Jamaica Bay (NYCDEP 2007). Although restoration attempts inside GATE have proven unsuccessful, it is important to note that there have been successful eelgrass restorations further south down the coast in Barnegat Bay, NJ (Bologna and Sinnema 2012).

The Sandy Hook unit has historically supported over 90 species of fish, as reported in various studies of Sandy Hook bay (US FWS 1997). The most abundant are some of the estuarine species that use the lower salinity areas as their permanent residence, in particular, mummichog (*Fundulus heteroclitus*), White perch, and hogchoker (*Trinectes macalatus*). The bay complex supports recreational fisheries for weakfish (*Cynoscion regalis*), bluefish (*Pomatomus saltatrix*), winter flounder (*Pleuronectes americanus*), summer flounder (*Paralichthys dentatus*), striped bass , sea bass (*Centropristis striata*), tautog (*Tautoga onitis*), scup (*Stenotomus chrysops*), and spot (*Leiostomas xanthurus*) (US FWS 1997).

The nearshore regions of this tidal habitat supports dynamic geomorphologic processes that deliver sand to Sandy Hook. The intertidal zone provides habitat for several species of crabs, mollusks, and marine worms, especially near groins. These organisms are scavengers, cleaning the beach of organic material, and provide shorebirds a food source (NPS 1978).

Beach or dune and swale

Within GATE, the Sandy Hook peninsula, as well as the ocean side of Rockaway Peninsula, that separates Jamaica Bay from the Atlantic Ocean, has wide beaches and dunes. These beach face areas and the sparsely vegetated upper beaches are some of the most significant areas for breeding shore birds, and provide habitat for a variety of species, some that are state or federally rare or threatened. These sandy beaches are important horseshoe crab spawning sites, and thousands converge at Plumb Beach between late and mid-June to lay eggs (NPS 2012b). Breezy Point also supports three species of rare plants, including the globally rare seabeach knotweed (*Polygonum glaucum*) along the ocean beach and dune, and state-listed rare Schweinitz's flatsedge (*Cyperus schweinitzii*) on the bay side of the barrier (US FWS 1997). The globally rare, federally threatened, seabeach amaranth (*Amaranthus pumilus*) reappeared in New York State in 1990 and in Sandy Hook in 2000 after a century of absence from New Jersey beaches (Waldman 2008). Unique to barrier islands, these early successional habitats are used by a variety of rare ground-nesting shorebirds and colonial waterbirds including least and common terns, black skimmers, and the federally threatened piping plover (*Charadrius melodus*). The beaches of Sandy Hook also provide habitat for the federally threatened northeastern beach tiger beetle (*Cicindela dorsalis dorsalis*) (USFWS 2002). Once common on beaches throughout the northeast, the beetle population declined due to development along ocean beaches, off-road recreational vehicle use, heavy pedestrian traffic, and the effects of storm surges (Lane 1995). Beaches in Sandy Hook also provide habitat for diamondback terrapins (*Malaclemys terrapin*) (Ner and Burke 2005).

Saltmarshes, mudflats, and sandbars

Wetlands and adjacent areas serve a number of environmental and economic values. They form a protective barrier for coastal ecosystems and development, improve degraded waters by recycling nutrients, and provide habitat for a variety of species. Saltmarsh, estuarine, and freshwater wetlands occur in the park. Jamaica Bay, one of the largest coastal wetland ecosystems in New York State, is an important natural system. It supports 91 species of fish, 325 bird species (62 of which breed locally), and provides important habitat for reptiles, amphibians, and mammals (NYCDEP 2007). The Bay is a critical stopover point on the Atlantic Flyway, and is one of the best birdwatching sites

in the United States (Waldman 2008). There are approximately 100 acres of saltmarsh extending along the bayside of Sandy Hook. The most common vegetation coverage in the marshes at Sandy Hook and Jamaica Bay is *Spartina alterniflora*. The saltmarshes sustain many resident and migrant animals, including the diamondback terrapin, a New Jersey threatened species.

Wetlands throughout GATE are currently disappearing due to sea level rise, physical damage from boat wakes, and dredging (Thornberry-Erhlich 2011). Wetland area has been lost as a result of filling and development, shoreline hardening, dredging all impacting the hydrological regimes throughout GATE. These activities have destroyed natural habitat and impacted water quality in the New York Harbor region (O'Neil et al., 2016). Two species commonly considered invasive, common reed (*Phragmites australis*) and Japanese honeysuckle (*Lonicera japonica*), are prevalent throughout the wetlands in Sandy Hook.

Forests

Each of GATE's three units has woodlands or forests. Two types of forest occur in or near the *critical zone* (an area in Sandy Hook specifically designated as vulnerable to erosion) in Sandy Hook: a maritime holly forest dominated by American holly (*Ilex opaca*) and a mixed hardwood forest that includes American holly (NPS 2014e). Sandy Hook has the largest of only two maritime holly forest sites found in world, with NatureServe ranking maritime holly forest as globally imperiled (Forrester et al. 2006). The red maple (*Acer rubrum*) -holly forests occupy approximately 270 acres near the Nike missile site and extending northward. The forests are important as roosting and nesting locations for a variety of birds, and include historical nesting by great blue heron, historical nesting and present roosting by blackcrowned night-heron (*Nycticorax nycticorax*), and nesting by several pairs of osprey (*Pandion haliaetus*) and several species of passerines. The American holly is also a host plant for the regionally rare butterfly Henry's Elfin (*Incisalia henrici*) (NPS 2016f).

The Miller Field area of Staten Island hosts a swamp white oak (*Quercus bicolor*) forest. Swamp white oak dominates only a small portion of the tree stand at Miller Field, with numerous other tree and shrub species present, including red maple (*Acer rubrum*), and other oaks (*Quercus spp.*) (USDA 2001). The diversion of Moravian Creek, and human disturbances threaten the natural community of the area. The absence of seedlings due to trampling have allowed for the success of non-native species such as Japanese knotweed (*Polygonum cuspidatum*) and garlic mustard (*Alliaria petiolata*) (USDA 2001).

The former municipal airport at Floyd Bennett Field, Brooklyn, offers a mixed woodland area, the North Forty Natural Area. The North Forty includes conifers, deciduous trees, vines, grass species and open space. Young forest of aspen (*Populus* sp.), black cherry (*Prunus serotina*) and grey birch (*Betula populifolia*) are interspersed with native shrubs like bayberry (*Morella pensylvanica*), blackberry (*Rubus* sp.) and sumacs (*Rhus* sp.).

Grasslands and herbaceous plants

Grassland and woodland-thicket communities are found at higher elevations that are not affected by the tide (NPS 1976). The grasslands of Floyd Bennett Field (totaling 1,300 acres) are among the largest in the New York City area and represent important habitat for grassland breeding bird species

and foraging species (NPS 2014c). Except for the portion known as the North Forty, all sections of Floyd Bennett Field are mowed to maintain low vegetation. A grassland management plan (GRAMP) for 407 acres was initiated in 1986 to maintain habitats for open-country birds. Since then, the area has been maintained as a grassland and mowing occurs annually (Greller et al. 2000). In 2015, 25 grassland bird species were detected within the Floyd Bennett Field grasslands (NPS 2015a). This was an increase in species from the 2013 survey when only 20 species were surveyed, but there has been an overall decline in the number of species detected since the survey began in 1984 (NPS 2015a). The Savannah sparrow (*Passerculus sandwichensis*) is the only grassland species still nesting regularly at Floyd Bennett Field (New York City Audubon 2016). Other nesting species include ring-necked pheasant (*Phasianus colchicus*), American woodcock (*Scolopax minor*), northern flicker (*Colaptes auratus*), white-eyed vireo (*Vireo griseus*), tree swallow (*Tachycineta bicolor*) (in man-made nest boxes), gray catbird (*Dumetella carolinensis*), brown thrasher (*Toxostoma rufum*), and common yellowthroat (*Geothlypis trichas*) (New York City Audubon 2016). In Sandy Hook, grasslands are located in the southern part of the park along the roadside and intermixed in thicket and shrubland areas. The common reed, or phragmites (*Phragmites australis*) is an invasive species present throughout GATE.

Shrublands and vines

Physical factors such as proximity to the water table, salt exposure, and disturbance from overwash promote distinct zonation patterns of vegetation, typical of coastal ecosystems. Maritime shrublands generally contain scattered stunted “salt pruned” trees with contorted branches and wilted leaves. Maritime shrubland is threatened by invasive exotic vines, oriental bittersweet (*Celastrus orbiculatus*) and Japanese honeysuckle (*Lonicera japonica*) (NYNHP 2015).

Freshwater and brackish ponds

Freshwater and brackish ponds are found sparsely throughout both the Jamaica Bay Unit and throughout the Sandy Hook Unit. The ponds to the North in the Sandy Hook unit are the Coast Guard Pond, Exclamation Point Pond, North Pond, Round Pond, and Nike Pond, moving from east to west and north to south (NPS 2016). Freshwater ponds within GATE serve as critical habitat for spawning and nurseries. Although the area in which the park is located was once much more abundantly covered in wetlands, many have been filled and developed, their water supplies channelized, infested by non-native invasive species, or polluted. Hundreds of bird species depend on these sources of freshwater, especially during migration season. The East and West Ponds, two man-made freshwater ponds within Jamaica Bay Wildlife Refuge, were breached by Hurricane Sandy. The Return-a-Gift pond is a 2-acre man-made freshwater pond in the North Forty at Floyd Bennett Field. The pond provides habitat for waterfowl, such as wood ducks (*Aix sponsa*), northern shovelers (*Anas clypeata*), green-winged teal (*Anas carolinensis*) and herons (*Ardeidae* sp.), as well as amphibians such as the spring peeper frog (*Pseudacris crucifer*).

2.2.6 Deer populations

White-tailed deer (*Odocoileus virginianus*) populations surrounding GATE have been identified as a possible threat to park health. Deer overpopulation can cause ecological damage through excessive feeding on or damaging of tree seedlings and saplings which in turn prevents a forest from

regenerating and can lead to the colonization of invasive species (Cote et al. 2004). Data collected from the Staten Island Unit show deer sightings inside the park (Figure 2-19). New York City has recently implemented an integrated deer management plan that is testing the efficacy of male sterilization as a method to control the deer population on Staten Island (City of New York 2017). Although data for the Jamaica Bay and Sandy Hook Units is not available, anecdotal evidence from discussions with GATE employees estimate that deer populations have increased in the past decade from only a few individuals to over 70 throughout the Sandy Hook Unit. Deer have not been identified as an issue in the Jamaica Bay Unit. For the purpose of this report, it is important to note that deer may become an issue that should be formally studied at affected park units in the future. To evaluate the impacts of deer browsing, the park has secured funding to initiate a vegetation study in 2019 within the Sandy Hook maritime holly forest.

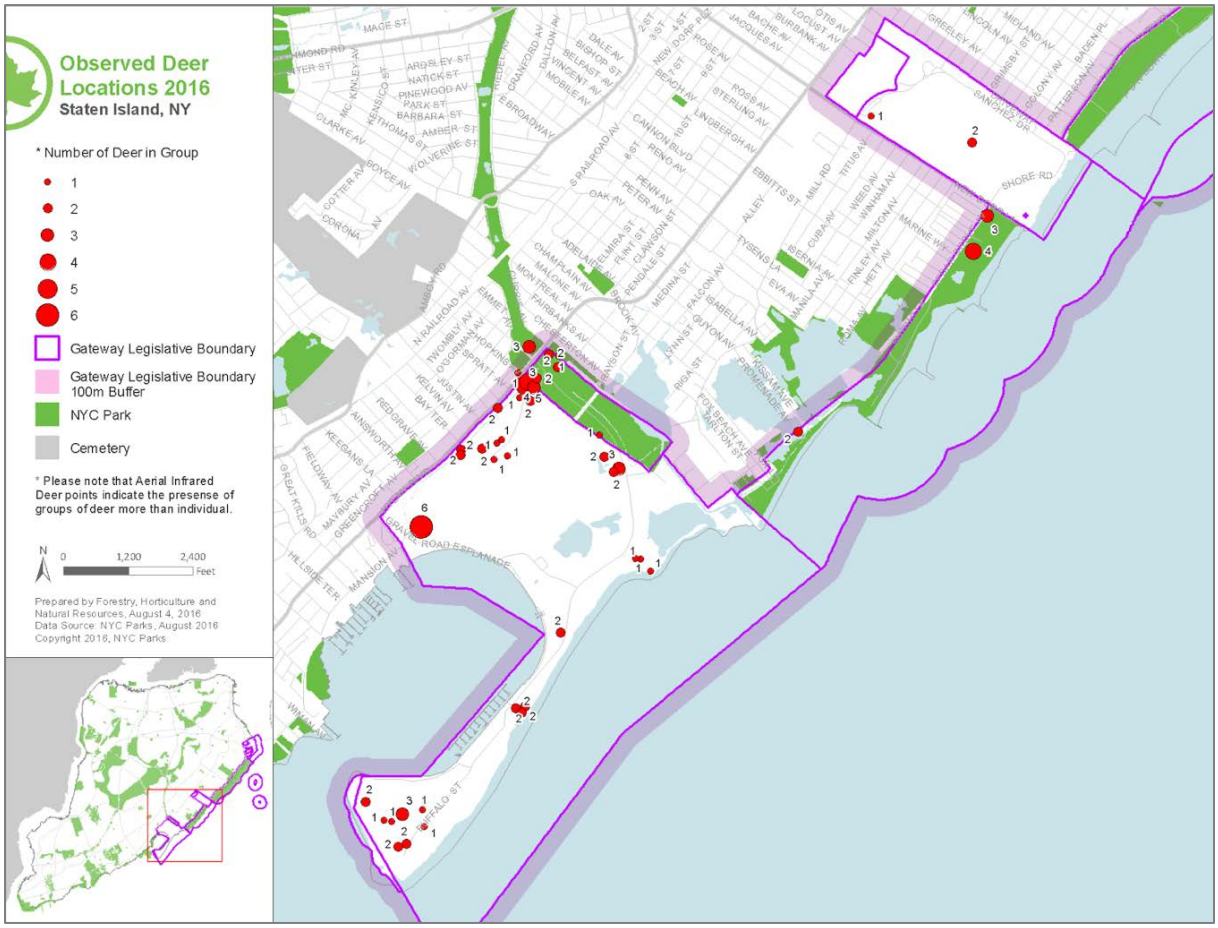


Figure 2-19. Deer sightings sorted by group size in the Staten Island Unit, Gateway National Recreation Area (NYC Department of Parks and Recreation 2016).

2.2.7 Soundscapes

The soundscape within a park comprises both the natural ambient sounds and human-made sounds. Natural sounds include geophysical (e.g. rain, running water, waves, wind), and biological sounds (e.g. frogs, insects, birds) (Pijanowski et al. 2011). This natural ambient environment enhances

visitor experience of the natural park landscape (Miller 2008). It is a critical component of wilderness character and plays an important role in wildlife communication, behavior, and other ecological processes (NPS 2016g). Noise from airports and highways is common within GATE. Jamaica Bay experiences high road and air traffic through John F. Kennedy Airport, and helicopter traffic from multiple jurisdictions. Although noise pollution is most prominent in the Jamaica Bay Unit, dense populations using roads bordering both the Staten Island and southern portion of Sandy Hook Unit's also contribute to the degraded or anthropogenic soundscapes of these park units (Figure 2.5).

The Natural Sounds and Night Skies Division (NSNSD) estimates acoustic conditions using predictions from a geospatial sound model. For the model, sound pressure levels for the continental United States were predicted using actual acoustical measurements combined with a multitude of explanatory variables such as location, climate, landcover, hydrology, wind speed, and proximity to noise sources (roads, railroads, and airports).

The mean existing sound level at GATE is estimated to be 47.3 dBA (decibels). This existing sound level is predicted by adding the median human impact sounds levels to the median natural sound levels in order to determine an overall median sound level for the park (Figure 2.19). At 35 dBA, human and wildlife sleep can be interrupted (Haralabidis et al. 2008).

The mean existing sound levels at the park are lower than the sound levels in nearby developed areas (Figure 2-20), demonstrating that sounds intrinsic to the park are a resource important to protect in the park environment.

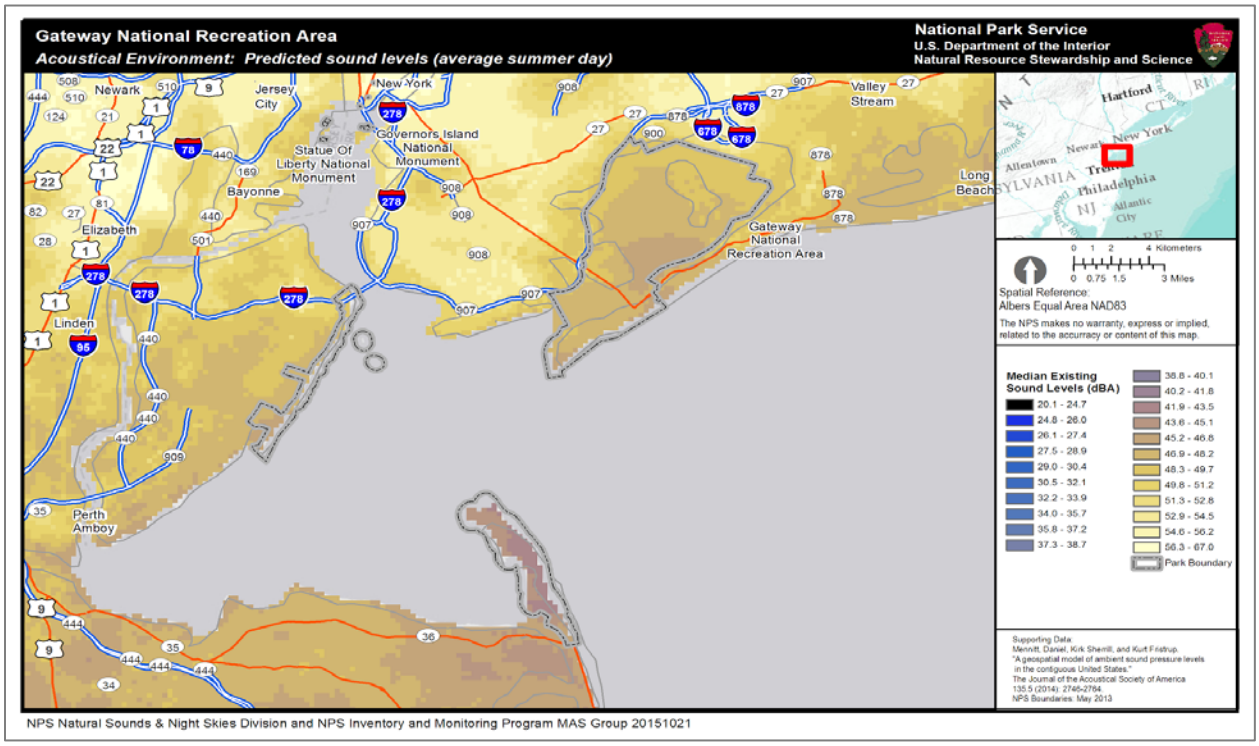


Figure 2-20. Median existing sound pressure levels for Gateway National Recreation Area (NPS 2016f).

2.2.8 Lightscapes

The natural darkness associated with the night sky is an important natural and cultural resource valued by the National Park Service (NPS 2012a). At GATE, “darkness and night sky” is a fundamental value, as the park’s general management plan states, “viewing of the night sky is an important aspect of visitor experience in Gateway” (NPS 2014). The clarity of night skies is not only important to the visitor experience, but also ecologically important (NPS 2013). Dark night skies are an important aspect of visitor experience at GATE, as many visitors are from urban areas with very limited access to night skies with relatively low levels of light pollution (NPS 2015). Light pollution is increasing globally, especially in areas of high growth, such as the east coast of the United States and in the park units that make up GATE (NPS 2012c). Two types of light pollution are recognized, ‘astronomical light pollution’, reducing the ability to view stars and other celestial bodies and ‘ecological light pollution’ which has effects on wildlife and wildlife behavior (Longcore and Rich 2004). Ecological light pollution includes direct glare, sky glow, and temporary, unexpected fluctuations in lighting. Ecological impacts on wildlife can include changes to biodiversity, migration patterns, and habitat quality for birds, trees, marine mammals, fish, and sea turtles, as well as changing animal interactions such as prey species losing the protective cover of darkness (Rich and Longcore 2006). Behavior and population-level ecology is affected based on individual and species differences in orientation or disorientation to increased light availability, attraction or repulsion to light sources, lowered reproductive capacity, and hindered visual and audio intraspecies communication. These factors culminate in changes in community ecology, influencing competition, including resource partitioning and predation, and ultimately favoring species that are most light tolerant (Longcore and Rich 2004). Floyd Bennett Field is recognized as one of the interior and/or more remote sections of GATE where artificial light sources do not impair night sky viewing opportunities as much as elsewhere in the park and New York Metro area (NPS 2015).

No park specific information on Night Skies at GATE is available at this time. Even without data or modeling, it is likely that the night skies are highly impacted due to the location of the park within the New York City metropolitan area. Artificial light sources both within and outside GATE have diminished the clarity of night skies by creating a ‘haze’ of light that obscures views of stars. The primary culprit in GATE is roadside lighting, car lights, and light from urbanized areas adjacent to the park as well as from park buildings and parking lots. The undeveloped portions of GATE most likely serves as a refuge from the bright areas in the city, and therefore, it is important to conserve these areas as key places to see the night skies and for wildlife to find a place that isn't quite so bright.

2.3 Resource condition threats and stressors

GATE provides a substantial, heavily visited, protected area within the New York City region. The New York metropolitan area is the most densely populated area of the United States, and local communities in and around the park continue to grow. The cumulative effect of visitation places increasing demands on protected areas within the parks, and the landscape response to potential visitor overuse is a resource management concern. These concerns, include visitor safety, especially along water edges, roads, and near waste facilities. Humans have significantly modified the

landscape of the area within and surrounding GATE. The proximity of Jamaica Bay to New York City's urban environment presents unique challenges.

2.3.1 Air quality

GATE lies within an air basin shared with a highly urbanized area. Of the pollutants regulated by the Clean Air Act, the basin is out of compliance for ozone and small particulates (EPA 2017). The NPS also measures and assesses ozone, as well as acid deposition and visibility at parks, and has determined that quality for these three factors at GATE is not meeting recommended desired conditions (NPS 2014c). Elevated ozone levels in rural areas have been shown to cause premature defoliation in plants while high levels of nitrogen deposition acidify and fertilize soils and waters, thereby affecting nutrient cycling, vegetation composition, biodiversity, and eutrophication (Sikora and Chappelka 2004). These effects may be present in GATE, however it has also been shown (Gregg et al. 2003) that low level ozone can be reduced by chemical interactions with other pollutants in urban areas, sometimes spurring faster than normal growth in these urban areas (Gregg et al. 2003). Air pollution can be transported over long distances, making management difficult at the local scale.

2.3.2 Non-native species

Invasive species are those which are non-native, become established in a new area and reproduce rapidly, and have negative ecological and/or economic impacts on that new area. One potential consequence of exotic species invasion is increased competition for native plants which can lead to losses of biodiversity. Most GATE natural areas are small and/or narrow in shape. As a result, the park's native plant communities are seriously impacted by disturbances caused by fragmentation and development. The least fragmented area of the park is the Jamaica Bay Unit, which also has the most space and has been designated a wildlife refuge. Almost half of the plant species in Jamaica Bay Wildlife Refuge and Floyd Bennett Field are non-native (NPS 2014c). Invasive species present in Floyd Bennett Field, Jamaica Bay Wildlife Refuge, and other areas of GATE include Tree-of-Heaven (*Ailanthus altissima*), russian-olive (*Elaeagnus angustifolia*), purple loosestrife (*Lythrum salicaria*), chinaberry (*Melia azedarach*), Japanese knotweed (*Polygonum cuspidatum*), common buckthorn (*Rhamnus cathartica*), multiflora rose (*Rosa multiflora*), wineberry (*Rubus phoenicolasius*), tall fescue (*Schedonorus phoenix*), and Chinese lespedeza (*Lespedeza cuneata*). Woody vines, such as porcelain berry (*Ampelopsis brevipedunculata*), Oriental bittersweet (*Celastrus orbiculatus*), and Japanese honeysuckle (*Lonicera japonica*), kill native vegetation by shading out native species and bringing down trees with their weight. These non-native species have altered the ecosystem in Jamaica Bay and some portions of Staten Island Unit primarily by suppressing forest regeneration of native plants and opening the canopy through tree mortality, allowing less desirable vegetation to thrive (Waldman 2008). This alteration has resulted in a less desirable habitat for native resident and migratory birds. This effect is further amplified by large disturbances, such as Hurricane Sandy (NPS 2014a). As trees fall from strong winds, this allows invasive species to take over open canopy area (NPS 2013a, Horvitz 1995).

2.3.3 Adverse recreational use

GATE provides numerous recreational amenities including hiking trails, ballfields, beach access, and sites for fishing, bird watching, camping, biking, jogging, and picnicking. Park visitors have the

potential for direct impacts such as disturbing habitat, for example with the use of oversand vehicles, as well as indirect impacts such as the development of supportive infrastructure, such as roads, parking lots, and bathrooms. Many trails wind through preserved biologic, historic, and geologic environments within GATE. Many of these environments are fragile, and off-trail hiking promotes the development of social trails which leads to habitat degradation and can lead to the spread of exotic, invasive species. One example of human recreational pressure in GATE is the poaching of holly branches in the Sandy Hook Unit. Around the arrival of the winter holidays, park rangers find an uptake in poachers: people cutting pieces of holly to add to their houses during the holidays (Ginzburg 1987). The removal of these boughs not only adversely affects the trees, but also the animals that feed on the holly berries and can create social trails that disturb wildlife. Although specific recreational use effects have not been formally studied at GATE, natural resources throughout National Parks have been damaged from overuse and GATE is certainly very susceptible to these pressures (Boyle and Samson 1985).

2.3.4 Water pollution

Increased development and associated increases in surface runoff, which result from the addition of impervious surfaces such as roads, parking lots, and buildings, are having major regional effects on water quality in rivers and bays around GATE. Water resources are under constant threat of contamination and damage because of uncontrolled and inadequately managed stormwater runoff from development in surrounding areas. Uncontrolled runoff and untreated sewer discharge from Combined Sewer Overflows (CSO's) have regional impacts on waters close by to GATE in New York Harbor and regional effects are likely to affect GATE, especially the Jamaica Bay Unit (O'Neil et al. 2016, NYCDEP 2016). Groundwater and surface water in, or feeding the park has been diverted and used for drinking water, commercial and industrial operations, and historically used for agriculture. Most freshwater sources in the watersheds surrounding the park have been filled, diverted into the storm sewer system, or altered by channelization. Hydrology in the surrounding marine and estuarine environments including Raritan Bay and Jamaica Bay is altered by deep dredging and engineering modifications. Water quality in Raritan and Sandy Hook bays is better than in Jamaica Bay because these areas receive freshwater from the Hudson and Raritan Rivers, and experience tidal flushing with ocean waters. Freshwater pollution input to Jamaica Bay is nearly completely composed of effluent from wastewater treatment plants and combined stormwater/sewer overflows (NPS 2014c).

The New York - New Jersey Harbor estuary is a eutrophic (nutrient-rich) estuary with high loadings of nutrients and organic matter that originate mainly from sewage treatment plants but also from a variety of other point and nonpoint sources. These loadings can/or may result in low dissolved oxygen concentrations in many parts of the Harbor. Low dissolved oxygen has acute and chronic effects on various life stages of benthic species and limits the use of the area by pelagic species. Another water quality problem, low levels of light penetration, results from high suspended solids and phytoplankton biomass that can reduce the amount of light reaching the bottom to levels below those able to support submerged aquatic vegetation, especially eelgrass (*Zostera marina*) (USFWS 1997).

2.3.5 Inland erosion

Artificial fill material at Great Kills overlies wetlands, connecting a remnant of the former barrier island to the mainland. This material is intermixed with artificial and natural sediments, and contains anthropogenic signatures including brick clasts and other debris (Thornberry-Ehrlich 2011). Erosion is creating small cliffs into the fill threatening infrastructure such as trails and parking areas. One major factor contributing to the loss of marsh in Jamaica Bay is a deficit in sediment supply to the area (Hartig et al. 2002, Renfro et al. 2010).

2.3.6 Sediment contamination and accumulation

Present and historic inputs of toxics, including hydrocarbons and heavy metals, have resulted in contaminated soils and sediments in many areas throughout GATE. These contaminants have lethal and sublethal effects on benthic organisms and may bioaccumulate in fish and bird predators feeding on these benthic organisms (O'Neil et al 2016).

Toxic contaminant bioaccumulation in fish populations surrounding GATE is a continuing threat to not only fish health but also recreational opportunities in all three park units. Toxics such as PCB's, chlordane, mercury, and lead have caused New York State Department of Health to issue annual fish consumption advisories for many species of fish such as weakfish, bluefish, striped bass, and blue crab in the GATE area, more often than not recommending with signage that people ''DON'T EAT'' (NYDOH 2017).

Approximately half of Great Kills Park (Staten Island Unit) is currently closed to the public due to an ongoing investigation of radium contamination (NPS 2014a). Great Kills park was originally managed by the City of New York's Department of Parks as a shorefront recreation area, until it was transferred to the National Park Service in 1972. From 1944 to1948 the City used waste material to fill in the wetlands and increase the usable land footprint which was common practice at the time. During a 2005 aerial survey, elevated levels of radioactivity were discovered in Great Kills Park, and as of July 2014, a radiological survey of 265 acres had been completed, and public access restricted (NPS 2014a).

2.3.7 Climate change

Climate change, and associated temperature and precipitation shifts, will have major impacts on the natural areas of GATE. Urban environments, such as New York City, have long been known to be subject to heat island effects (Bernstein 1968), and increases in development, impervious surfaces and climatic warming trends will exacerbate this effect and result in negative impacts on species composition and health within GATE (Kirchhoff *et al.* 2009). Other impacts of climate change that will impact species diversity and composition within GATE include sea level rise and extreme weather events negatively affecting plants like the seabeach amaranth and Schweinitz flatsedge, whereas favoring species like *Phragmites* (NPS 2009).

<u>Superstorm Sandy and likely future coastal storms</u>

In October 2012, Hurricane Sandy heavily impacted GATE. The hurricane produced heavy winds, tidal surge, and rain that resulted in severe flooding and extensive damage to park areas including Jacob Riis Park, Fort Tilden, Jamaica Bay Wildlife Refuge, Great Kills Park, and Sandy Hook

(Mahan 2015, Psuty et al. 2017). The considerable modification of the topography to GATE by Hurricane Sandy are shown in Figures 2-21, 2-22, and 2-23 (sourced from Psuty et al. 2017). Tidal surges from Hurricane Sandy were the highest in almost 200 years, and consistent with projections of coastal storm damage for the next century (NYCDEP 2013).

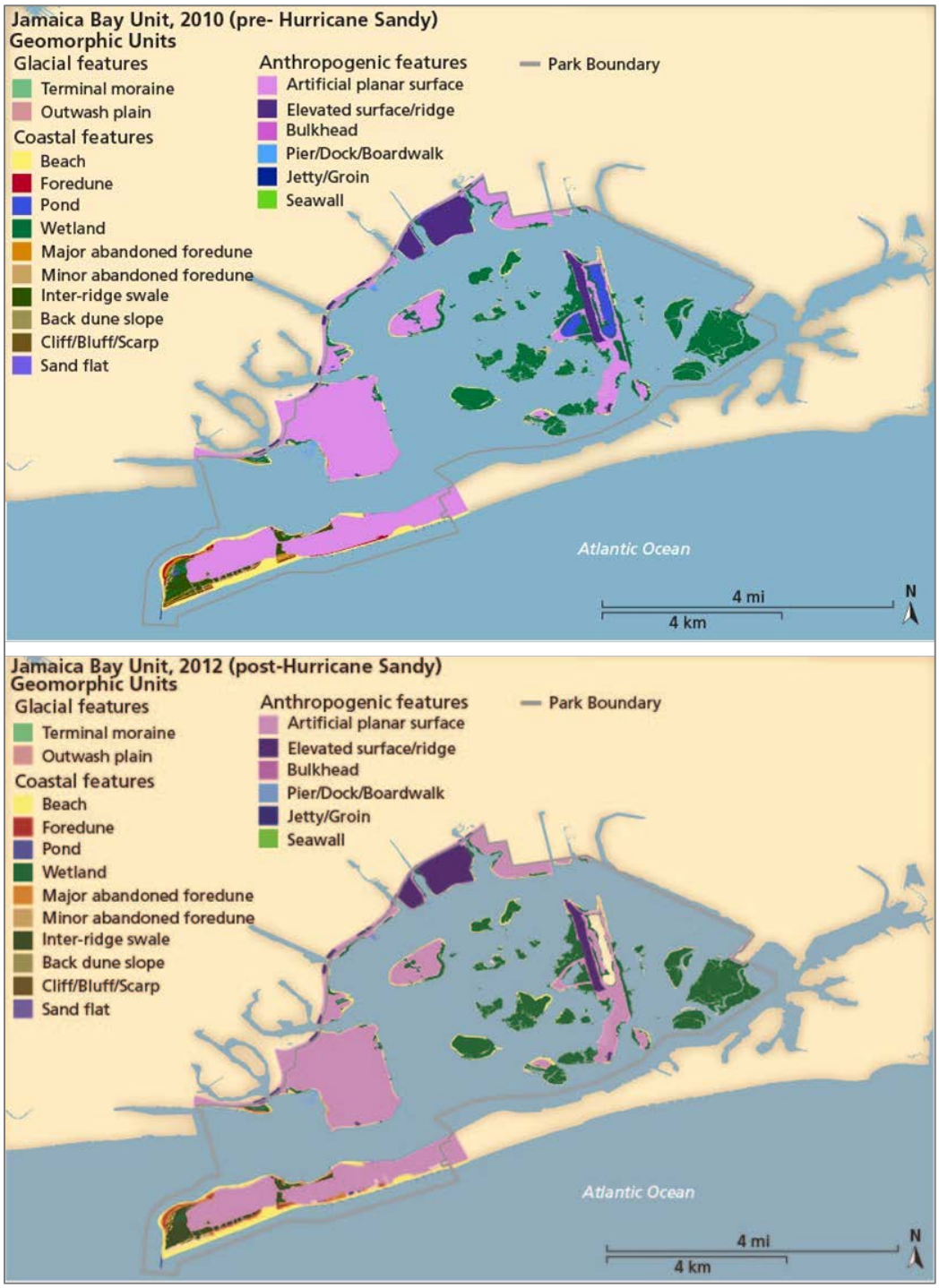


Figure 2-21. Jamaica Bay Unit geomorphic units pre- (top), and post- (bottom) Hurricane Sandy, Gateway National Recreation Area. Source: Psuty et al. 2017.

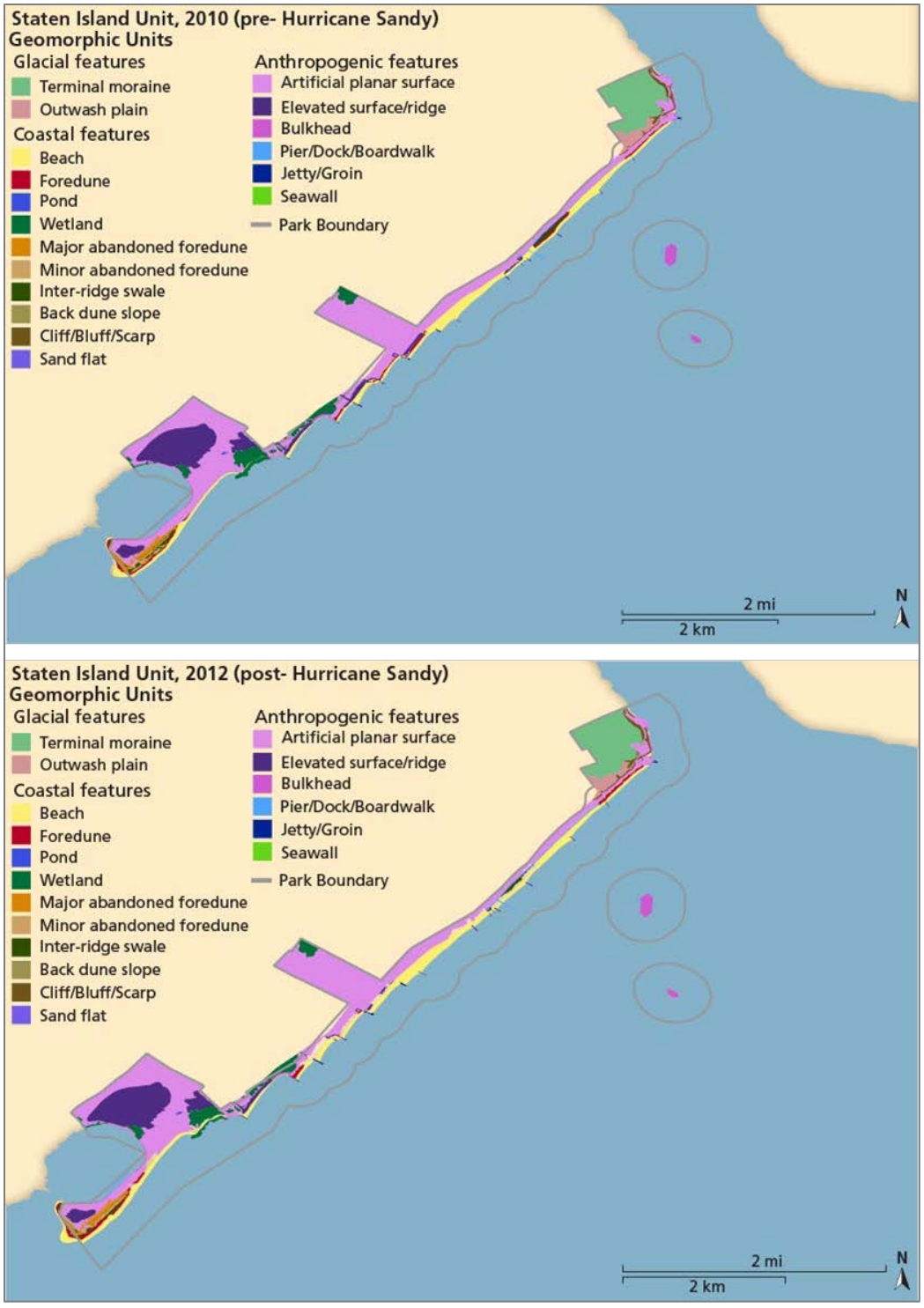


Figure 2-22. Staten Island Unit geomorphic units pre- (top), and post- (bottom) Hurricane Sandy, Gateway National Recreation Area. Source: Psuty et al. 2017.

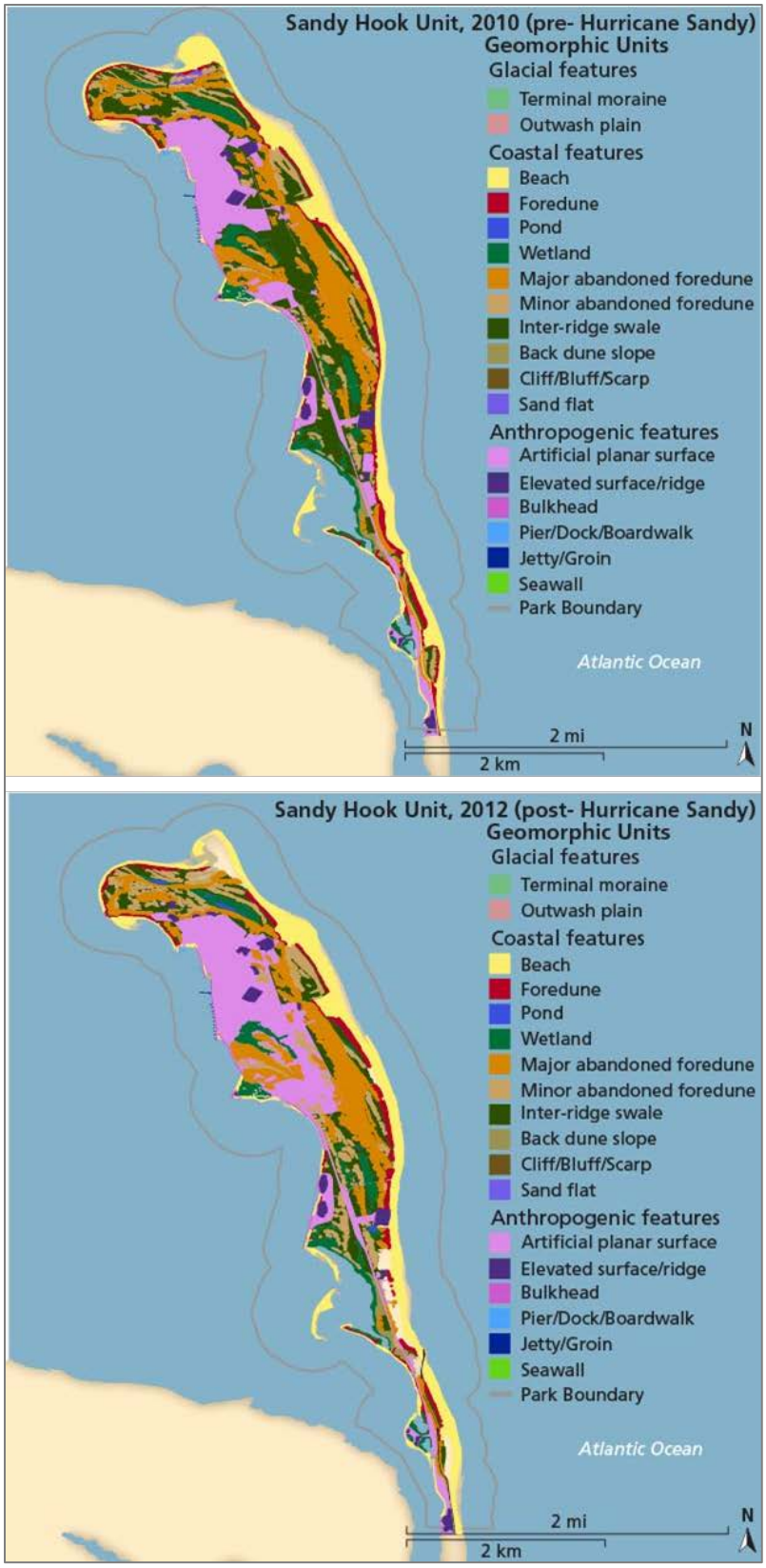


Figure 2-23. Sandy Hook Unit geomorphic units pre- (top), and post- (bottom) Hurricane Sandy, Gateway National Recreation Area. Source: Psuty et al. 2017.

In response to the storm, Congress approved the Hurricane Sandy Disaster Relief Supplemental Appropriations Act of 2013, which appropriated funds for response, recovery, and mitigation projects. Funding was also provided to improve resilience through scientific data collection and research to support the recovery in the region, as well as historic preservation efforts.

Sea level rise and coastal erosion

Because GATE is located primarily on the coast, sea level rise is of particular concern because it will threaten both cultural and natural resources. Infrastructure on or near the shoreline will be in the most immediate danger, while ecosystems and habitats that exist in transitional areas between water and land become vulnerable. Even a small change in sea level will have dramatic effects on the coastal landforms within the park. Increasing sea levels and changes in storm intensity and frequency will severely impact the park causing significant dune movement (NPS 2009). In November 2009, a severe winter storm caused major coastal landform changes. In March 2010, an extended nor'easter storm lasted over six high tides and caused drastic damage and erosion (Thornberry-Ehrlich 2011). Damage caused by these more recent storms has not been historically common in the New York area and may impact the landscapes and ecosystems of GATE in the future as their frequency and severity increases. Erosion has threatened cultural resources and infrastructure, 1.5 to 4.5 m (5 to 15 ft) of cliffside area was lost at Great Kills, and unexploded ordnances were exposed in park dunes at Sandy Hook (Thornberry-Ehrlich 2011). If climate change causes increased storm frequency and intensity, the park resources are in danger of severe degradation and change.

2.4 Resource stewardship

2.4.1 Management directive and planning guidance

Park purpose

GATE provides a national park experience in the country's largest metropolitan area. The park preserves a mosaic of coastal ecosystems and natural areas interwoven with historical coastal defense and maritime sites around New York's Outer Harbor. Beaches, marshes, waters, scenic views, and open space offer resource-based recreational opportunities to a diverse public, recognizing the importance to preserve these special places for future generations.

Park significance

Statements of significance define what makes the park unique-why it is important enough to our cultural heritage to warrant national park designation and how it differs from other parts of the country. These statements are tools for setting resource protection priorities and for identifying appropriate experiences. Each area of the park contains many significant resources, but not all these resources contribute to why the park was designated. The following significant statements have been identified for GATE:

Significance statement I

Gateway contains an assemblage of coastal ecosystems formed by natural features, both physical and biological, that include barrier peninsulas, estuaries, oceans, and maritime uplands. The habitats that comprise these ecosystems, so rare in such highly developed areas, support a rich biota that includes migratory birds, marine finfish and shellfish, plant communities, and rare, threatened, and

endangered species. These features provide opportunities to restore, study, enhance, and experience coastal habitats and ecosystem processes.

Fundamental resources and values related to Significance Statement I

- Beaches/dune system at Bergen Beach, Breezy Point Tip, Great Kills, Jacob Riis Park, Plumb Beach and Sandy Hook
- Natural areas at Breezy Point Tip, Crooke's Point, Floyd Bennett Field, Great Kills, Hoffman and Swinburne Islands, Jamaica Bay Wildlife Refuge and Sandy Hook
- Sandy Hook Maritime Forest
- Beach experience including access to ocean surf
- Direct sensory experience with natural elements
- Public access to bay and ocean shorelines
- Experience of being out on the water
- Darkness and night sky

Significance statement II

The park includes one of the largest and most complete collections of military installations and fortifications in the country, dating from the Revolutionary Era through the 20th century. These installations served as the military defense of New York, America's largest city. This long period of military presence has yielded one of the most extensive collections of historic military architecture in the national park system.

Fundamental resources and values related to significance statement II

- Coastal defense resources at Fort Hancock, Fort Tilden, and Fort Wadsworth including batteries, gun emplacements, buildings, collections, and other associated structures
- Connections of national history

Significance Statement III

The maritime resources of GATE include the first federally sponsored lifesaving station in the country and the oldest working lighthouse in the United States. These resources served to protect ocean commerce and enhance the safety of the busiest American seaport.

Fundamental resources and values related to significance statement III

- Maritime resources at Sandy Hook including the Lighthouse and Life Saving Station

Significance Statement IV

The vast and diverse park resources at the gateway to the most densely populated region of the United States provide an abundance of outstanding recreational and education opportunities.

Fundamental resources and values related to significance statement IV

- Historic landscape at Riis Park including the beaches, boardwalk, bathhouse, and back beach area
- Feelings associated with open space in a high density area
- Views that frame the Outer Harbor
- Undeveloped open space that is safe, designated, and managed
- Parks to people story-federal government role and numbers of people in area
- Recreation experience including:
    - Nature observation such as bird watching, contemplation of physical environment, quiet, astronomy
    - Water-based activities such as surfing, boating, fishing, and swimming
    - Walking/hiking, biking and horseback riding on trails
    - Picnicking
    - Visiting of historic sites

Other important cultural resources not related to the purpose of the park:

- Civil and military aviation history resources at Floyd Bennett Field and Miller Field
- Archeological resources

2.4.2 Status of supporting science

The National Park Service Inventory and Monitoring Program is divided into over 270 parks into 32 ecoregional networks throughout the country. GATE falls geographically into the Northeast Coastal and Barrier Network (NCBN), a network of eight coastal parks stretching from Virginia to Massachusetts created and managed by the NPS. One of the goals of the National Park Service's Inventory and Monitoring (I&M) Program is to provide current and accurate information for effective, long-term management of the natural resources held in trust.

Natural resource inventories and regular monitoring within a park are methods that allow park managers to more effectively manage and better protect resources. The NPS Inventory and Monitoring (I&M) Program has designated inventory teams charged with acquiring baseline data on 12 core resources, from bibliographic information to species occurrence and distribution. Through the I&M Vital Signs Monitoring program, staff from 32 Networks monitor physical, chemical, and biological processes of park ecosystems that represent the overall park health. The Northeast Coastal and Barrier Network (NCBN) – which includes GATE and seven other coastal parks – has identified 17 vital signs that have been divided into five categories: estuarine eutrophication, saltmarsh change, geomorphologic change, visitor use impacts, and forest health (Stevens et al. 2005).

While NRCAs do not recommend action regarding any change to management in the park, they represent regularly updated and review sources of scientific data. These data are collected, analyzed, archived, and publicized for management use. Park managers are briefed on any changes in the

park's vital signs on an annual basis in order to better implement new protective policies (Stevens et al. 2005).

In order to collect the greatest variety of data and better monitor the health of parks, the NPS often works with other data collecting sources. Combined with information gathered by other NPS programs, government agencies, park-funded projects, and external scientists, the I&M program works to format data in a more usable and relevant manner. This knowledge can then be used by the broader public for educational and research purposes as well as viewed by people in management positions, such as park planners, superintendents, Congress, and the Office of Management and Budget. Regular means of data collection, and timely publications of results, means that field-level practitioners can effectively communicate clear, scientifically-backed knowledge to the general public and policy makers who ultimately decide the fate of the resources (Fancy et al. 2008).

3. Study Scoping and Design

3.1 Preliminary scoping

Preliminary scoping for the assessment of Gateway National Recreation Area began in November 2015 with a meeting at Jamaica Bay National Wildlife Refuge, Broad Channel, New York. In attendance were staff from GATE, the Northeast and Coastal and Barrier Network (NCBN) of the NPS Inventory and Monitoring (I&M) Program, NPS Northeast Regional Office, Columbia University, and the University of Maryland Center for Environmental Science - Integration and Application Network (UMCES-IAN). At the meeting, the historical background and geographic layout of the park were discussed; along with its natural and cultural resources, stressors to those resources, and current and future management goals.

After the inception meeting, collection of data and background information on the park began. Data for park resources were organized into an electronic library comprised of management reports, hard data files, geospatial data (GIS), and aerial imagery. Much of the data and information were obtained from different branches of the NPS, including the Northeast Coastal and Barrier Network Inventory and Monitoring Program, the Air Resources Division, and the park itself. Additional datasets were obtained from New York Department of Environmental Protection, Brooklyn College New York State Department of Environmental Conservation, New Jersey Department of Environmental Protection and Hofstra University.



Project partners present at the initial scoping meeting in November 2015. Front row (left to right): Patti Rafferty, Doug Adamo, Brianne Walsh. Back row (left to right): Simon Costanzo, Matt Palmer, Bill Dennsion, Charles Roman, Christine Arnott, Dave Taft.

Discussion with park personnel and the NPS I&M Program assisted in choosing the indicators and reference conditions to be used for the park assessment. Regular conference calls with staff from GATE, NCBN I&M, and UMCES-IAN staff were used to identify and locate key resources for completing the assessment, to present work and calculations already completed, and interpretation of key findings and trends. A final summary meeting was held at GATE Headquarters in June 2017 where preliminary results were presented to park staff and a list of recommendations were developed and discussed.

Strong collaboration with park natural resource staff was essential to the success of this assessment, and key park staff invested significant time to assist in the development of reference conditions, calculation of metrics, and interpretation of calculated results.

3.2 Study design

3.2.1 Assessment framework

The Ecological Monitoring Framework (Fancy et al. 2008) used by the National Park Service Inventory and Monitoring Program (NPS I&M) was used in this assessment to choose indicators for the following categories:

- Air and climate
- Water
- Biological integrity
- Landscapes

Indicators were chosen by park staff in collaboration with UMCES-IAN and NPS NCBN I&M, and are outlined in Table 3-1. Final indicator selection was largely limited by the availability of long-term monitoring data that could be evaluated within this report. Efforts were made to integrate indicators from the NPS I&M Vital Signs Monitoring Program into this assessment when possible. Detailed information on relevance, methods, reference condition, and attainment are provided for each indicator in Chapter 4. Each indicator also contains a section describing data gaps and level of confidence, based on best professional judgement. Confidence in assessment did not influence the calculation of attainment or assessment of scores.

Table 3-1. Vital signs indicators and associated metrics chosen for the Natural Resource Condition Assessment of Gateway National Recreation Area.

Framework Category	Resource	Assessment Level	Indicators and Measures
Air resources	Wet deposition	Full assessment	• Wet sulfur deposition (kg/ha/yr) • Wet nitrogen deposition (kg/ha/yr) • Mercury wet deposition (mg/m2) • Methylmercury (ng/L)
	Ozone	Full assessment	• Ozone (ppb) • Ozone W126 (ppm-hrs)
	Visibility	Full assessment	• Visibility
Water resources	Water quality	Full assessment	• Total nitrogen (mg/L) • Total phosphorus (mg/L) • Dissolved oxygen (mg/L) • pH • Chlorophyll a ($\mu g/L^{-1}$) • Secchi depth (feet) • *Enterococcus* (cfu/100mL)
Biological integrity	Seabeach amaranth	Limited assessment	• Abundance (# of plants)
	Piping plover	Limited assessment	• Productivity (# fledged/# of pairs)
	Diamondback terrapin	Limited assessment	• Abundance (# of nesting females)
	Holly forest	Limited assessment	• Importance value
	Horseshoe crabs	Informational purposes only	• Index of spawning activity
Landscape dynamics	Land cover	Limited assessment	• Elevation change • Impervious surface • Shoreline change (%)

3.2.2 Reporting areas

The focus of the reporting area for the NRCA was the Gateway National Recreation Area administrative boundary. This boundary includes three distinct units: the Jamaica Bay Unit, Staten Island Unit, and Sandy Hook Unit. Where possible, reporting on the condition of indicators was by park unit. However, dependent on data availability and/or indicator type, there were instances where no distinction was made between the three park units (e.g. air resource indicators were reported for the park as a whole), and other instances where reporting was not possible for all park units (e.g. horseshoe crab data was restricted to Sandy Hook). All data used for the final assessment of park condition were collected within the park, with the exception of air quality data, which were taken from the closest air monitoring stations. In addition, there was water quality data used that was outside the administrative boundary of the Jamaica Bay Unit.

3.2.3 General approach and methods

A total of 21 indicators were used to assess natural resource condition. The approach for assessing resource condition within the park required the establishment of criteria for defining desired, as well as current ecological conditions. Reference conditions were derived from the scientific literature, and regulatory and management-based standards and guidelines.

Reference condition attainment of indicators was calculated based on the percentage of sites or samples that met or exceeded threshold values set for each metric. An attainment score of 100% reflected that the metric at all sites and at all times met the reference condition. Conversely, a score of 0% indicated that no sites at any sampling time met the reference condition value.

Indicators and reporting areas were assigned the following ratings corresponding to their score (Table 3-2, Table 3-3):

- Significant concern (0-25% reference condition attainment),
- Caution (26-75% reference condition attainment), and
- Good condition (76-100% reference condition attainment).

The four Vital Signs scores were then averaged to produce a single assessment score for the entire park. Key findings, conclusions, and recommendations are also given for each Vital Sign and for the park as a whole in Chapter 5.

Table 3-2. Indicator symbols used to indicate condition, trend, and confidence in the assessment.

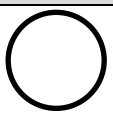
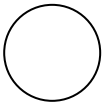
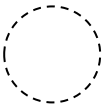
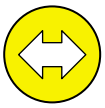
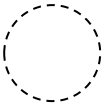
Condition Status		Trend in Condition		Confidence in Assessment	
	Resource is in Good Condition		Condition is Improving		High
	Resource warrants Moderate Concern		Condition is Unchanging		Medium
	Resource warrants Significant Concern		Condition is Deteriorating		Low

Table 3-3. Example indicator symbols and descriptions of how to interpret them in WCS tables.

Symbol Example	Verbal Description
	Resource is in good condition; its condition is improving; high confidence in the assessment.
	Condition of resource warrants moderate concern; condition is unchanging; medium confidence in the assessment.
	Condition of resource warrants significant concern; trend in condition is unknown or not applicable; low confidence in the assessment.
	Current condition is unknown or indeterminate due to inadequate data, lack of reference value(s) for comparative purposes, and/or insufficient expert knowledge to reach a more specific condition determination; trend in condition is unknown or not applicable; low confidence in the assessment.

4. Natural Resource Conditions

4.1 Air quality

Gateway National Recreation Area is located in New York City, New York, and Monmouth County, New Jersey, and air quality in the park is typical of that found in an urban area. Ambient air quality is affected by stationary, mobile, and area source emissions. Local sources include port facilities, the New York/New Jersey Harbor's shipping traffic, and air and vehicular traffic in the region. Air quality in the New York City metropolitan area has improved over the past several decades due to actions taken to reduce pollution emissions (e.g. the U.S. EPA Clean Air Act) (NYCDEP 2016). Despite this progress, concentrations of air pollutants remain at levels that can be harmful to environmental and public health. GATE and the rest of the New York-New Jersey metropolitan region receive greater than average levels of air particulates and wet deposition of chlorides, nitrates, and sulfates (NYCDEP 2016).

The Clean Air Act requires the U.S. EPA to set national air quality standards for specific pollutants that can negatively impact human health and the environment (U.S. EPA 2016). The U.S. EPA has established standards for six common air pollutants. These six air pollutants, referred to as "criteria" pollutants, include ozone, particulate matter (PM), lead, nitrogen dioxide (NO_x), carbon monoxide, and sulfur dioxide (SO_2) (U.S. EPA 2016).

A classification scheme established by Congress as part of the Clean Air Act denotes "clean air areas" that are further protected through ceilings on additional amounts of air pollutants (USFWS 2015). These areas are labeled as Class I, II, and III areas where Class I areas are national parks or national wilderness areas that receive the greatest degree of air quality protection (USFWS 2015). All remaining lands (public and private) outside of those designated as Class I are Class II areas. Gateway National Recreation Area is a Class II air quality area. This designation protects air quality by allowing only limited increases over baseline concentrations for NO_x, SO_2, and PM. These pollutants are characteristic of the EPA's New York-New Jersey-Connecticut Air Quality Control Region, an area that includes the park (NPS 2014).

Of the EPA criteria pollutants, the NPS Air Resources Division (ARD) provides assessments of all except lead and carbon monoxide. Five indicators were used to assess air quality at GATE: wet sulfur deposition, wet nitrogen deposition, ozone (human health and plant exposure), visibility (as a proxy for particulate matter), and mercury deposition (wet mercury deposition and methylmercury) (Table 4-1) (NPS ARD 2016).

Table 4-1. Vital signs indicators chosen for the Natural Resource Condition Assessment of air resources within Gateway National Recreation Area.

Indicator	Metric	Agency	Reference/source
Atmospheric deposition	Sulfur wet deposition (kg/ha/yr)	NPS ARD	NPS ARD 2015; NPS ARD 2013
	Nitrogen wet deposition (kg/ha/yr)	NPS ARD	NPS ARD 2015; NPS ARD 2013
Ozone	4th-highest daily maximum 8-hour concentration (ppb)	NPS ARD	NPS ARD 2015; NPS ARD 2013
	Vegetation health: 3-month maximum 12-hour W126 (ppm-hrs)	NPS ARD	NPS ARD 2015; NPS ARD 2013
Visibility	Visibility on mid-range days minus natural visibility condition on mid-range days (dv)	NPS ARD	NPS ARD 2015; NPS ARD 2013
Mercury	Wet deposition (mg/m^2)	NPS ARD	NPS ARD 2015
	Methlymercury (ng/L)	NPS ARD	NPS ARD 2015

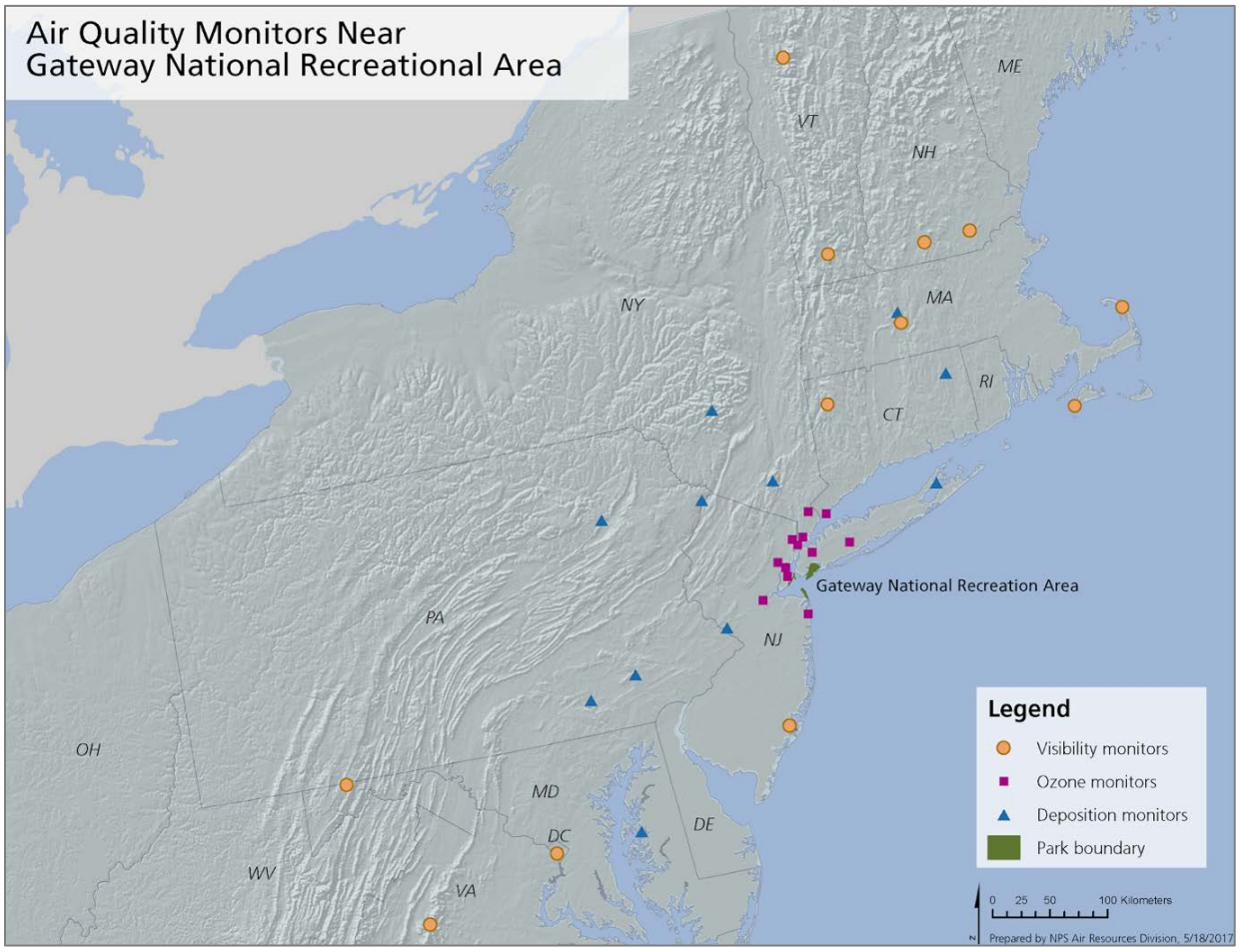


Figure 4-1. Air quality monitors near Gateway National Recreation Area (Source: NPS Air Resources Division).

Table 4-2. Air quality metrics, data availability, reference conditions, and condition assessment categories used in the natural resources assessment of Gateway National Recreation Area.

Metric	Number of sites	Period of observation	Reference conditions/percent attainment
Sulfur wet deposition (kg/ha/yr)	1	2011-2015	• <1 (100%) • 1-3 (0-100% scaled linearly) • >3 (0%)
Nitrogen wet deposition (kg/ha/yr)	1	2011-2015	• <1 (100%) • 1-3 (0-100% scaled linearly) • >3 (0%)
Ozone (ppb)	1	2011-2015	• ≤60 (100%) • 61-75 (0-100% scaled linearly) • ≥76 (0%)
Ozone W126 (ppm-hrs)	1	2011-2015	• <7 (100%) • 7-13 (0-100% scaled linearly) • >13 (0%)
Visibility (dv)	1	2011-2015	• <2 (100%) • 2-8 (0-100% scaled linearly) • >8 (0%)
Mercury wet deposition (mg/m2)	1	2011-2013	• <3 (100%) • 3-9 (0-100% scaled linearly) • >9 (0%)
Methlymercury (ng/L)	1	2011-2013	• <0.038 (100%) • 0.038-0.075 (0-100% scaled linearly) • >0.075 (0%)

4.1.1 Nitrogen and sulfur wet deposition

Description

Wet sulfur and nitrogen deposition are significant in the eastern parts of the United States, and since 1970, it has been increasingly recognized that both result in significant ecosystem impacts. In the United States, sulfur (S) emissions are produced primarily by electricity generating power plants, and secondarily from industrial and mobile sources (Figure 4-2). Sulfur is emitted into the atmosphere as sulfur dioxide (SO_2), released when S-containing coal or other fuels are burned (Sullivan et al. 2011b). There are two major types of human caused emissions of nitrogen (N) into the atmosphere in the U.S., nitrogen oxides (NOx) and NHx (Sullivan et al. 2011b). The oxidized forms (nitrogen dioxide) derive mainly from motor vehicles, power plants, and industrial facilities. The reduced forms (ammonia), derive mainly from agriculture, via volatilization of N contained in animal manures and fertilizers (Figure 4-3; Sullivan et al. 2011b).

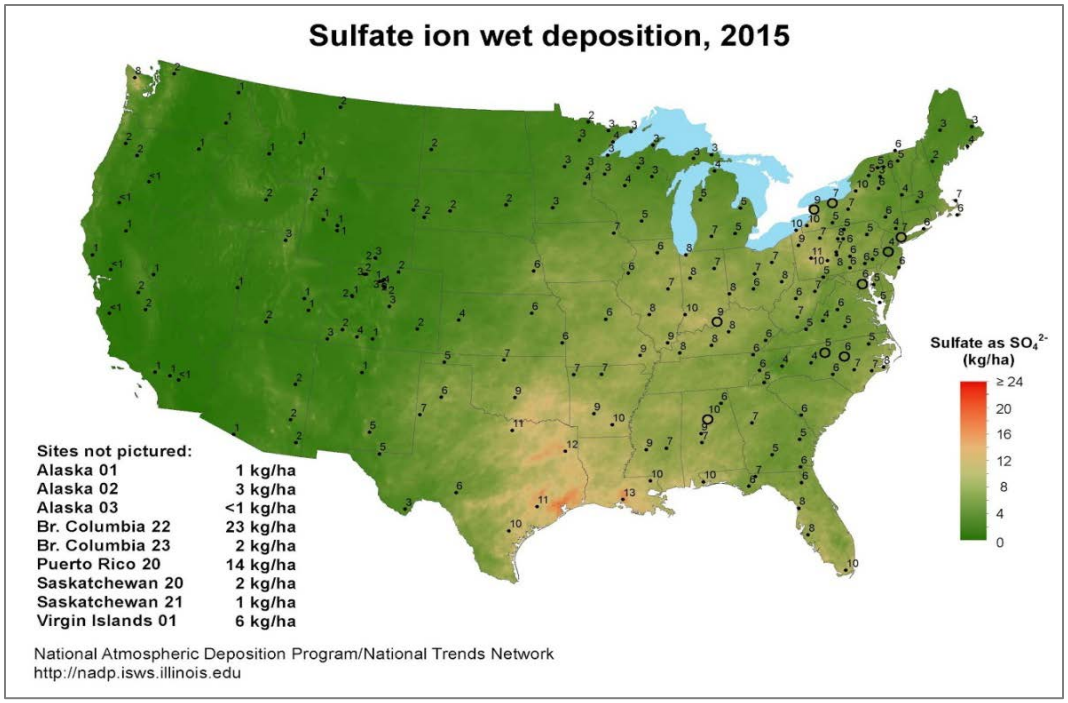


Figure 4-2. Total wet deposition of sulfate as SO_4^{2-} (kg/ha) for the continental United States in 2015 (Source: NADP/NTN 2016).

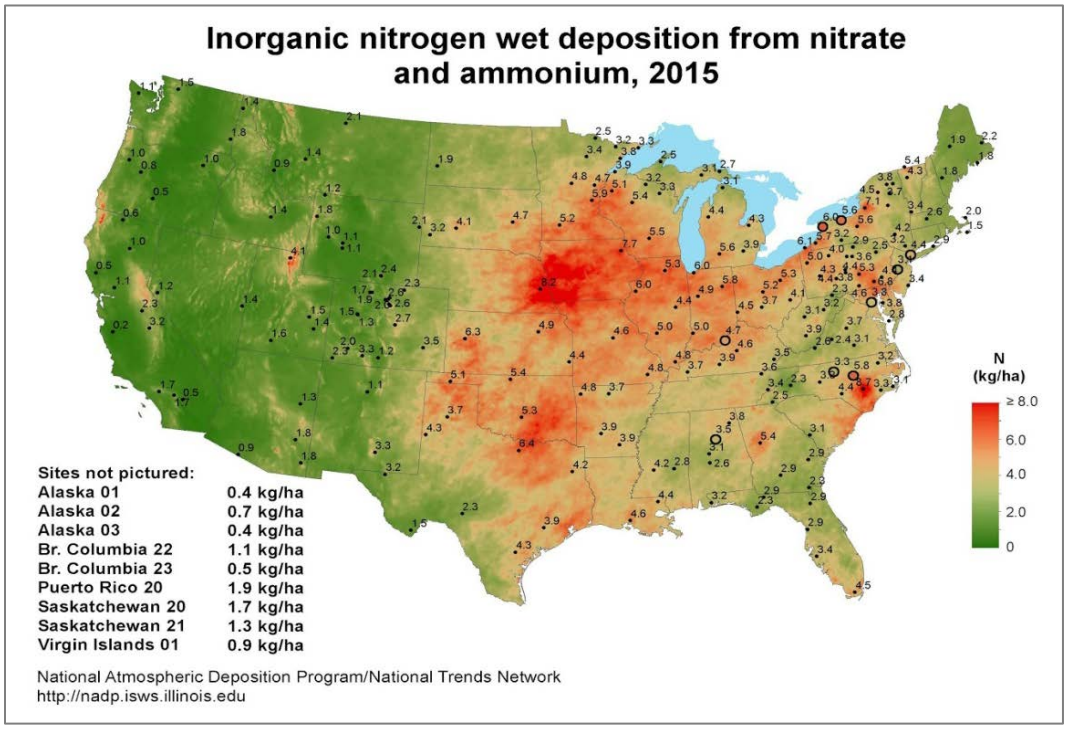


Figure 4-3. Total wet deposition of nitrate and ammonium (N) (kg/ha) for the continental United States in 2015 (Source: NADP/NTN 2016).

Atmospheric pollutants move to the ground in rain, snow, clouds, and as dry particles and gases. The overall transfer process is called acidic deposition, which can be broken down into wet, dry, and cloud or fog components. Deposition of S and/or N can cause acidification of soil, soil water, lakes, and streams. These impacts include measureable effects as the disruption of nutrient cycling, changes to vegetation structure, loss of stream biodiversity, and the acidification and eutrophication of streams and coastal waters (Driscoll et al., 2001, Porter and Johnson, 2007, Sullivan et al. 2011b). Deposition of nitrogenous compounds from the atmosphere is a significant non-point source of nitrogen to Jamaica Bay (Benotti et al. 2007). Nutrient enrichment can be detrimental to saltmarshes, as excess nutrients result in poorly rooted grasses, leading to destabilization of saltmarsh (NY DEC 2014).

Data and Methods

Data used for the assessment was spatially interpolated for the central point within GATE using data between 2011 and 2015 (NPS ARD 2015). There is currently only one assessment point for the park so this single value was assessed against the reference condition, either attaining or failing to attain the threshold value.

The reference condition for total nitrogen wet deposition is ecological. Natural background total nitrogen deposition in the eastern United States is 0.5 kg h^{-1} yr^{-1} which equates to a wet deposition of approximately 0.25 kg h^{-1} yr^{-1} (Porter and Morris, 2007, NPS ARD 2010). Some sensitive ecosystems, such as coastal and estuarine waters, and upland areas, show responses to wet nitrogen deposition rates of 1.5 kg h^{-1} yr^{-1}, while there is no evidence of ecosystem harm at deposition rates less than 1.0 kg h^{-1} yr^{-1} (Fenn et al. 2003).

NPS Air Resource Division has established wet deposition guidelines as <1.0 kg h^{-1} yr^{-1} indicating good condition (100% attainment of reference condition), and >3.0 kg h^{-1} yr^{-1} indicating significant concern (0% attainment of reference condition) (NPS ARD 2015). Concentrations of 1.0-3.0 kg h^{-1} yr^{-1} are considered moderate condition, and attainment scores were scaled linearly from 0-100% between these two reference points. For the current assessment, the reported wet deposition value was assessed against these guidelines.

Condition and Trend

Interpolated wet nitrogen deposition between 2011 and 2015 for GATE was 4.4 kg h^{-1} yr^{-1} which resulted in 0% attainment of reference condition, or a condition of significant concern (Figure 4-4) (NPS ARD 2016). Ecosystems in the park are rated as having moderate sensitivity to nutrient-enrichment effects relative to all Inventory & Monitoring parks (Sullivan et al., 2011c; Sullivan et al. 2011d). Nitrogen deposition may disrupt soil nutrient cycling and affect biodiversity of some plant communities, including grassland and wetlands.

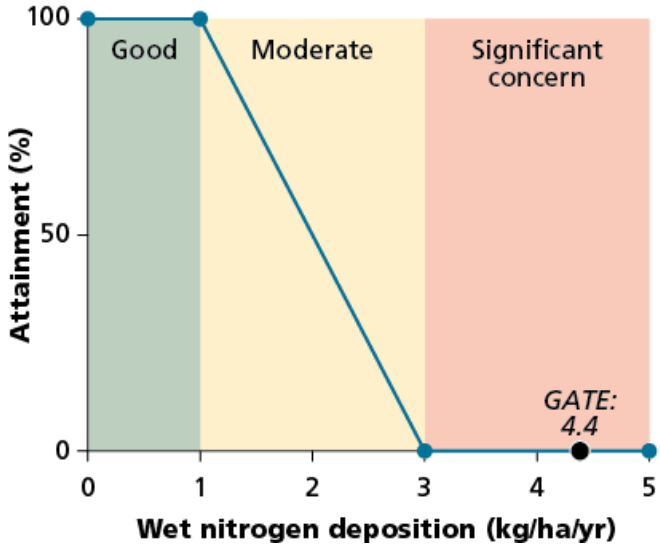


Figure 4-4. Application of the percent attainment categories to the wet nitrogen deposition value categories. Wet Nitrogenous compounds deposition at Gateway National Recreation Area was 4.4 kg h-1 yr-1, which equated to 0% attainment of the reference condition.

Interpolated wet sulfur deposition between 2011-2015 for GATE was 2.8 kg ha^{-1} yr^{-1} which resulted in 10% attainment of the reference condition, which is moderate condition (Figure 4-5). Although GATE receives high levels of sulfur deposition, ecosystems in the park are not typical of sulfur-sensitive systems and were rated as having low sensitivity to acidification effects relative to all Inventory & Monitoring parks (Sullivan et al., 2011a; Sullivan et al., 2011b).

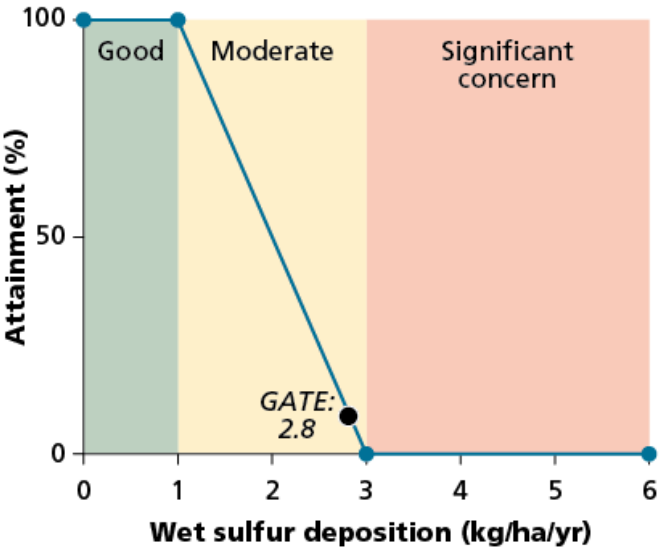


Figure 4-5. Application of the percent attainment categories to the wet sulfur deposition value categories. Wet sulfur deposition at Gateway National Recreation Area was 2.8 kg h^{-1} yr^{-1}, which equated to 10% attainment of the reference condition.

No trend information is available because there are not sufficient on-site or nearby deposition monitoring data (NPS ARD 2016).

Sources of Expertise

- National Park Service Air Resources Division; http://www.nature.nps.gov/air/
- Holly Salazer, National Park Service Air Resources Division, Northeast Regional Coordinator.

4.1.2 Mercury atmospheric deposition

Description

Atmospheric mercury (Hg) comes from natural sources, including volcanic and geothermal activity, geological weathering, and anthropogenic sources such as burning of fossil fuels, processing of mineral ores, and incineration of certain waste products (UNEP 2008). At a global scale, annual anthropogenic emissions of Hg approximately equal all natural marine and terrestrial emissions, with anthropogenic emissions in North America being 153 indicator tonnes in 2005 (UNEP 2008) (Figure 4-6).

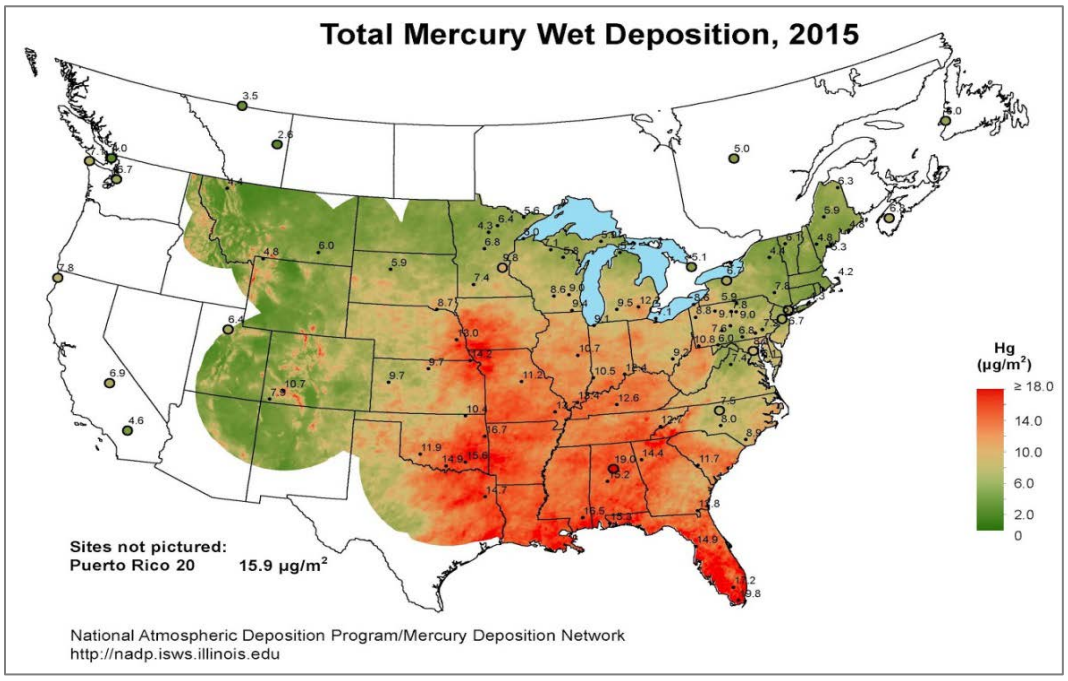


Figure 4-6. Total mercury wet deposition across the United States in 2015 (Source: NADP/MDN 2016).

High mercury concentrations in birds, mammals, amphibians, and fish can result in reduced foraging efficiency, survival, and reproductive success. Elevated levels of mercury in humans can affect the brain, kidneys, and reproductive function. Wet and dry deposition can lead to mercury loadings in water bodies, where mercury may be converted to a bioavailable toxic form of mercury, methylmercury, and bioaccumulate through the food chain. Wetlands, especially those rich in organic matter, are important sites for methylmercury production (NPS ARD 2017).

Mercury deposited from air pollution through the Gateway National Recreation Area park units originates from coal fired power plants in other states. This has resulted in statewide fish consumption advisories for both New York and New Jersey (Dutzik and O'Malley 2010). The U.S. EPA monitors and maintains a database of fish advisories by state. Within Gateway National Recreation Area, fish consumption recommendations have been outlined in both the New York and New Jersey units of the park. These consumption advisories vary based on fish species, location of catch, and age of consumer (NYS Department of Health 2016).

Data and Methods

Data was obtained from the National Atmospheric Deposition Program, Mercury Deposition Network. Samples are collected weekly and within 24 hours of a precipitation event and analyzed for Hg concentration, measured in nanograms per liter (ng/L) of Hg. Annual mean Hg concentrations were calculated for each sampling site (NPS ARD 2015).

Condition and Trend

Mercury/toxics deposition warrants moderate concern. Given that landscape factors influence the uptake of mercury in the ecosystem, the status is based on estimated wet mercury deposition and predicted levels of methylmercury in surface waters. The 2011-2013 estimated wet mercury deposition is moderate at the park, ranging from 8.0 to 8.7 micrograms per square meter (communications with NPS-ARD 2016) and predicted methylmercury concentrations in surface waters is high, ranging from 0.068 to 0.079 nanogram per liter (USGS 2015). To maintain the greatest level of protection, the highest values for both factors were compared to NPS Air Resources Division benchmarks to determine the significant concern status.

Ratings for mercury wet deposition and predicted methylmercury concentration are considered concurrently in the mercury status assessment for the park. GATE is considered in the category of "warrants moderate concern" because mercury wet deposition is considered moderate and predicted methylmercury concentration is considered high (NPS 2015).

The degree of confidence in the wet deposition status is low because sulfur and nitrogen wet deposition and methylmercury concentration estimates are based on interpolated or modeled data rather than in-park studies.

Sources of Expertise

- National Park Service Air Resources Division; http://www.nature.nps.gov/air/
- Holly Salazer, National Park Service Air Resources Division, Northeast Regional Coordinator.

4.1.3 Ozone

Description

Ozone is a secondary atmospheric pollutant, meaning it is not directly emitted, but rather formed by a sunlight-driven chemical reaction on nitrous oxides (NOx) and volatile organic compounds (VOC) emitted largely from burning fossil fuels (Haagen-Smit and Fox 1956). Because the reactions are

slow and occur as the pollutants move downward, elevated ozone levels are often found many miles from sources of the precursor pollutants (NPS 2013). The effects of NOx and VOC emissions from all sources are therefore generally analyzed on a regional basis. Both stationary and mobile sources contribute to the combined total of these pollutants (FHWA 2006, NPS 2013).

In addition to being a concern to the health of park staff and visitors, long-term exposures to ground-level ozone can cause injury to ozone-sensitive plants (NPS 2015). Some plant species are more sensitive to ozone than humans. These sensitive plants can develop foliar injury from elevated ozone exposure levels much lower than the public health ozone standard especially when soil moisture levels are moderate to high. Under these conditions, plants have their stomata open, allowing gas exchange for photosynthesis, but also allowing ozone to enter. In a study of 28 plant species exposed to ozone between three and six weeks, foliar impacts, including premature defoliation were reported in all species at ozone concentrations between 60-90 ppb (Kline et al. 2008). Ozone can also negatively affect pollination by destroying the scent-bearing molecules released by flowers to attract pollinators.

A risk survey completed by the National Park Service Air Resources Division identified a high risk of foliar ozone injury at Gateway National Recreation Area (Table 4-3).

Table 4-3. Plant species sensitive to ozone in Gateway National Recreation Area (NPS ARD 2004).

Plant type	Species present in GATE
Grass	Smooth cordgrass (*Spartina alterniflora*)
Forb/herb	Common milkweed (*Asclepias syriaca*)
Shrub	American elder (*Sambucus canadensis*)
	Allegheny blackberry (*Rubus allegheniensis*)
	Common snowberry (*Symphoricarpos albus*)
	Flameleaf sumac (*Rhus copallina*)
	Sweet mock-orange (*Philadelphus coronarius*)
Tree	American sweetgum (*Liquidambar styraciflua*)
	American sycamore (*Platanus occidentalis*)
	Black cherry (*Prunus serotina*)
	Black locust (*Robinia pseudoacacia*)
	Green ash (*Fraxinus pennsylvanica*)
	Pitch pine (*Pinus rigida*)
	Quaking aspen (*Populus tremuloides*)
	Sassafrass (*Sassafras albidum*)
	Tree-of-heaven (*Ailanthus altissima*)*
	Virginia pine (*Pinus virginiana*)

*denotes non-native species

Table 4-3 (continued). Plant species sensitive to ozone in Gateway National Recreation Area (NPS ARD 2004).

Plant type	Species present in GATE
Tree (continued)	White ash (*Fraxinus americana*)
	Yellow poplar (*Liriodendron tulipifera*)
Vine	Northern fox grape (*Vitis labrusca*)
	Virginia creeper (*Parthenocissus quinquefolia*)

*denotes non-native species

Data and Methods

Ozone data used for the assessment of GATE were taken from the NPS Air Resources Division (ARD) Air Quality Estimates (NPS ARD 2016). These estimates were calculated on a national scale between 2011 and 2015 using an interpolation model based on monitoring data. The value for GATE was taken from the interpolation at the park centroid.

Data used for the assessment was interpolated as the five-year average of the fourth-highest daily maximum eight-hour average ozone concentration measured at each monitoring station, between 2011 and 2015, for the central point within Gateway National Recreation Area, and supplied by the NPS ARD (NPS ARD 2016). There is currently only one assessment point for GATE so this value was assessed against the reference condition, either attaining or failing to attain this threshold value.

Ground-level ozone is regulated under the Clean Air Act and the U.S. EPA is required to set standard concentrations for ozone (U.S. EPA 2004). The current National Ambient Air Quality Standards (NAAQS) standard is 75 ppb, based on the three-year average annual fourth-highest daily maximum eight-hour ozone concentration at a monitor (NAAQS 2008).

NPS ARD has established ozone concentration (three-year average fourth-highest daily maximum eight-hour ozone concentration, averaged over five years) guidelines as ≤ 60.0 ppb (set as 80% of the current standard of 75 ppb indicating good condition) and ≥ 76 ppb indicating significant concern (or 0% attainment) (U.S. EPA 2007, NPS ARD 2013). Concentrations of 61-75 ppb were considered moderate condition, and attainment scores were scaled linearly from 0 to 100% between these two reference points.

Vegetation sensitivity is also considered for ozone condition assessment. Data shows that some plant species are more sensitive to ozone than humans and the ozone standard is not protective of some vegetation. Both the three-year average annual fourth-highest daily maximum eight-hour concentration (averaged over five years) and the plant exposure indicator, the W126, are incorporated into the benchmarks to assess ozone condition within National Park units by the NPS ARD (NPS ARD 2011, NPS ARD 2013).

NPS ARD also looks at the W126 standard to assess the risk for ozone-induced foliar damage to sensitive plants. W126 provides an index of the cumulative ozone exposure to plants during daylight hours. The W126 weights higher ozone concentration more heavily because it is more likely to cause

injury. Values less than 7 parts per million-hour (ppm-hrs) are considered safe for sensitive plants (or 100% attainment of reference condition) and values > 13 ppm-hrs is considered a significant concern for very sensitive plant species (or 0% attainment). Values of 7-13 ppm-hrs represent a moderate condition, and attainment scores were scaled linearly from 0 to 100% between these two reference points (NPS ARD 2011, NPS ARD 2013).

Condition and Trend

Human health risk from ground-level ozone warrants significant concern at GATE. Interpolated fourth-highest daily maximum eight-hour ozone concentration between 2009 and 2013 for GATE was 76.4 ppb, which resulted in 0% attainment of reference condition (Figure 4-7) (NPS ARD 2016). The park falls within areas designated by the Environmental Protection Agency (EPA) as nonattainment (not meeting) for the ground-level ozone standard of an 8-hour average concentration of 75 ppb.

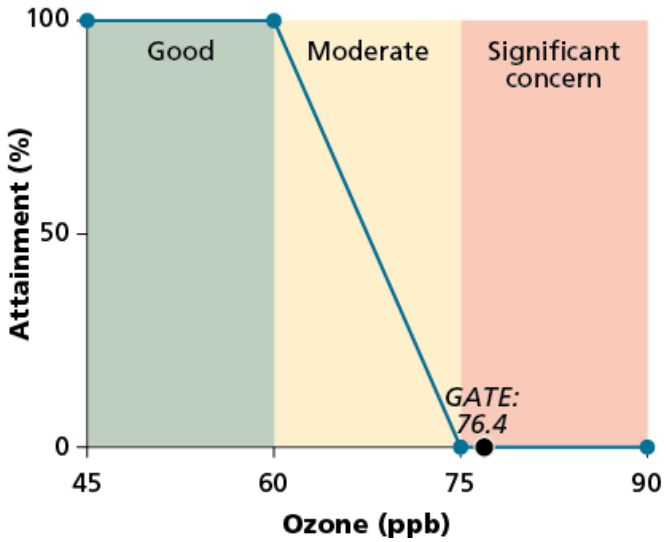


Figure 4-7. Interpolated ozone at Gateway National Recreation Area was 76.4 ppb, which results in 0% attainment of the reference condition for human health.

Interpolated W126 value between 2009 and 2013 for GATE was 11.1 ppm-hours, which resulted in 30% attainment of the reference condition, or a condition of moderate concern (Figure 4-8) (NPS ARD 2016). The W126 metric relates plant response to ozone exposure. A risk assessment concluded that plants at GATE were at high risk for ozone damage (Kohut, 2007, Kohut, 2004).

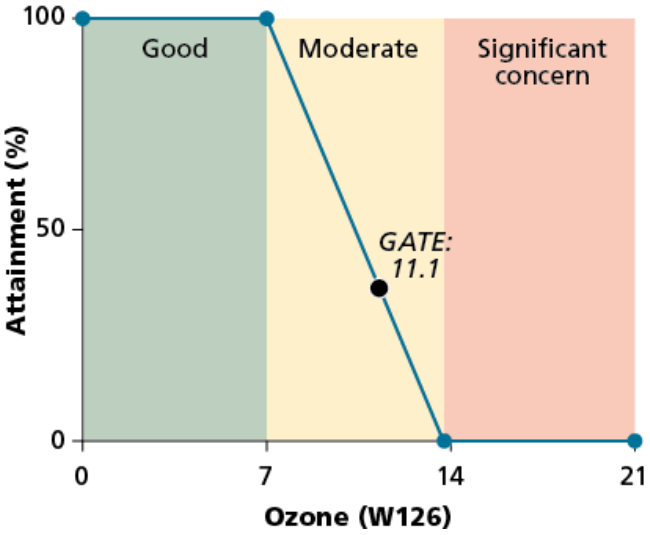


Figure 4-8. Interpolated ozone W126 at Gateway National Recreation Area was 11.1 ppb, which results in 30% attainment of the reference condition.

For 2006-2015, the trend in both the human health and the W126 metric at GATE remained relatively unchanged (no statistically significant trend) (Figure 4-9 and Figure 4-10) (AQS Monitor ID: 360850067, NY) (NPS ARD 2016).

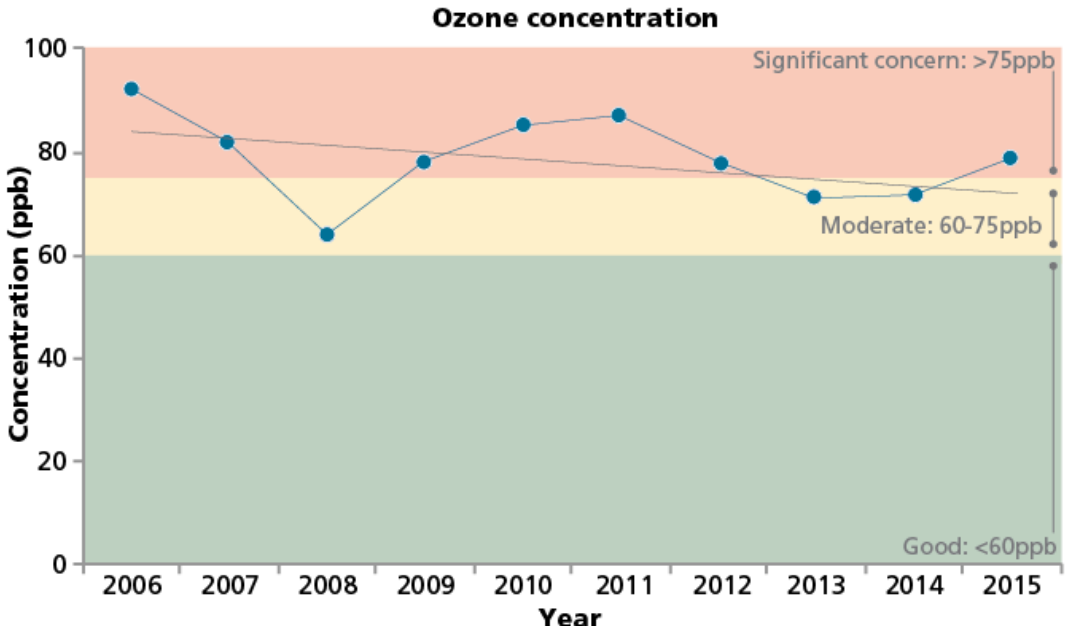


Figure 4-9. Long term trend in ozone concentration (ppb) for Gateway National Recreation Area for 2006-2015. Trend line slope of -1.2ppb/yr indicates that there is not a significant trend in ozone concentration (Source: NPS ARD 2016).

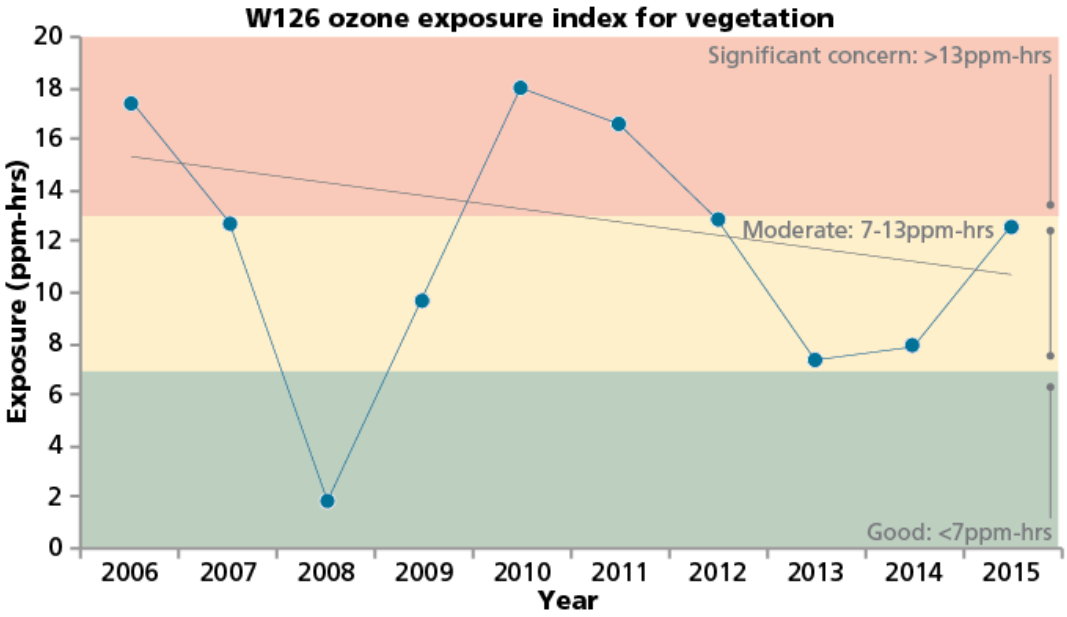


Figure 4-10. Long term trend in W126 ozone exposure index for vegetation for Gateway National Recreation Area for 2006-2015. Theil trend line, slope of -0.54ppm-hrs/yr indicates that there is not a significant trend in ozone exposure (Source: NPS ARD 2016).

The degree of confidence at GATE is high because there is an on-site or nearby ozone monitor.

Sources of Expertise

- National Park Service Air Resources Division; http://www.nature.nps.gov/air/
- Holly Salazer, National Park Service Air Resources Division, Northeast Regional Coordinator.

4.1.4 Atmospheric visibility

Description

Visibility is the ability to clearly see color and detail and distant views, and can be impacted by air pollution. Air pollution can create a white or brown haze that affects how far we can see, but also the ability to see colors, forms, and textures of a scenic vista. Haze results from air pollutants, such as fine particles that absorb and scatter light. The presence of sulfates, organic matter, soot, nitrates, and soil dust can impair visibility. In the eastern U.S., the major cause of reduced visibility is sulfate particles formed from SO_2 emitted from coal combustion (National Research Council 1993). Some haze can also occur naturally due to dust, fog, and wildfire smoke. The Clean Air Act includes visibility as one of its national goals as an indicator of emissions (U.S. EPA 2004). The Clean Air Act established a national goal to return visibility to "natural conditions" in Class I areas. Natural visibility conditions are those estimated to exist in a given area in the absence of human-caused visibility impairment. The NPS ARD recommends a visibility desired condition that is consistent with this Clean Air Act goal. Based on the Organic Act mandates, the NPS ARD recommends the same desired conditions for Class I and Class II parks.

Data and Methods

Air pollution causes haze and reduces visibility. Visibility is measured using the Haze Index in deciviews (dv). As the Haze Index increases, visibility worsens. Conditions for visibility are based on five-year average visibility minus estimated average natural visibility, where average visibility is the mean of visibility between 40th and 60th percentiles (U.S. EPA 2003, NPS ARD 2013). Interpolated 5-year averages are used within the contiguous U.S. The visibility condition is expressed as:

Visibility condition = average current visibility – estimated average natural visibility

Natural visibility conditions represent the long-term degree of visibility that is estimated to exist in a given mandatory federal Class I area in the absence of human-caused impairment. Natural visibility conditions are calculated on the average or best visibility (20% least haziest) days monitored over several years.

The reference condition for visibility is based on the national goal of restoring natural visibility. The Regional Haze Rule requires remedying existing and preventing any future visibility impairment in the nation's largest parks and wilderness areas, known as the 'Class I' areas (NPS ARD 2010). NPS has adopted this goal for all parks, including GATE and all others designated as Class II under the Clean Air Act.

The haze index data used for the assessment of current condition at GNRA were taken from the NPS Air Resources Division (ARD) Air Quality Estimates (NPS ARD 2016). These estimates were calculated on a national scale between 2009 and 2015 using an interpolation model based on monitoring data. The value for GATE was taken from the interpolation at the park centroid.

NPS ARD has established visibility guidelines as ≤ 2 dv above natural conditions indicating good condition (or 100% attainment of reference condition) and ≥ 8 dv above natural conditions indicating significant concern (or 0% attainment). Concentrations of 2-8 dv above natural conditions were considered in moderate condition, and attainment scores were scaled linearly from 0 to 100% between these two reference points. For this assessment, the reported visibility value was assessed against these guidelines (NPS ARD 2013).

This analysis meant that there was only one value reported for the haze index for GATE, so this value was assessed against the three reference condition ranges described above.

Condition and Trend

Interpolated haze index between 2009 and 2013 for GATE was 6.2 dv, which resulted in 25% attainment of the reference condition, or a condition of moderate concern (Figure 4-11) (NPS ARD 2016).

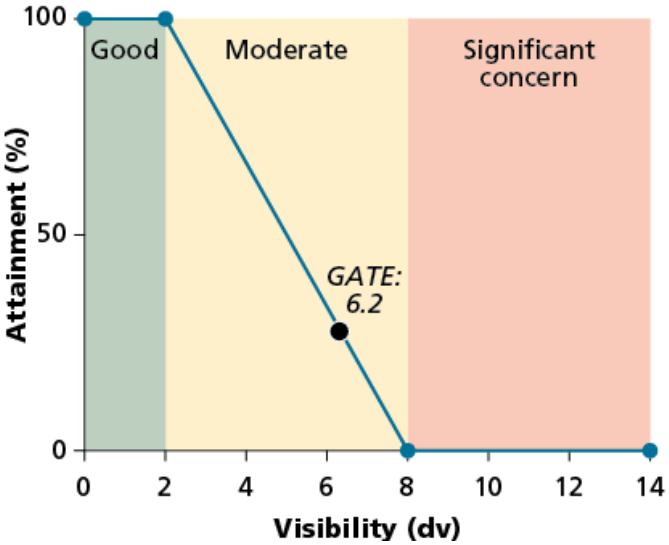


Figure 4-11. Application of percent attainment categories to the visibility value categories. Visibility at Gateway National Recreation Area was 6.2 dv, which resulted in 25% attainment of the reference condition.

No trend information is available because there are not sufficient on-site or nearby visibility monitoring data.

The degree of confidence at GATE is medium because estimates are based on interpolated data from more distant visibility monitors.

Sources of Expertise

- National Park Service Air Resources Division; http://www.nature.nps.gov/air/
- Holly Salazer, National Park Service Air Resources Division, Northeast Regional Coordinator.

4.2 Water resources

4.2.1 Water resources summary

New York Harbor is a highly productive estuary that provides habitat for a variety of aquatic and terrestrial species, and ecosystem services for surrounding communities. For over 300 years, the NY/NJ Harbor and New York metropolitan areas have been a center of urban development, transportation, and commerce, and therefore experienced extreme land use change and human population growth (NY/NJ Harbor Estuary Program 2010). Loadings of nutrients and organic matter from wastewater treatment plants combined with high levels of biological productivity have resulted in poor water quality conditions. The historical and ongoing alterations to the estuarine regions of GATE (e.g. dredging, filling, channelizing, shoreline hardening and harvesting of flora and fauna) have resulted in degraded water quality within the bays (NYCDEP 2007). The City of New York New York Harbor Survey Program has been collecting water quality data in New York Harbor since 1909, and National Park Service monitoring began in 1979. Over this time period, upgrades to

wastewater infrastructure have been completed, and the City has reported that water quality has improved (NYCDEP 2016).

Jamaica Bay is connected to Lower New York Bay, the Hudson River and the Atlantic Ocean via the Rockaway Inlet (US FWS 1997). The Bay has an average semidiurnal tidal range of 1.5 meters (5 feet). The Bay's original low tide depth of 3 feet has increased to 16 feet as a result of landfilling of shallows, dredging, and sediment removal creating borrow pits. Subsequently, the residence time within Jamaica Bay has increased from 11 days to 33 days (NYCDEP 2007). By adding these deeper channels, flow within Jamaica Bay has been restricted, which can cause increased stratification (NYCDEP 2007). The largest sources of freshwater to Jamaica Bay are from four wastewater treatment plants that discharge into the bay - Coney Island, 26th Ward, Jamaica, and Rockaway (NYCDEP 2012). Jamaica Bay's tributaries and dead-end canals (including the Paerdegat, Shellbank, and Bergen Basins) are prone to reduced water quality due to direct surface runoff and poor flushing (NYCDEP 2012).

All waters in New York State are classified for use by the New York Department of Environmental Conservation. Standards set forth the maximum allowable levels of chemical pollutants and are used as regulatory targets for permitting, compliance, enforcement, and monitoring. Despite the open waters of Jamaica Bay being classified as saline surface waters (Class SB, NYDEC 2016), primary contact recreation is prohibitive in Jamaica Bay.

Seven metrics were used to assess water resources in GATE: dissolved oxygen, water clarity, chlorophyll a, total nitrogen, total phosphorus, pH, and *Enterococcus* (Table 4-4). With the exception of *Enterococcus*, data for the metrics assessed was only available for the Jamaica Bay Unit. Data used in this assessment was provided by NPS, USGS, New York City Department of Environmental Protection, and the New Jersey Department of Environmental Protection (NJDEP) Cooperative Coastal Monitoring Program for years 2010-2015 at monitoring sites in each of the three park units (Figures 4-12, 4-13, 4-14). Data for the Jamaica Bay Unit is available online on the Jamaica Bay Water Quality Data Visualization and Access Tool (http://www.ciesin.columbia.edu/jbwq/). Reference conditions were established for each of the seven indicators and data were compared to these reference conditions to obtain the percent attainment or non-attainment, which was then converted to the condition assessment for that indicator.

Table 4-4. Indicators, metrics, and data sources used to assess water resources of Gateway National Recreation Area.

Water resource indicator	Agency	# of sites	Years	Reference condition	Reference condition source
Dissolved oxygen	NPS/NYC DEP	16	2010-2015	• ≥5 mg/L (Good condition) • 2 - 5 mg/L (Moderate concern) • ≤2 mg/L (Signficant concern)	NPS NCBN Estuarine Water Quality; U.S. EPA National Coastal Assessment; NOAA National Eutrophication Assessment (USEPA 2001, 2002, 2004, Brickler et al. 1999).
Secchi depth	NPS/NYC DEP	36	2010-2015	• >5 ft (Good condition) • 3 - 5 ft (Moderate concern) • <3 ft (Significant concern)	NYCDEP 2010
Chlorophyll *a*	NPS/NYC DEP	28	2010-2015	• <5 µg L^{-1} (Good condition) • 5 - 20 µg L^{-1} (Moderate concern) • >20 µg L^{-1} (Significant concern)	NPS NCBN Estuarine Water Quality; U.S. EPA National Coastal Assessment; NOAA National Eutrophication Assessment (USEPA 2001, 2002, 2004, Brickler et al. 1999).
Total nitrogen	NPS/NYC DEP	34	2010-2015	• 0.4, 0.5, 0.6, 0.8, and 1.2 mg L^{-1}	Mid-Atlantic Tributary Assessment Coalition tidal indicator protocol (EcoCheck 2011)
Total phosphorus	NPS/NYC DEP	34	2010-2015	• 0.03, 0.05, 0.07, 0.09, and 0.13 mg L^{-1}	Mid-Atlantic Tributary Assessment Coalition tidal indicator protocol (EcoCheck 2011)
pH	NPS/NYC DEP	48	2010-2015	• 6.5-8.5 (pass/fail)	NPS NCBN Estuarine Water Quality; U.S. EPA National Coastal Assessment; NOAA National Eutrophication Assessment (USEPA 2001, 2002, 2004, Brickler et al. 1999).
Enterococcus	NPS/NYC DEP	31	2010-2015	• 104 cfu/100mL (pass/fail)	NPS, U.S. EPA

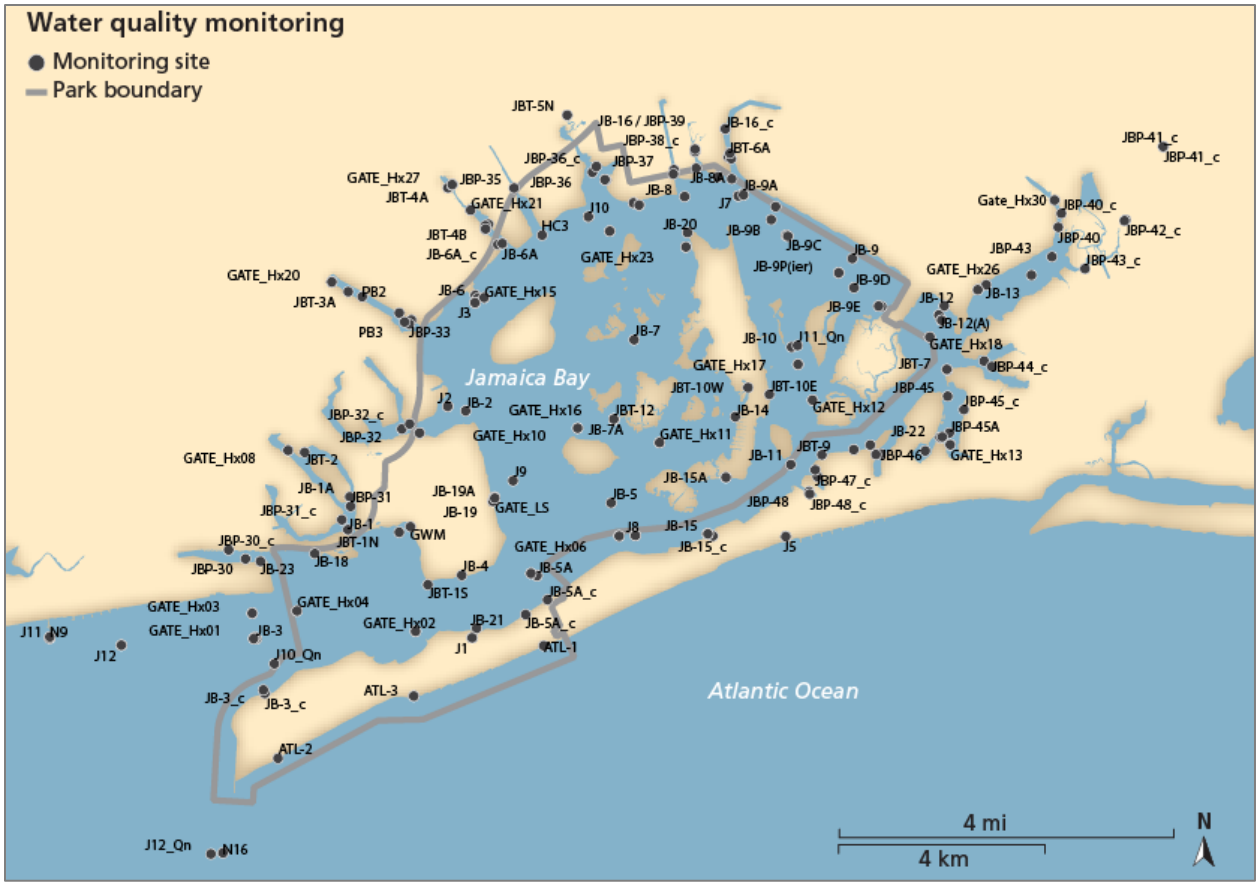


Figure 4-12. Water quality monitoring sites used in the assessment of water resources within the Jamaica Bay Unit of Gateway National Recreation Area.



Figure 4-13. Water quality monitoring sites used in the assessment of water resources within the Staten Island Unit of Gateway National Recreation Area.



Figure 4-14. Water quality monitoring sites used in the assessment of water resources within the Sandy Hook Unit of Gateway National Recreation Area.

4.2.2 Dissolved oxygen

Description

Dissolved oxygen (DO) concentration in water is often used as an indicator to gauge the overall health of the aquatic environment. It is needed to maintain suitable habitat for the survival and growth of fish and many other aquatic organisms (USGS 2013). Adequate levels of DO in the water column are necessary for respiration of most aquatic life forms, including fish, invertebrates, clams, and zooplankton (NYCDEP 2011). Low DO is of great concern due to detrimental effects on aquatic life. Conditions that generally contribute to low DO levels include warm temperatures, low flows, water stagnation, organic matter inputs, and high respiration rates. Decay of excessive organic debris in the water column from aquatic plants, municipal or industrial discharges, or storm runoff can also cause DO concentrations to be undersaturated or depleted. Insufficient DO can lead to unsuitable conditions for aquatic life and its absence can result in the unpleasant odors associated with anaerobic decomposition (Thomas et al. 2013).

In some areas of Jamaica Bay that have been dredged, the creation of borrow pits and channel dredging have created regions of deep water with reduced circulation, and is stratified in the summer months. These areas have the potential to experience hypoxic events (dissolved oxygen ≤2 mg/L), as plankton and detritus settle to the lower layer and decompose (NPS 2008). Summer average DO levels in both surface and bottom waters of the Inner Harbor have increased from less than 4 mg/L in the mid-1970s to above 5 mg/L beginning in the early 1990s (NYCDEP 2002).

Data and Methods

The data used to assess DO with GATE was measured annually at 59 sites within the Jamaica Bay Unit. The data analyzed were collected between 2010 and 2015 by the National Park Service, USGS, and New York City Department of Environmental Protection (Kopp and Neckles 2009, NYC DEC 2017). Samples were collected near the bottom of the water column. The dissolved oxygen reference condition was determined using commonly accepted levels of dissolved oxygen that are protective of aquatic animals (fish). The dissolved oxygen reference condition used for the assessment of DO was from the New York State Department of Environmental Conservation (NYS regulation 6 NYCRR Part 703), and the U.S. EPA National Coastal Condition Assessment (NCCA). State standards represent a range of acceptable DO levels corresponding to the state designated “best usage” of the water body. In NYS, the best usage of “fish survival” is a dissolved oxygen level never less than 3.0mg/L. The NCCA established the following scale for assessing dissolved oxygen values: ≤2 mg/L (poor), 2-5mg/L (fair), ≥5 mg/L (good). To assess DO within GATE, all values were compared against the reference conditions, and percent attainment was calculated based on the number of samples in the fair and good categories.

Condition and Trend

The condition of DO within GATE is very good with 95% attainment of the reference condition.

Ten year historical trend in dissolved oxygen from 2003 to 2015 is shown in Figure 4-15. Each point is the annual median of all dissolved oxygen values at all sites.

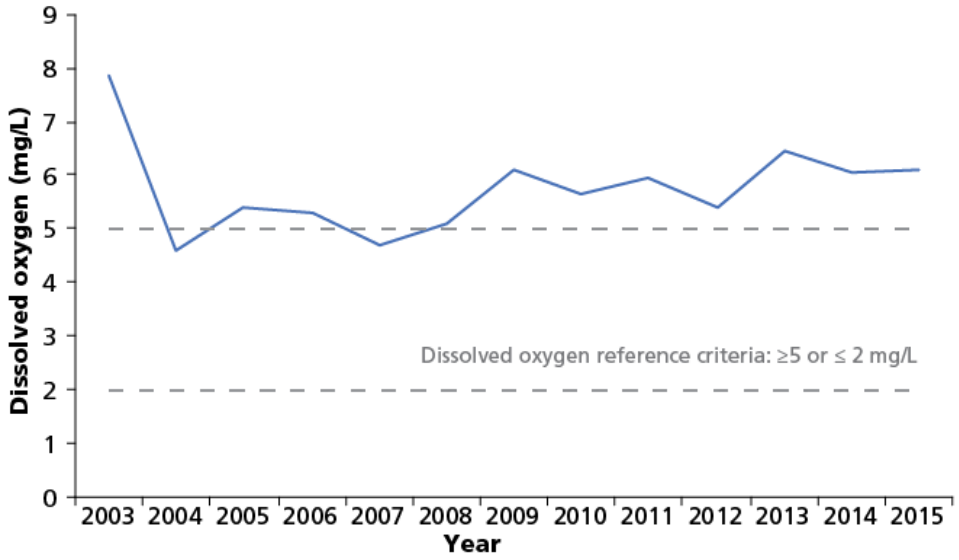


Figure 4-15. Annual median dissolved oxygen values from 2003 to 2015 for Jamaica Bay Unit of Gateway National Recreation Area. Reference condition ≤2 mg/L (poor), 2-5 mg/L (fair), ≥5 mg/L (good) shown in gray. The dissolved oxygen reference condition used for the assessment of DO was from the New York State Department of Environmental Conservation (NYS regulation 6 NYCRR Part 703), and the U.S. EPA National Coastal Condition Assessment (NCCA)

Sources of Expertise

- Dennis Skidds, National Park Service, Northeast Coastal Barrier Island Network
- Brett Branco, Brooklyn College, The City University of New York
- Beau Ranheim, NYC Department of Environmental Protection

4.2.3 Water clarity (secchi depth)

Description

Water clarity is a measure of how much light penetrates through the water column. It is dependent upon the amount of suspended particles (e.g., sediment and plankton) and colored organic matter present. A Secchi disk is used to determine the clarity of surface waters (NYCDEP 2011). High secchi transparency (≥5 feet) is indicative of clear water, which is critical for the growth and survival of eelgrass as well as fish, crabs, and other aquatic organisms (NYCDEP 2011). A Secchi transparency of <3 feet is typically associated with poor water quality. Poor water clarity is usually caused by a combination of excess suspended sediments from runoff and the growth of phytoplankton, which is fueled by nutrients. These conditions limit the penetration of light through the water column, which result in reductions in primary productivity and changes in nutrient cycling (NYCDEP 2011).

Submerged aquatic vegetation (SAV) are a vital habitat and food source for fish and waterfowl, important nutrient and carbon cyclers, sediment stabilizers, contributors to food web, and indicator species of estuarine health and quality. Historically, Jamaica Bay was characterized by dense SAV beds that hindered navigation; however, today there are no SAV beds within the bay. Water

temperature, water clarity, and eutrophication are thought to be factors limiting the restoration of SAV in Jamaica Bay (NY DEC 2011). SAV growth is dependent on light and is therefore sensitive to factors that attenuate light availability in the overlying water column such as phytoplankton, total suspended solids, and dissolved organic matter. Since 1986, algae levels have increased and water clarity in Jamaica Bay has declined more than 20 percent (Jamaica Bay Watershed Protection Plan Advisory Committee 2006).

Data and Methods

The data used to assess water clarity within GATE was measured annually at 36 sites within the Jamaica Bay Unit (Kopp and Neckles 2009, NYC DEC 2017). The data analyzed were collected between 2010 and 2015 by the National Park Service and New York City Department of Environmental Protection. The thresholds for Secchi depth were sourced using the NYCDEP water quality standards. The thresholds for Secchi depth are 3 feet and 5 feet. To calculate the percent attainment, each sample was measured against the threshold criteria (NYCDEP 2010).

Condition and Trend

Water clarity condition within GATE is of moderate concern with 65% attainment of the reference value.

Ten-year historical trend in dissolved oxygen is shown in Figure 4-16. Each is the annual median of secchi depth values at all sites.

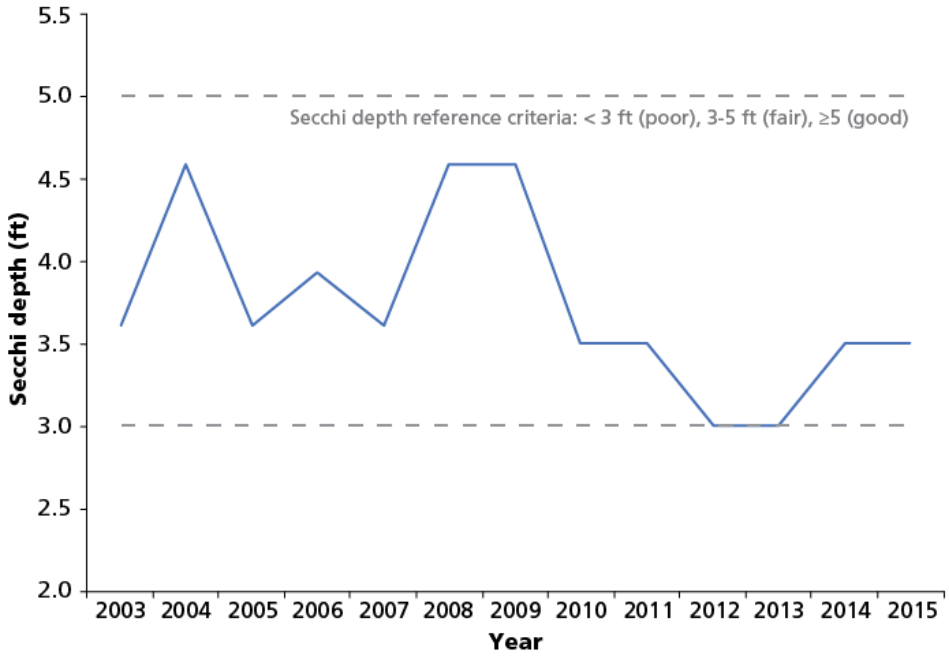


Figure 4-16 Annual median Secchi depth (ft) values from 2003 to 2015 for the Jamaica Bay Unit of Gateway National Recreation Area. Reference condition <3 ft (poor), 3-5 ft (fair), ≥5 mg/L (good) shown in gray. The thresholds for Secchi depth were sourced using the NYCDEP water quality standards (NYCDEP 2010).

Sources of Expertise

- Dennis Skidds, National Park Service, Northeast Coastal Barrier Island Network
- Brett Branco, Brooklyn College, The City University of New York
- Beau Ranheim, NYC Department of Environmental Protection

4.2.4 Chlorophyll a

Description

Chlorophyll is the green pigment that allows plants to convert sunlight into organic compounds during photosynthesis. Of the several kinds of chlorophyll, chlorophyll-*a* is the predominant type found in microalgae (phytoplankton) in fresh and saltwater ecosystems. Chl-*a* can be used as a measure of phytoplankton biomass, which is controlled by factors such as water temperature, light infiltration and nutrient availability. Excess nutrients can result in a high growth rate of phytoplankton and algae, leading to secondary impacts such as reduced light availability, low dissolved oxygen, and the formation of hypoxic "dead zones" (NYCDEP 2012). Blooms of *Thalassiosira* spp. are common within Jamaica Bay during spring, summer, and fall (Wallace and Gobler 2014). The age of water has been found to be highly correlated with phytoplankton blooms within Jamaica Bay, with larger chlorophyll values in the Northeast regions of the bay, suggesting phytoplankton biomass accumulation is controlled by flushing (Wallace and Gobler 2014). In addition, the macroalgae *Ulva lactuca* carpets the tidal flats of Jamaica Bay in response to high nitrogen loading (NPS 2008).

Data and Methods

The data used to assess Chlorophyll-*a* within GATE was measured annually at 48 sites within the Jamaica Bay Unit. The data analyzed were collected between 2010 and 2015 by the National Park Service and New York City Department of Environmental Protection (Kopp and Neckles 2009, NYC DEC 2017). The reference condition for chlorophyll-*a* was sourced from the National Coastal Condition Assessment (NCCA). The NCCA distinguishes between regions, and GATE falls completely within the Northeast region. The NCCA uses a multiple threshold approach when assessing chlorophyll-*a*. The thresholds for chlorophyll-*a* are 5 and 20 µg/L. The range of Chlorophyll-a scores from 5 to 20 µg/L $^{-1}$ was scaled linearly from 0 to 100% attainment. The annual median of all the data points was compared to these reference conditions, assigned a percent attainment, and converted to a condition assessment (Table 4-5).

Table 4-5. Chlorophyll a criteria for the assessment in Gateway National Recreation Area.

Chlorophyll a value	% attainment	Condition
< 5 µg/L	100%	Good condition
5-20 µg/L	0-100% scaled linearly	Moderate concern
> 20 µg/L	0%	Significant concern

Condition and Trend

Chlorophyll-*a* is a condition of moderate concern, with 54% attainment of the reference condition. The discharge of several large wastewater treatment plants into Jamaica Bay, in conjunction with long residence times, allows for the proliferation of phytoplankton populations (Gobler 2016).

Ten-year historical trend in chlorophyll *a* is shown in Figure 4-17. Each is the annual median of chlorophyll *a* values at all sites.

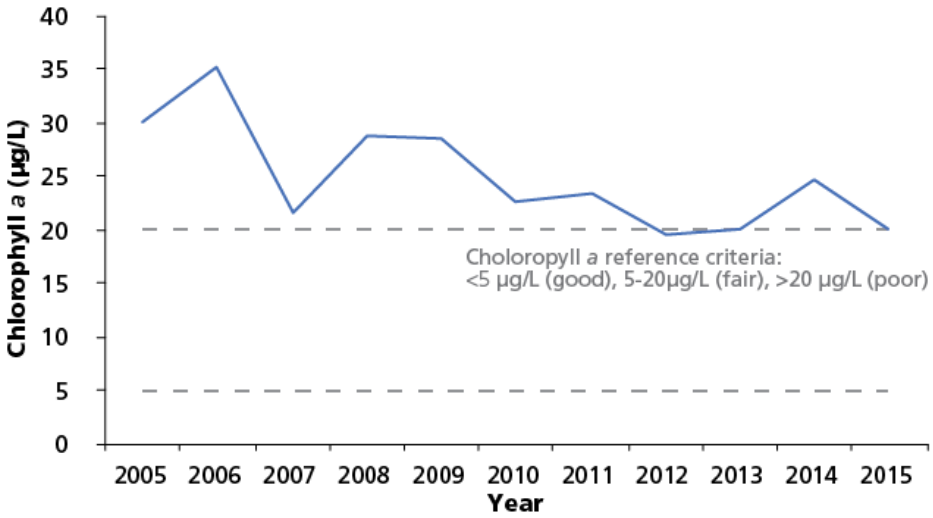


Figure 4-17. Annual median chlorophyll a values from 2005 to 2015 for the Jamaica Bay Unit of Gateway National Recreation Area. Reference condition <5 mg/L (significant concern), 5-20 µg/L (moderate), >20 µg/L (good) shown in gray. The reference condition for chlorophyll-*a* was sourced from the National Coastal Condition Assessment (NCCA).

Sources of Expertise

- Chris Gobler, SUNY Stony Brook
- Brett Branco, Brooklyn College, The City University of New York
- Beau Ranheim, NYC Department of Environmental Protection

4.2.5 Total nitrogen and total phosphorus

Description

Nutrients are essential to the health and diversity of estuaries. The primary nutrients of concern in New York Harbor are nitrogen and phosphorus. Both are required for plants and animals to grow; however, when in excess, they can cause serious problems. When nitrogen and phosphorus are present in excess, algae overgrowth may occur, resulting in an algal bloom that eventually dies and decays. The decomposition process depletes dissolved oxygen, which can lead to very low dissolved oxygen levels and subsequent fish kills. Lower algae levels promote cleaner, clearer water, and more available habitat.

Point sources of nutrients to New York Harbor include wastewater treatment plants, combined sewer overflow/stormwater discharge during heavy precipitation, and subway dewatering. Nonpoint sources include landfill leachate, groundwater flow, and atmospheric deposition (Benotti et al. 2007). In the past century, nitrogen loading to Jamaica Bay had increased from an estimated predevelopment date of 35.6 kg/d to an estimated 15,800 kg/d in 2005 (Benotti et al. 2007). Coupled with improvements in wastewater treatment, and a decrease in discharge rate, current nitrogen loading from sewage treatment plants are approximately 16,330 kg/d (Sanderson et al. 2016). The New York State Department of Environmental Conservation has outlined a goal for wastewater dischargers to decrease nitrogen loads by 20,000 pounds per day, or 9,7072 kg/d by 2020 (Sanderson et al. 2016).

High nitrogen levels in Jamaica Bay contribute to increased organic matter, which can influence hydrogen sulfide levels in marsh sediments, potentially contributing to the loss of important marsh species, such as *Spartina alterniflora* (NYCDEP 2007, NPS 2008). High concentrations of nutrients may stimulate the growth of sea lettuce (*Ulva* sp.), smothering other marsh vegetation, including smooth cordgrass (*Spartina alterniflora*) (Benotti et al. 2007).

Data and Methods

The data used to assess total nitrogen within GATE was measured annually at 34 sites within the Jamaica Bay Unit, and total phosphorus measured annually at 34 sites in the Jamaica Bay Unit. The data analyzed were collected between 2010 and 2015 by the National Park Service and New York City Department of Environmental Protection (Kopp and Neckles 2009, NYC DEC 2017).

The NYSDEC does not have established numerical criteria for total nitrogen (TN) or total phosphorus (TP). The narrative TP and TN standard is “none in amounts that will result in growths of algae, weeds, and slimes that will impair waters for their best usages” (NY Code 6 NYCRR 703.2). Therefore, for the assessment of natural resources within GATE, the thresholds used for the assessment of TN and TP were taken from the Mid-Atlantic Tributary Assessment Coalition Tidal Indicator Protocol (EcoCheck 2011). The protocol provides multiple nutrient standards based on salinity regime. GATE falls within the polyhaline (18-30) range for salinity. Each nutrient observation is measured against a multiple threshold criteria and assigned a score from 0-5 (Table 4.5). Each measurement score (0-5) is averaged into a station score for the entire region. A score of 0 indicates high concentration and 0% attainment of the reference condition. A score of 5 indicates low concentration and 100% attainment of the reference condition. The scores at each individual site were averaged across time to develop a score for each site. These were averaged to find an overall score for the park. To calculate percent of reference condition attained, scores were divided by 5 and multiplied by 100 (Table 4-6) (EcoCheck 2011).

Table 4-6. Total nitrogen and total phosphorus multiple threshold criteria used for the assessment of Gateway National Recreation Area (EcoCheck 2011).

Indicator	Thresholds	Score
Total nitrogen (mg/L)	≤0.4	5
	>0.4 - ≤0.5	4
	>0.5 - ≤0.6	3
	>0.6 - ≤0.8	2
	>0.8 - ≤1.2	1
	>1.2	0
Total phosphorus (mg/L)	≤0.3	5
	>0.03 - ≤0.5	4
	>0.05 - ≤0.7	3
	>0.07 - ≤0.9	2
	>0.09 - ≤0.13	1
	>0.13	0

Condition and Trend

Condition of TN within GATE was of significant concern, with 19% attainment of the reference condition. The highest values of TN were observed at sites HC1, HC2, HC3, BB2, and BB4. HC3 is located at the mouth of Hendrix Creek, and HC1 and HC2 are upstream in the creek, which originates in Brooklyn, and is directly fed by the 26th Ward Wastewater treatment plant. (Figure 4-15). BB2 and BB4 are located in Bergen Basin. Bergen Basin is impacted by stormwater runoff, combined sewer overflows, sanitary sewer overflows, and nutrient load from the Jamaica WWTP (NY DEC 2017). Ten-year historical trend in total nitrogen is shown in Figure 4-18. Each point is the annual median of all total phosphorus values at all sites.

Condition of TP within GATE was of significant concern with 7% attainment of the reference condition. Ten-year historical trend in total phosphorus is shown in Figure 4-19. Each point is the annual median of all total phosphorus values at all sites.

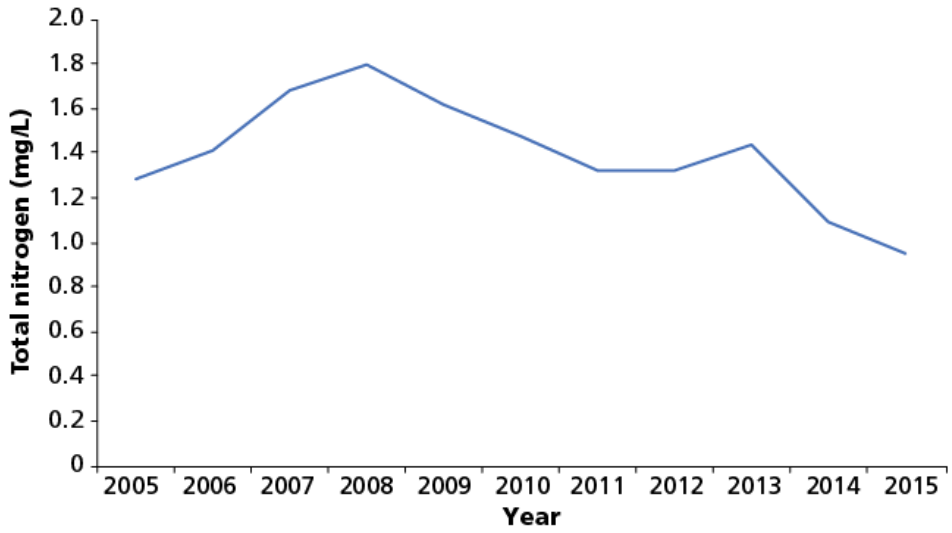


Figure 4-18. Annual median total nitrogen values from 2005 to 2015 for the Jamaica Bay Unit of Gateway National Recreation Area.

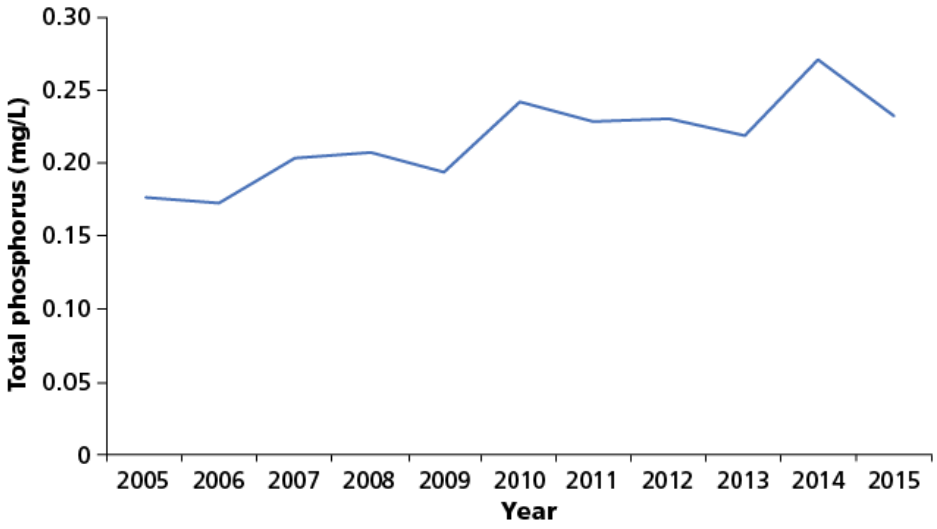


Figure 4-19. Annual median total phosphorus values from 2005 to 2015 for the Jamaica Bay Unit of Gateway National Recreation Area.

Source of Expertise

- Dennis Skidds, National Park Service, Northeast Coastal Barrier Island Network
- Brett Branco, Brooklyn College, The City University of New York
- Beau Ranheim, NYC Department of Environmental Protection

4.2.6 pH

Description

During photosynthesis, algae remove CO_2 from the water, making the water more alkaline, or basic. Therefore, when algal populations increase in estuaries in the spring, pH levels tend to rise. With

deposition rates of wet sulfate and wet nitrogen being of significant concern regionally, water habitats have the potential to be impacted by acidification. An algal bloom may cause pH levels in an estuary to rise significantly, which can be lethal to aquatic animals (NOAA 2012). During an August 2012 hypoxia event, much of the water column in Jamaica Bay had acidified (median pH <7.4) (Wallace et al. 2014). After hurricane Sandy, when the water column mixed and returned to fully oxygenated conditions, the pH of the system was still slightly reduced (pH <7.9) (Wallace et al. 2014).

Data and Methods

The data used to assess pHwithin GATE was measured annually at 48 sites within the Jamaica Bay Unit. The data analyzed were collected between 2010 and 2015 by the National Park Service and New York City Department of Environmental Protection. The threshold for pH was determined using the U.S. EPA National Coastal Condition Assessment (NCCA). While the NCCA distinguishes between regions, GATE falls completely within the Northeast region. The thresholds for pH are ≥6.5 and ≤8.5. Each data point was compared against the reference condition, assigned a value of pass or fail, and a percent attainment then calculated.

Condition and Trend

Condition of pH within GATE was good with 98% attainment of the reference condition between 2010 and 2015.

Ten-year historical trend in pH is shown in Figure 4-20. Each is the annual median of pH values at all sites.

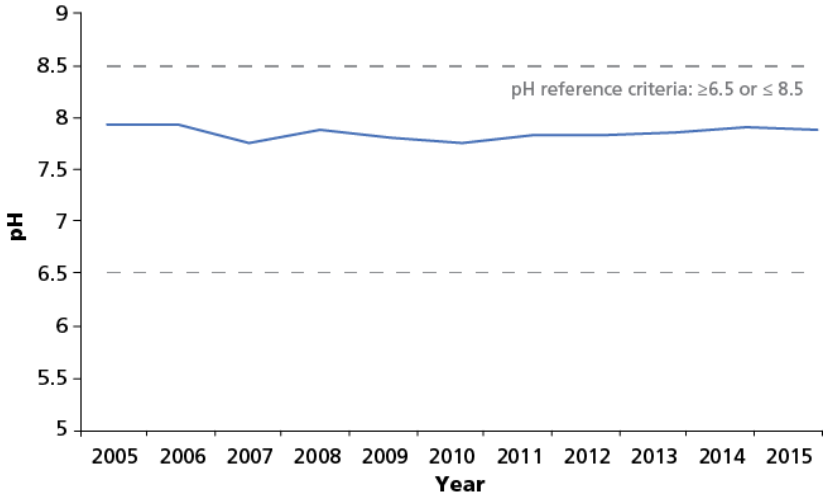


Figure 4-20. Annual pH median values from 2005 to 2015 for the Jamaica Bay Unit of Gateway National Recreation Area. Reference condition ≥6.5 and ≤8.5 shown in gray. The threshold for pH was determined using the U.S. EPA National Coastal Condition Assessment (NCCA).

Sources of Expertise

- Dennis Skidds, National Park Service, Northeast Coastal Barrier Island Network

- Brett Branco, Brooklyn College, The City University of New York
- Beau Ranheim, NYC Department of Environmental Protection

4.2.7 Enterococcus

Description

An increase in development adjacent to GATE increases the risk of public health hazards from contact with sanitary wastes. Exposure to marine recreational water with high bacterial densities from natural (e.g. mammals) and human-induced (sewage, wastewater, runoff) sources has been linked to eye, ear, and skin infections, as well as gastroenteritis (Pruss, 1998, Haile et al. 1999). Of several bacterial measures that are often used for microbial risk assessment, the *Enterococcus* density in seawater has been specified as the best single bacterial indicator of human health risk of infectious disease while swimming (Cabelli et al. 1983). *Enterococcus* is an indicator of pathogens in the water column and is directly related to human and animal (wild and domesticated) waste entering into local waters. When it rains, runoff from land washes into local streams and into the embayments around Jamaica Bay, NY Bay, Sandy Hook Bay, and the Atlantic Ocean. This runoff carries waste and its bacteria into local waters. The bacteria thrive in the warm water associated with swimming seasons. Although, indicator bacteria can cause infection, the primary human illness associated with swimming in contaminated waters is virus (Recreational Water Quality Criteria USEPA 2012).

Data and Methods

Enterococcus was measured annually from May to August in GATE at 28 sites in the Jamaica Bay Unit, 6 sites in the Staten Island Unit, and 6 sites in the Sandy Hook Unit. The data analyzed were collected between 2010 and 2015 by the National Park Service and New York City Department of Environmental Protection. In addition, *Enterococcus* data was collected at 6 sites within Sandy Hook as part of the New Jersey Department of Environmental Protection (NJDEP) Cooperative Coastal Monitoring Program from 2010 to 2014, and this data was also included in the assessment. The reference condition for *Enterococcus* is equal to or less than 104 cfu/100mL. Each data point was compared against the reference condition, assigned a value of pass or fail, and a percent attainment was then calculated.

Condition and Trend

Current condition of *Enterococcus* parkwide for 2010-2015 is good condition, with 94% attainment of reference condition over all samples. *Enteroccoccus* concentrations are sampled annually from May to August, Over the past ten years of data, no significant trend was present (p-value>0.01) (Figure 4-21).

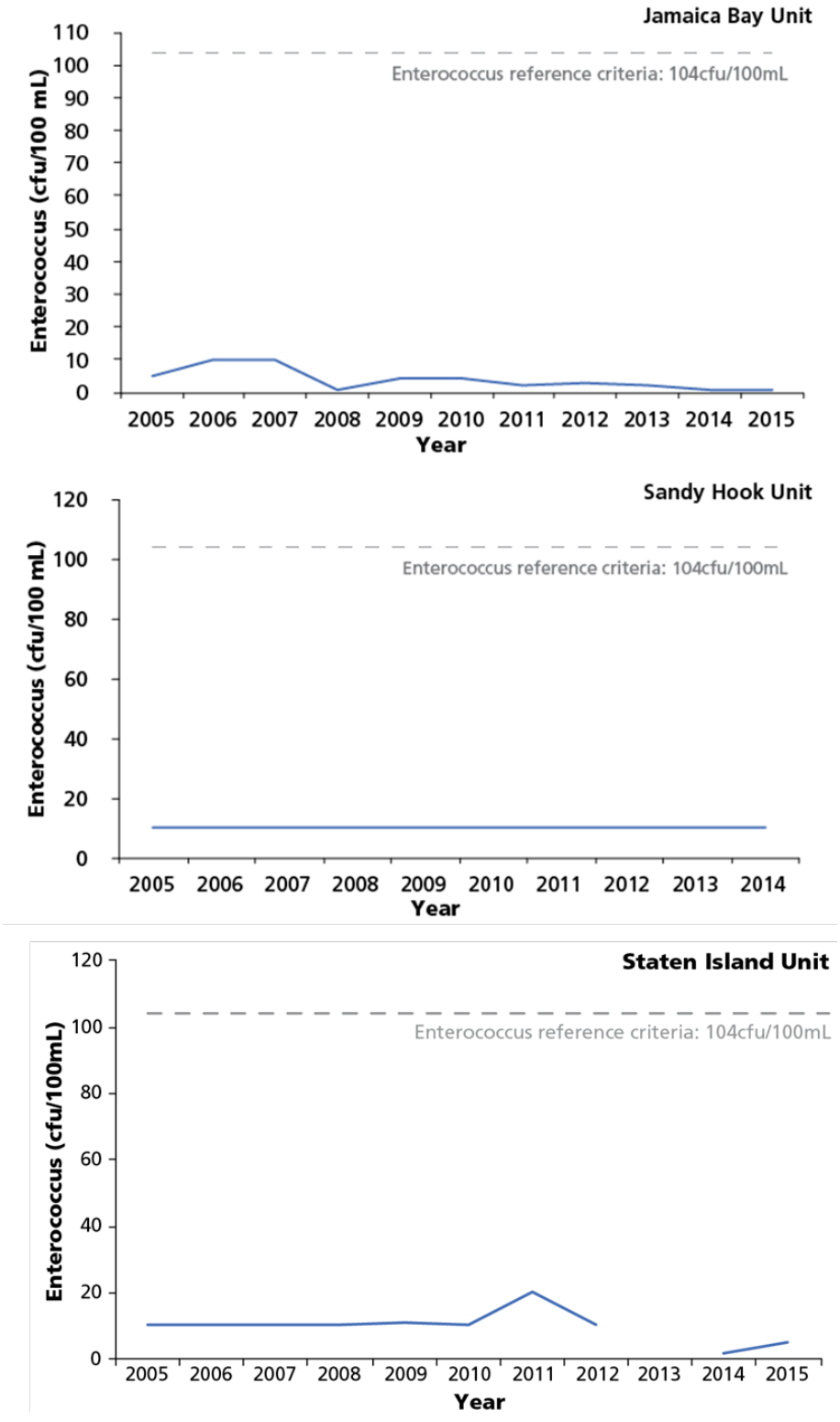


Figure 4-21 Annual median *Enterococcus* values from 2005 to 2015 for the Jamaica Bay, Sandy Hook, and Staten Island Units of GATE. Please note that no data was available for 2015 in the Sandy Hook Unit, and no data was available for 2013 in the Staten Island Unit. Reference condition less than or equal to 104cfu/100mL shown in gray.

Sources of Expertise

- Dennis Skidds, National Park Service, Northeast Coastal Barrier Island Network
- Brett Branco, Brooklyn College, The City University of New York
- Beau Ranheim, NYC Department of Environmental Protection

4.3 Biological integrity

Gateway National Recreation Area (GATE) supports a wide variety of fauna and flora, including mammals, birds, reptiles, amphibians, and a large diversity of invertebrates. The park, located at the turning point of the primarily east-west oriented coastline of New England and Long Island, and the north-south oriented coastline of the mid-Atlantic coast, acts to concentrate marine and estuarine species migrating between the New York Bight portion of the North Atlantic and the Hudson–Raritan Estuary (NPS 2016f).

Four indicators were used to assess biological integrity within GATE: seabeach amaranth abundance, piping plover productivity, diamondback terrapin abundance, and holly forest extent. A fifth indicator, horseshoe crab Index of Spawning Activity, was not scored or included in the overall assessment of GATE, but included for informational purposes (Table 4-7). Data used to determine the condition of these indicators at GATE were sourced from flora and fauna surveys conducted by the National Park Service, New York State Department of Environmental Conservation, and Hofstra University. Seabeach amaranth and piping plover data was available for the Jamaica Bay Unit and Sandy Hook Unit. Data for holly forest extent was only available for the Sandy Hook Unit of the park. Diamondback terrapin data was only available for Ruler's Bar Hassock in the Jamaica Bay Unit.

Reference conditions were established for each of the four metrics and the data were compared to these reference conditions to obtain percent attainment, which was then converted to the condition assessment for that metric.

Table 4-7. Indicators, metrics, and data sources used to assess biological integrity of Gateway National Recreation Area.

Indicator	Metric	Agency/Source	Region of assessment
Piping plover	Annual productivity (# of chicks fledged per # of nesting pairs)	NPS GATE	Jamaica Bay Unit (Breezy Point), Sandy Hook Unit
Diamondback terrapin	Abundance of female nesting individuals	Russell Burke, Hostra University	Jamaica Bay Unit (Ruler's Bar Hassock)
Horseshoe crab	# of individuals	NPS GATE	Raritan Bay-Sandy Hook
American Holly	Importance value	NPS GATE	Sandy Hook Unit
Seabeach amaranth	Abundance (# of individuals)	NPS GATE, NY Natural Heritage Program	Jamaica Bay Unit, Staten Island Unit, Sandy Hook Unit

Table 4-7 (continued). Indicators, metrics, and data sources used to assess biological integrity of Gateway National Recreation Area.

Indicator	Metric	Agency/Source	Region of assessment
Horseshoe crab	Index of Spawning Activity	Cornell Cooperative Extension, NPS GATE, New Jersey Bayshore Regional Watershed Council	Jamaica Bay Unit, Staten Island Unit, Sandy Hook Unit

4.3.1 Seabeach amaranth abundance

Description

Seabeach amaranth (*Amaranthus pumilus*), an annual beach plant, is endemic to Atlantic Coast beaches and barrier islands, and has historically occurred from Massachusetts to South Carolina (USFWS 2014). In 1993, it was listed as federally threatened and globally rare (USFWS 1993, USFWS 2014, Weakley et al. 1996). Seabeach amaranth is dependent on terrestrial, upper-beach habitat that does not flood during the growing season. It occupies a narrow beach zone that lies at elevations from 0.2 to 1.5 m above mean high tide (USFWS 2002). Waterfront development, beach stabilization, and other activities resulting in habitat degradation are the main reasons for the decline of seabeach amaranth populations (Weakley et al. 1996; NJDEP 2016). Seabeach amaranth is a pioneer species that is largely restricted to open sandy portions of ocean beach and overwash habitats (NJDEP 2016).

Seabeach amaranth was extirpated from New York State in the 1950s, including from GATE (Stalter et al. 1996). The species was considered absent from New York State until the 1990s, when it was discovered at several locations on Long Island (NPS 2009). Theories for the reappearance of *A. pumilus* within the New York–New Jersey region include transport of seeds through storm events and/or the resurfacing of seed from beachfill operations (NJDEP 2016). In the Jamaica Bay Unit, seabeach amaranth has been observed on the beaches along the Rockaway Peninsula. A population occurs among sparsely vegetated American beachgrass (*Ammophila breviligulata*) stands on the flat or gently sloped sands at West Beach at Breezy Point (NPS 2009). This population has been monitored since 1990; however, the population is considered not stable (Stalter et al. 1996). From 2011 to 2014, seabeach amaranth numbers in Jamaica Bay have decreased 72 percent. In 2014, amaranth was observed on all beaches except Jacob Riis beach. Riis beach is heavily managed via beach grooming for summer recreation, which makes it difficult for amaranth plants to establish (Abouelezz 2014). In 2000, seabeach amaranth returned to newly created beaches in Monmouth County, New Jersey and adjacent habitat in Sandy Hook after being absent from New Jersey since 1913 (USCG 2014, NJDEP 2016).

Data and Methods

Within GATE, seabeach amaranth populations are surveyed annually within the Jamaica Bay Unit and the Sandy Hook Unit. In Jamaica Bay, populations are surveyed at five NPS sites: Breezy Point Tip, Breezy Point Coop, West Beach, Fort Tilden Beach, and Jacob Riis Park (Abouelezz 2014). Seabeach amaranth populations are surveyed at 12 sites within the Sandy Hook Unit of GATE.

Population counts are completed in August or September by park staff and NYSDEC. Surveys were not completed at the Jamaica Bay sites in 2010. Given the uncertainty regarding historic abundance, and high interannual variability in abundance, there is no current management goal for seabeach amaranth (*Amaranthus pumilu*s) within GATE. For this assessment the reference condition was determined to be the 10-year historical median of *A. pumilus* abundance between 2000-2009. Historic data for the Jamaica Bay Unit was only available from 2004-2009, and therefore the threshold was based on the five year median. A threshold was calculated for both the Jamaica Bay Unit (≥794.5) and the Sandy Hook Unit (≥1372.5). Annual abundance measures for the years 2010-2015 were compared to this reference condition.

Condition and Trend

Condition of seabeach amaranth within GATE was assessed as a significant concern. Sites in Jamaica Bay attained the reference condition in zero of six (0%) sampled years between 2010 and 2015. The mean population size between 2010 and 2015 was 794.5 plants (Figure 4-22). In Sandy Hook, there was a 33.3% attainment of the reference condition, with two of six years attaining the reference condition of populations greater than 1372.5 plants (Figure 4-23). Note that abundances are much higher in the Sandy Hook Unit (median of 1220.5) than in the Jamaica Bay Unit (median of 63.5). There are 12 sites monitored annually in the Sandy Hook Unit for seabeach amaranth, and three sites monitored annually in Jamaica Bay and length of beach across sites is not consistent. Therefore, the difference in observed abundance is likely due to the difference in monitoring effort at the two units, and these populations cannot be compared against one another.

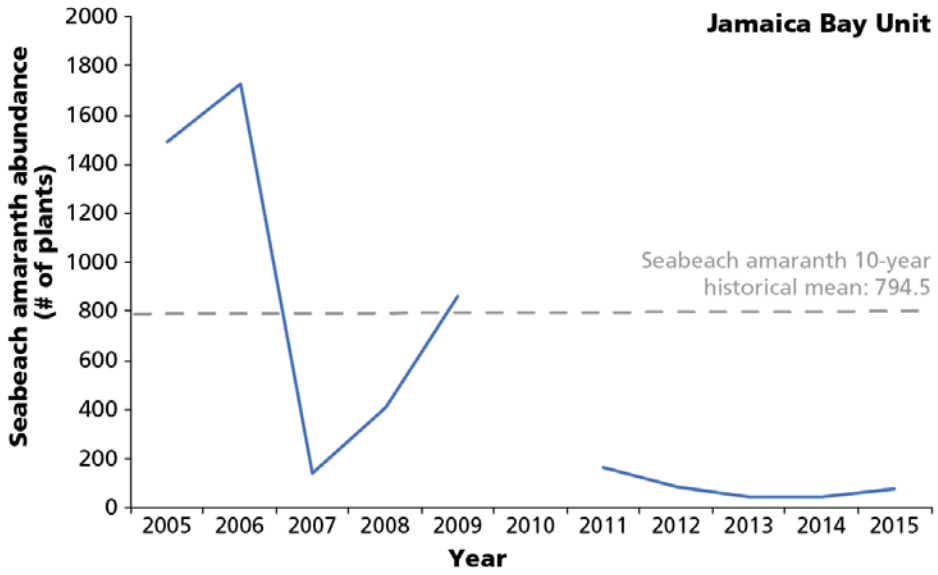


Figure 4-22. Abundance of individual seabeach amaranth (Amaranthus pumilus) plants in the Jamaica Bay Unit of Gateway National Recreation Area between 2005 and 2015. No sampling was completed in 2010.



Figure 4-23. Abundance of individual seabeach amaranth (*Amaranthus pumilus*) plants in the Sandy Hook Unit of Gateway National Recreation Area between 2005 and 2015.

4.3.2 Piping plover

Description

Piping plovers breed on the coastal beaches from Newfoundland and southeastern Quebec to North Carolina (USFWS 2007). Once common along the Atlantic coast during the 19th century, the species nearly became extinct in the early 20th century due to hunting for its feathers (Haig and Oring, 1985; USFWS 1996; USFWS 2007). The passage of the Migratory Bird Treaty Act in 1918 resulted in the recovery of some breeding populations, and numbers reached a peak in the 1930s (Haig and Oring, 1985; USFWS 2016). However, due to increased coastal development and beach recreation, populations have declined since World War II (Haig and Oring, 1985; USFWS 2016). The Atlantic population, which includes Canada, New England, New York–New Jersey and portions of the Southeast U.S., does not interbreed with inland populations, and experienced a documented decline of some 30% of breeding pairs between 1980 and 1984 (Haig and Orgin, 1985; USFWS 1996). In 1986, piping plovers were federally listed as endangered in the Great Lakes and threatened on the Atlantic Coast (Perkins, 2015; USFWS 2016). The New York State Department of Environmental Conservation (NYSDEC) and New Jersey Department of Environmental Protection (NJDEP) have listed the species as endangered (Perkins, 2015). Predation, coupled with habitat loss and degradation, has led to a decrease in piping plover populations within the region. Piping plovers have very specific habitat requirements that include a combination of dry open nesting area along with unvegetated wetlands that are moist but not wet. Nests can be found above the high tide line on beaches, sand flats, foredunes, and between dunes, and the birds may also nest in areas where dredge materials have been deposited (USFWS 2002). Widespread beach stabilization projects in both New York and New Jersey, including the construction of jetties, seawalls and revetments, planting of vegetation, and placement of sand-trapping fences have resulted in the elimination, or degradation of potential plover nesting habitat (Hecht and Melvin 2008). Plovers are also under threat by ongoing coastal development and human recreation on beaches (Hecht and Melvin 2008).

Within GATE, federally listed species are monitored and managed under the guidance of the USFWS species recovery plans and in cooperation with USFWS. Piping plovers are managed in the Sandy Hook unit in accordance with the 2007 Environmental Assessment and in the Jamaica Bay unit according to the strategy outlined in "Management plan for the threatened piping plover (*Charadrius melodus*), Breezy Point District" (NPS 2007, Abouelezz 2013). Atlantic coast plovers arrive on the beaches in and around GATE from mid March to early April (USGC 2014). Plover populations have been severely affected by water level changes, development, predation by domestic and feral cats, and natural predators (USGC 2014). Human activities on beaches can cause nesting pairs to abandon nests.

Breezy Point, at the western tip of the Rockaway Peninsula, supports some of the highest concentrations of beach nesting birds in the New York–New Jersey Bight coastal region, including the federally endangered piping plover (*Charadrius melodus*) (Tsipoura et al. 2013). Since 2010, Sandy Hook has consistently provided habitat for 40 to 50% of the breeding pairs of piping plovers in New Jersey (Pover and Davis 2015).

Data and Methods

Piping plover populations are surveyed annually within the Jamaica Bay and Sandy Hook Units of GATE by park staff. Data are collected through a series of population surveys, which record the number of breeding pairs and hatching and fledging success, and calculate overall productivity as the ratio of the number of chicks fledged per nesting pair. Nesting data for Breezy Point (Jamaica Bay Unit) was available for 2011-2015. Sandy Hook Unit nesting data was available for 2010-2015.

The recovery objective for the Atlantic Coast piping plover population is to increase and maintain for five years a total of 2000 breeding pairs, distributed among the four recovery units: Atlantic Canada, New England, New York-New Jersey, and Southern (DE-MD-VA-NC) (FWS 1996). These units are large enough that carrying capacity will be buffered from natural processes while still maintaining a geographically well-distributed population (USFWS 1996). For the New York–New Jersey recovery unit, the USFWS target conservation goal is a minimum subpopulation of 575 pairs, and a five-year average productivity of 1.5 fledged chicks per pair (USFWS 1996). The conservation goal of 1.5 fledged chicks per pair annual productivity was used as the reference condition for this assessment.

Condition and Trend

Between 2011 and 2016, piping plover productivity at Breezy Point (Jamaica Bay Unit) ranged from 0.7 in 2013, to 1.10 in 2014 and 2015, and was below the conservation goal of 1.5 in all years sampled (Figure 4-24). Piping plover productivity at the Sandy Hook Unit ranged from 1.04 (2012) to 1.75 (2010) with two of the six sampling years (2010 and 2011) above the conservation goal (Figure 4-25). Overall piping plover productivity within GATE had a 16.5% attainment of the reference condition, or a condition of significant concern.

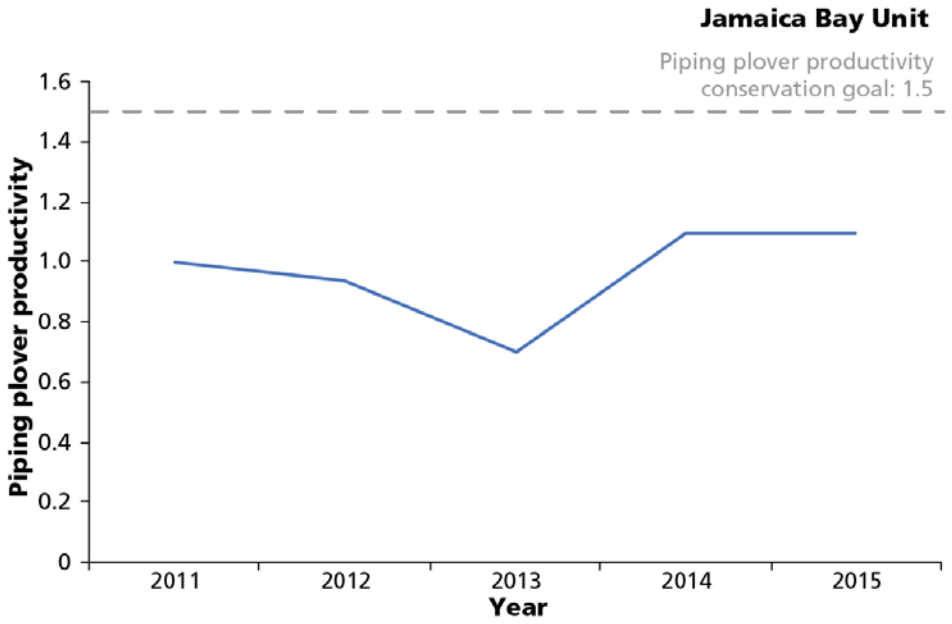


Figure 4-24. Piping plover productivity at Breezy Point, Jamaica Bay Unit of Gateway National Recreation Area between 2011 and 2015. Dotted line represents the conservation goal of 1.5 fledged chicks per breeding pair (annual productivity).

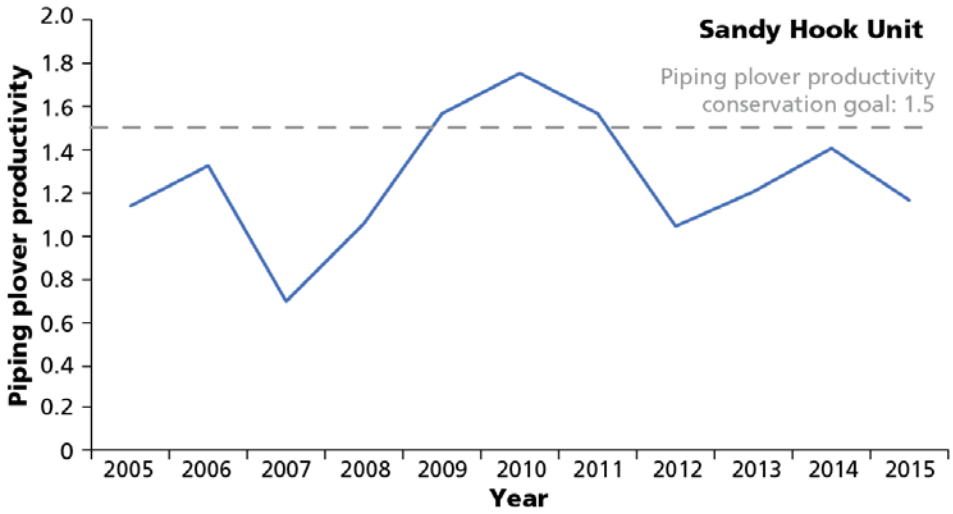


Figure 4-25. Piping plover productivity in the Sandy Hook Unit of Gateway National Recreation Area between 2005 and 2015. Dotted line represents the conservation goal of 1.5 fledged chicks per breeding pair (annual productivity).

Despite the expansion of potential quality habitat between 2003–2013, low fledge rates are the driving factor behind poor productivity. Recorded issues that may contribute to low fledge rates include human pedestrian and vehicular trespassing on the beach and in nesting areas, extreme weather events and predation. On Sandy Hook, the biggest predator to piping plover are red fox (*Vulpes vulpes*). Issues also arise with humans stealing eggs and destroying nests, deer walking on nests, and potential predators, including dogs, cats, raccoons, ghost crabs, gulls, crows, American

oystercatchers and skunks. Within the Jamaica Bay Unit, predators observed during monitoring include domestic dogs, feral cats, raccoons, ghost crabs, gulls, crows, and American oystercatchers (Abouelezz 2013).

4.3.3 Diamondback terrapin

Description

Diamondback terrapins (*Malaclemys terrapin*) are keystone species in estuarine and coastal ecosystems. Terrapins feed on crustaceans, crabs, mollusks, and other invertebrates, helping to control these populations and reduce impacts on saltmarsh grass species. The gastropod periwinkle (*Littorina spp.*), grazes on saltmarsh cordgrass (*Spartina alterniflora*), an important species within saltmarshes, and predation by terrapins has been shown to dramatically reduce the abundance of periwinkle and increase saltmarsh cordgrass populations (JBTR 2016). In addition, terrapin eggs and hatchlings are eaten by a variety of predators.

In the 1700s and 1800s, terrapins were hunted and eaten in large numbers, which decimated populations across their range. In New York and New Jersey, this pattern intensified through the 1920s with the trade of terrapin meat and the close proximity to terrapin habitats (JBTR 2017). After the collapse of the turtle soup industry in the late 1920s, terrapin populations began to rebound, only to be impacted again in the mid-20th century as large-scale coastal development resulted in habitat loss (JBTR 2017). Increased sediment and nutrient pollution in waterways, diking, dredging and filling of saltmarshes, and the development and maintenance of shipping channels all threaten terrapin habitat (U.S. FWS 2013).

Today, terrapin populations occur along much of the East Coast and Gulf Coast of the United States (DTWG 2017). Within New York, diamondback terrapin populations occur around Long Island, Staten Island, and the lower Hudson River north to Rockland, Putnam, and Orange Counties (Feinberg and Burke 2003). In New Jersey, terrapins inhabit coastal saltmarshes and estuaries along the Atlantic Coast and Delaware Bay (CWF 2017). In 2014 and 2015, a moratorium was placed on harvesting of terrapins within New Jersey, and in 2016, legislation was passed to make terrapins a non-game species with no hunting season within the state (CWF 2017).

Throughout GATE, terrapin populations are tightly linked to *Spartina* marshes. Significant losses of saltmarsh have occurred throughout Jamaica Bay, especially *Spartina alterniflora* marsh (NYDEC 2017). Within Jamaica Bay Wildlife Refuge, terrapins experience very high predation rates by raccoons, which were introduced to the area in the 1980s (Kanonik and Burke 2011; Feinberg and Burke 2003). Important terrapin nesting areas have also been identified in the Sandy Hook Unit of GATE. A 2002 study identified eight important nesting areas within Sandy Hook: Horseshoe Cove, Battery zone, Sandy spit #1, Sandy spit #2, Skelton Hill Island, Plum Island, Holly Forest, and the Critical Zone (Ner and Burke 2005). Although these areas are generally not accessible to the public, racoons are a major predator to nesting turtles on Sandy Hook. Predation on nesting females could have major implications for the success of terrapin populations within Sandy Hook (Ner and Burke 2005).

Data and Methods

The number of female diamondback terrapins nesting on the island of Ruler's Bar Hassock within the Jamaica Bay Unit of GATE, have been surveyed annually by the Jamaica Bay Terrapin Research Project since 2003. Because there are no established guidelines for terrapins within Jamaica Bay, the reference condition was determined to be the historical median of nesting female diamondback terrapin abundance between 2003-2009 (≧921 individuals). Annual abundance for the years 2010-2015 was compared to the reference condition.

Condition and Trend

Female diamondback terrapin density at Ruler's Bar Hassock between 2010 and 2015 varied from 418 individuals (2015) to 769 individuals (2010) (Figure 4-26). Condition of the diamondback terrapin population within the Jamaica Bay Unit of GATE was assessed as being of significant concern, as all sampling years between 2010 and 2015 failed to attain the reference condition (0 percent attainment). Over the past 10 years of survey data, the population of nesting female diamondback terrapins has decreased by almost 50% (Figure 4-26).

Sources of Expertise

- Russell Burke, Hofstra University

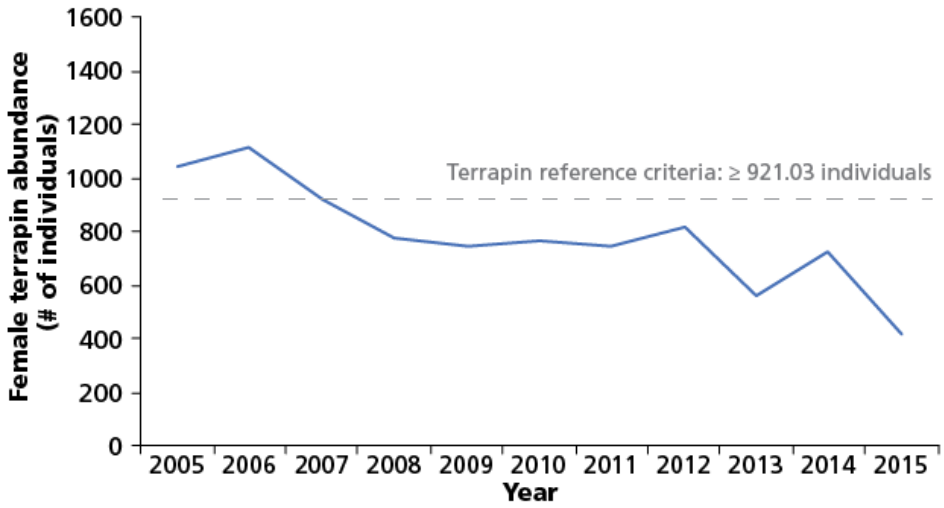


Figure 4-26. Abundance of female terrapin individuals at Ruler's Bar Hassock (Jamaica Bay Unit of Gateway National Recreation Area) between 2005 and 2015 (Source: R. Burke, Hofstra University). Terrapin reference condition is the median of nesting female diamondback terrapin abundance between 2003-2009 (≧921 individuals).

4.3.4 American holly

Description

The Sandy Hook Unit of GATE contains the best-developed American holly (*Ilex opaca*) forest on the east coast of the United States (Stalter et al. 2015). No other instances of well-developed holly forest have been identified within GATE park limits. Instances of holly forest within the park are considered maritime holly forest as they occur on maritime dunes (NPS 2016). Maritime holly forest

is considered incredibly rare as it is only present in two areas throughout the world, one of which is in the Sandy Hook Unit (Forrester et al. 2007). Sandy Hook's maritime holly forest (231 acres) occurs from Spermaceti to north of Horseshoe Cove (Figure 4-27).

Deer populations have been identified as a threat to the holly populations in GATE. Forester and others (2007) attributed forest stability at SAHO to the low number of deer on Sandy Hook from 1989 to 2003; however, park staff report that the deer population has increased from only a few individuals a decade ago to more than 70 individuals (Forester et al. 2007). Deer are very likely browsing and killing holly seedlings, so the park probably will see a decrease in holly recruitment during the next few years. It is currently unknown how this phenomena will affect holly forest condition throughout the park. The park has secured funding to initiate vegetation monitoring in 2019 to evaluate the short-term impacts of deer browse on regeneration and to facilitate long-term evaluation of deer browse on forest structure and composition.

Other threats to holly forest include sea level rise and human pressure, although these will likely have less effect than the rising deer populations. GATEs holly forest was shown to be resistant to short periods of saltwater intrusion and high winds after the 2012 Sandy Superstorm (Stalter and McArthur-Heuser 2015). Trees in Stalter and McArthur Heuser's study area were exposed to intensive salt spray and wind, and inundated with salt water during the storm and experienced severe leaf loss afterwards, but ultimately recovered in the ensuing months (Stalter and McArthur-Heuser 2015).

Data and Methods

Data used to assess the holly forest condition in the Sandy Hook Unit is from three repeat studies performed by Stalter and McArthur-Heuser in 1977, 1992, and 2002. Stalter and McArthur-Heuser (2004) studied only a 74-acre portion of the holly forest. The complete extent of holly forest mapped in 2007 (Figure 4-27) totals 231 acres, therefore, the remaining 157-acres of holly forest not included in the Stalter and McArthur-Heuser study are not included in this assessment.



Figure 4-27. Maritime holly forest extent throughout the Sandy Hook Unit, Gateway National Recreation Area, with the section used in the assessment of biological integrity shown in dark green. Data from 2007 NPS Vegetation Mapping.

The holly forest was assessed using data from the Importance Value (IV) of American holly as a condition index for holly forest health. IV is a composite function that incorporates the relative frequency of holly (the number of plots where hollies occur, a measure of distribution), the relative density of holly (the number of holly individuals as a proportion of all trees measured in the plots, a measure of population size), and the relative size of holly (the summed total of the stem cross-sectional area of holly as a percent of the total cross-sectional area of all trees; a measure of biomass). This combination of useful ecological measurements makes IV a useful metric for health of holly forest. However, it is explicitly a measure of the importance of holly relative to the other

trees in the holly forest; it is not an absolute measure of the changes in holly frequency, population size, or biomass.

Holly forest condition in Sandy Hook was evaluated by comparing recent IV to the IV score of 268 that was estimated by Stalter and McArthur-Heuser in 1977 (considered here as its historic state).

Condition and Trend

Holly forest in Sandy Hook has been assessed at 91% of the historic state, or good condition. It is important to note that the current condition of whole forest is unknown, as only the portion studied by Stalter and McArthur-Heuser could be assessed in this report and the most recent data is from 2002.

The importance value of holly within the holly forest in Sandy Hook is declining at a rate of 0.4% per year, averaged over the periods between three study years for which holly forest health was calculated:

- 1977: IV of 268/268 = 100%
- 1992: IV of 256/268 = 95.6%
- 2002: IV of 243/268 = 90.6%

Park employees have noted that while the 74-acre section studied by Stalter and McArthur-Heuser is in slow decline, additional holly forest area outside of the assessed area has been expanding northward and eastward since the army left Sandy Hook in 1974. This high-value parameter (expansion of holly forest area), younger forest is colonizing higher ground, and represents the future holly forest at the Sandy Hook Unit.

Stalter et al. (2015) published a more recent study detailing the survival of American Holly following superstorm Sandy in 2012. Although the original study area was not assessed again for importance value in this study (so it could not be included in this assessment), holly trees demonstrated an ability to survive tidal flooding and severe salt spray (Stalter et al. 2015).

4.3.5 Horseshoe crab

Description

The bay beaches and tidal flats of Jamaica Bay and Sandy Hook (see map in Chapter 2) serve as breeding grounds for horseshoe crabs (*Limulus polyphemus*). Horseshoe crab eggs are an important food source for migratory shorebirds, gulls, and shore-zone fish species (Botton et al. 2006; NPS 2009). High-priority bird species, such as federally listed (threatened) red knots (*Calidris canutus*) and semipalmated sandpipers (*Caldris pusilla*) depend on this food source for energy reserves necessary to complete their migration to Arctic breeding grounds (Mizrahi 2006, NPS 2009). Horseshoe crabs also provide economic, biomedical and tourism benefits to the region (Botton et al. 2006, ASMFC 2017).

Horseshoe crabs depend on the narrow sandy beaches and alluvial sand bar deposits within Jamaica Bay as spawning grounds (NPS 2009). These sandy beaches are important horseshoe crab spawning sites, and nearly 3,000 converge at Plumb Beach between late May and mid-June to lay eggs (NPS

2012). Horseshoe crab populations within Jamaica Bay may be limited by the extent of suitable habitat types for spawning (Botton et al. 2006), as sediment availability rather than water quality may limit spatial distribution of horseshoe crabs. As sea level rise threatens the coastal portions of the New York-New Jersey region, the loss of beach habitat may further diminish horseshoe crab spawning (NPS 2009).

Populations of horseshoe crabs within GATE have decreased due to overharvesting from the bait industry (Sclafani 2006, NPS 2009) and loss of spawning grounds. Horseshoe crabs are managed under the Interstate Fishery Management Plan for Horseshoe Crab (December 1998). The Atlantic States Marine Fisheries Commission has established state-by-state quotas in all Atlantic states for crabs harvested for bait (ASMFC 2017). Any state that allows harvest must have a monitoring program and submit annual reports to ASMFC. In New York State, the Department of Environmental Conservation is the regulatory agency, and Cornell Cooperative Extension oversees monitoring. The harvesting of horseshoe crabs is prohibited in New Jersey (NJDEP Fish and Wildlife 2016), but allowed in New York (NPS 2015). As of 2016, the horseshoe crab harvest quota for New York waters was approximately 150,000 individuals per year (January–November) (NYSDEC 2016). GATE enabling legislation does not permit the harvest of wildlife, therefore the taking of horseshoe crabs is prohibited within park boundaries (NPS 2009).

Compared to knowledge of horseshoe crabs in Delaware Bay and southern New England, there is limited information on the populations within Jamaica Bay and Long Island. Hanna (2001) recorded crab population counts from May-October 1998 at Plum Beach and the Jamaica Bay Wildlife Refuge, and Botton and Loveland (1992) studied mating behavior on the beaches of Sandy Hook, New Jersey (Botton et al. 2006).

Data and Methods

Horseshoe crab spawning surveys are completed annually within GATE by park staff and volunteers, the New Jersey Bayshore Regional Watershed Council, and Cornell Cooperative Extension. Sampling locations are at Plumb Beach (Jamaica Bay Unit), Breezy Point (Jamaica Bay Unit), Great Kills (Staten Island Unit), and Plumb Island (Sandy Hook Unit). Plumb Beach, in the Jamaica Bay Unit of GATE, and Grat Kills, in the Staten Island Unit, are part of the New York State horseshoe crab monitoring program. Since 2012, GATE has enlisted citizen scientists to conduct monitoring in the Jamaica Bay Unit at Breezy Point beach. The New Jersey Bayshore Regional Watershed Council has been conducting spawning surveys in Sandy Hook Bay since 2009. Data are collected through a series of population surveys, which record numbers of male and female crabs in the surf. An Index of Spawning Activity (ISA), defined as the average number of female crabs per 1 m^2 of the surf zone, is calculated for each night survey, beach, and moon period. The ISA is calculated with the female segment of the crab population because it best represents the fluctuations in reproductive potential and egg availability to shorebirds (Smith et al. 2002).

There is currently no established reference condition for ISA, nor is there sufficient long-term historical data to develop a baseline, thus this indicator was not able to be scored and or included in the overall assessment of GATE, but is included for informational purposes only.

Condition and Trend

The Index of Spawning Activity is variable between sampling locations within GATE. At Plumb Beach, in the Jamaica Bay Unit, ISA values ranged from an average of 0.46 in 2013 to 0.07 in 2015. While there is no statistically significant trend in the data set, there does appear to be a visual downward trend in mean ISA values from 2010 to 2016 (Figure 4-28). At the Breezy Point beach sampling location, average ISA ranged from 0 in 2014 to 0.12 in 2012 (Figure 4-29). Data was only available for two years at Great Kills in Staten Island. In 2015, average ISA at Great Kills was 0.004. This average increased slightly in 2016 to 0.005 (Figure 4-30). ISA at Plumb Island in Sandy Hook ranged from 0.01 in 2015 to 0.12 in 2009 (Figure 4-31).

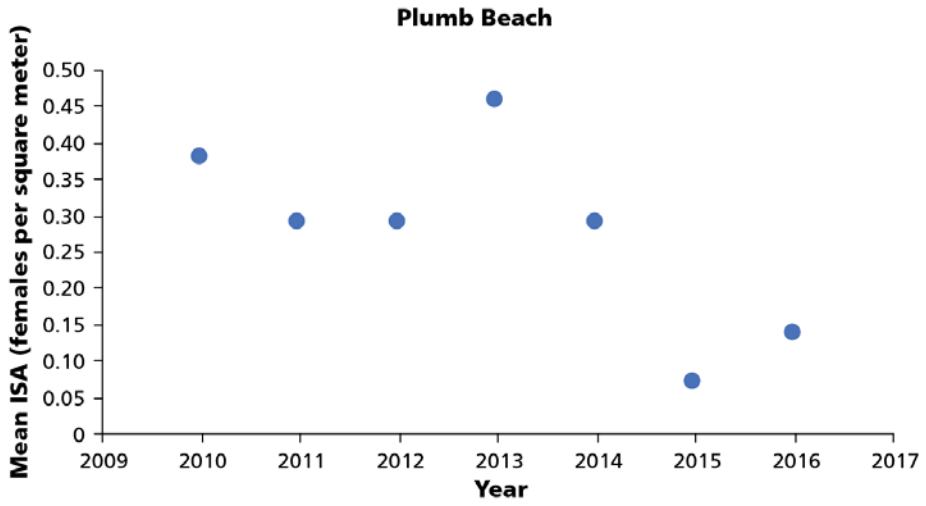


Figure 4-28. Mean Index of Spawning Activity for Plumb Beach (Jamaica Bay Unit of Gateway National Recreation Area) between 2009 and 2016 (Source: Cornell Cooperative Extension).

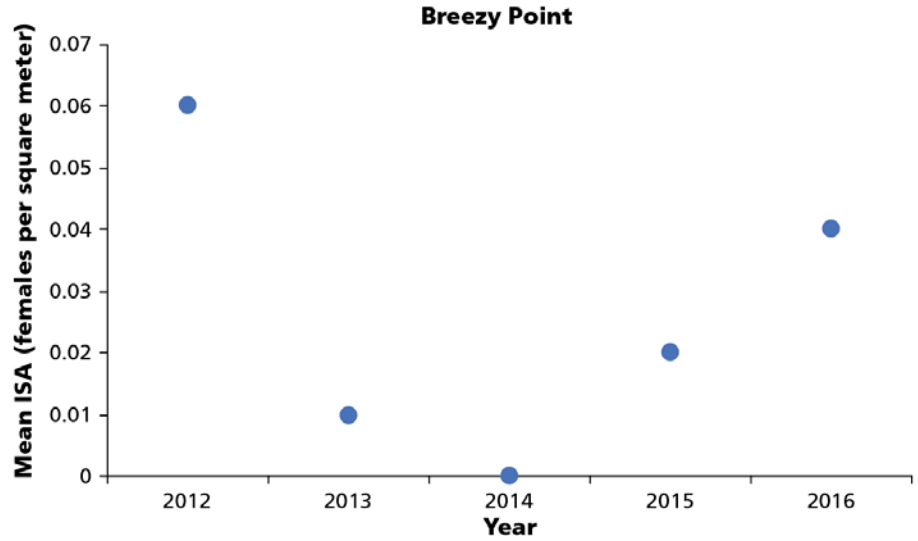


Figure 4-29. Mean Index of Spawning Activity for Breezy Point (Jamaica Bay Unit of Gateway National Recreation Area) between 2009 and 2016 (Source: NPS).

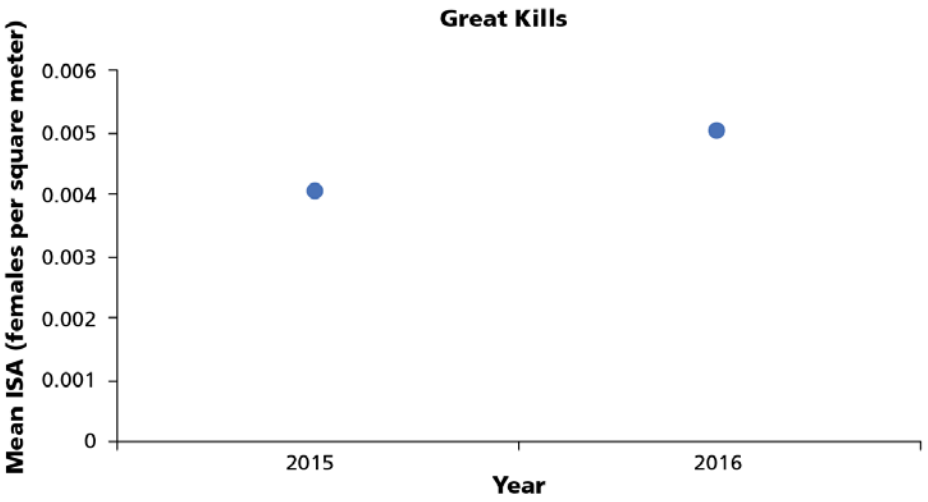


Figure 4-30. Mean Index of Spawning Activity for Great Kills (Staten Island Unit of Gateway National Recreation Area) for years 2015 and 2016 (Source: Cornell Cooperative Extension).

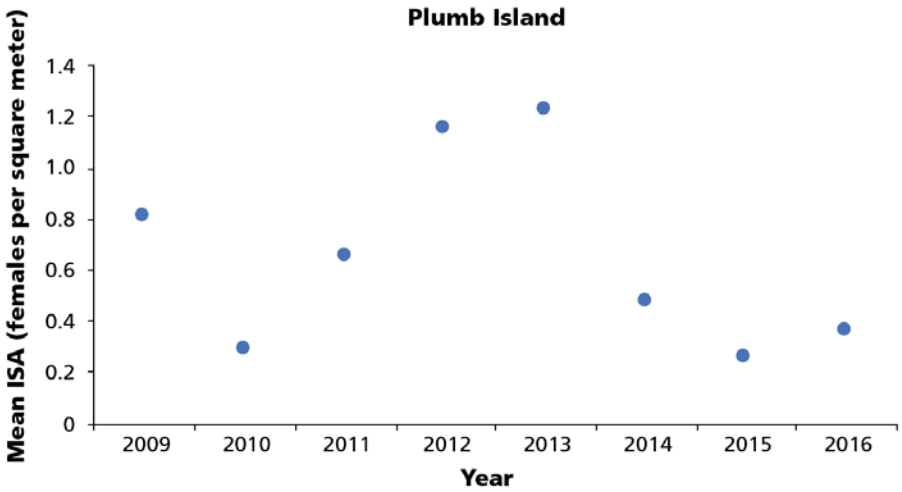


Figure 4-31. Mean Index of Spawning Activity for Plumb Island (Sandy Hook Unit of Gateway National Recreation Area) between years 2009 and 2015 (Source: NPS).

Source(s) of Expertise

- Matt Sclafani, Cornell Cooperative Extension Suffolk County

4.4 Landscapes dynamics

4.4.1 Landscape dynamics summary

Three metrics were used to assess landscape dynamics in GATE: saltmarsh elevation, impervious surface, and shoreline change. Data used for the assessment were sourced from the National Park Service, and the Institute of Marine and Coastal Sciences at Rutgers University (Table 4-8). Reference conditions were established for each metric, and the data were compared to these reference conditions to obtain the percent attainment and converted to the condition assessment for that metric.

Table 4-8. Indicators, metrics, and data sources used to assess Landscapes dynamics of Gateway National Recreation Area.

Indicator	Metric	Agency/Source	Region of assessment
Saltmarsh elevation	Marsh elevation surveys	National Park Service	• Jamaica Bay • Sandy Hook
Impervious surface	% impervious surface	National Park Service	• Jamaica Bay • Staten Island • Sandy Hook
Shoreline change	Distance from monitoring monument and NAVD88	Institute of Marine and Coastal Sciences Rutgers – The State University of New Jersey	• Jamaica Bay • Staten Island • Sandy Hook

4.4.2 Saltmarsh elevation

Description

Saltmarshes are low lying, intertidal grasslands that are alternately inundated and drained by tides. These areas function as nursery and feeding grounds for fish and shellfish, habitat for abundant wildlife, and act as natural filters that improve water quality. As evidence and awareness of the effects of climate change on sea level grows, the National Park Service has determined that monitoring saltmarsh elevation change is a top priority in North Atlantic Coastal parks (NPS, 2010; Stevens et al. 2010).

Saltmarshes within GATE are located primarily within Jamaica Bay and along the western shore of Sandy Hook. It is estimated that approximately 1,400 acres of tidal saltmarsh have been lost from Jamaica Bay alone since 1924, with the rate of loss rapidly increasing in recent years to a rate of 47 acres per year (US Army Corp of Engineers, 2016). Without intervention, the marshes could vanish by the year 2025, destroying wildlife habitat and threatening the bay's shorelines (US Army Corp of Engineers, 2016).

The mean elevation of saltmarsh surfaces must increase to keep pace with the annual rise in sea level and subsidence of saltmarsh organic substrates. If the sedimentation rates in a saltmarsh do not equal or exceed the net loss in elevation due to the steady increase in sea level and saltmarsh subsidence, the surface of the marsh will become sub-tidal which can cause drastic habitat changes.

Data and Methods

Saltmarsh elevation information was collected in 2014 for Jamaica Bay and in 2016 for Sandy Hook as part of the Surface Elevation and Vegetation Canopy Cover Survey. Real Time Kinematic Global Positioning System (RTK-GPS) was used to collect elevation data at 25 locations in the Jamaica Bay Unit (Figure 4-32) and 3 locations in the Sandy Hook Unit (Figure 4-33). Surveys were conducted on a 20 m by 20 m grid resulting in a total of 9547 measurements in Jamaica Bay and 577 measurements at Sandy Hook. Vegetation composition and canopy cover data was collected within a

0.25 m^2 quadrat adjacent to elevation survey points. The data set includes field collected data that has undergone QA/QC.

Wetland plants are usually found above mean tidal level (MTL) at GATE, due to excessive flooding below this elevation. For the purpose of this assessment, marsh elevations closer to MTL were considered more at risk than marshes with an elevation closer to mean high water (MHW). MTL and MHW information was sourced from tidal gauges at seven locations in Jamaica Bay and two locations at Sandy Hook (Table 4-9).

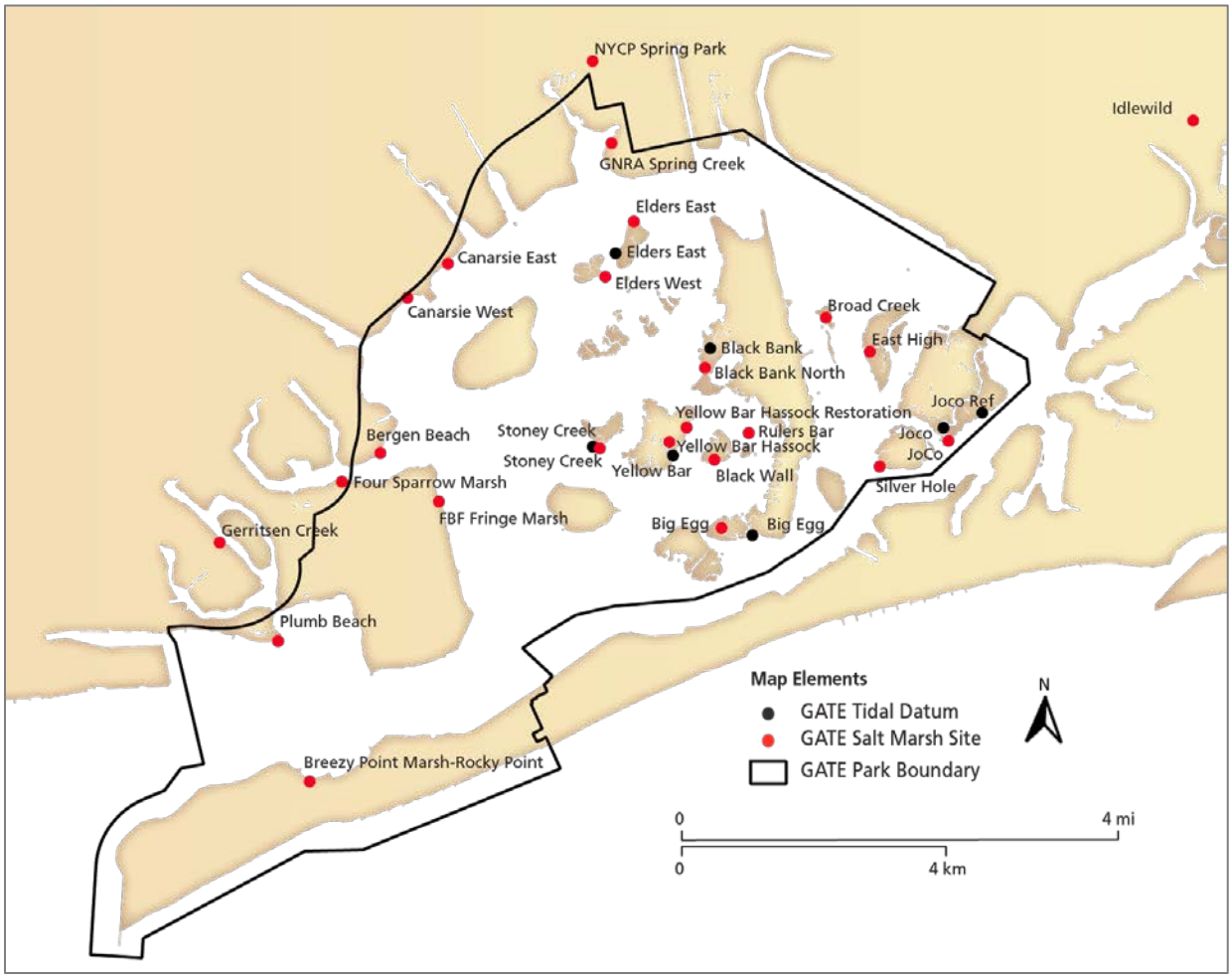


Figure 4-32. Marsh elevation surveys and tidal datum gauging stations in Jamaica Bay of Gateway National Recreation Area.

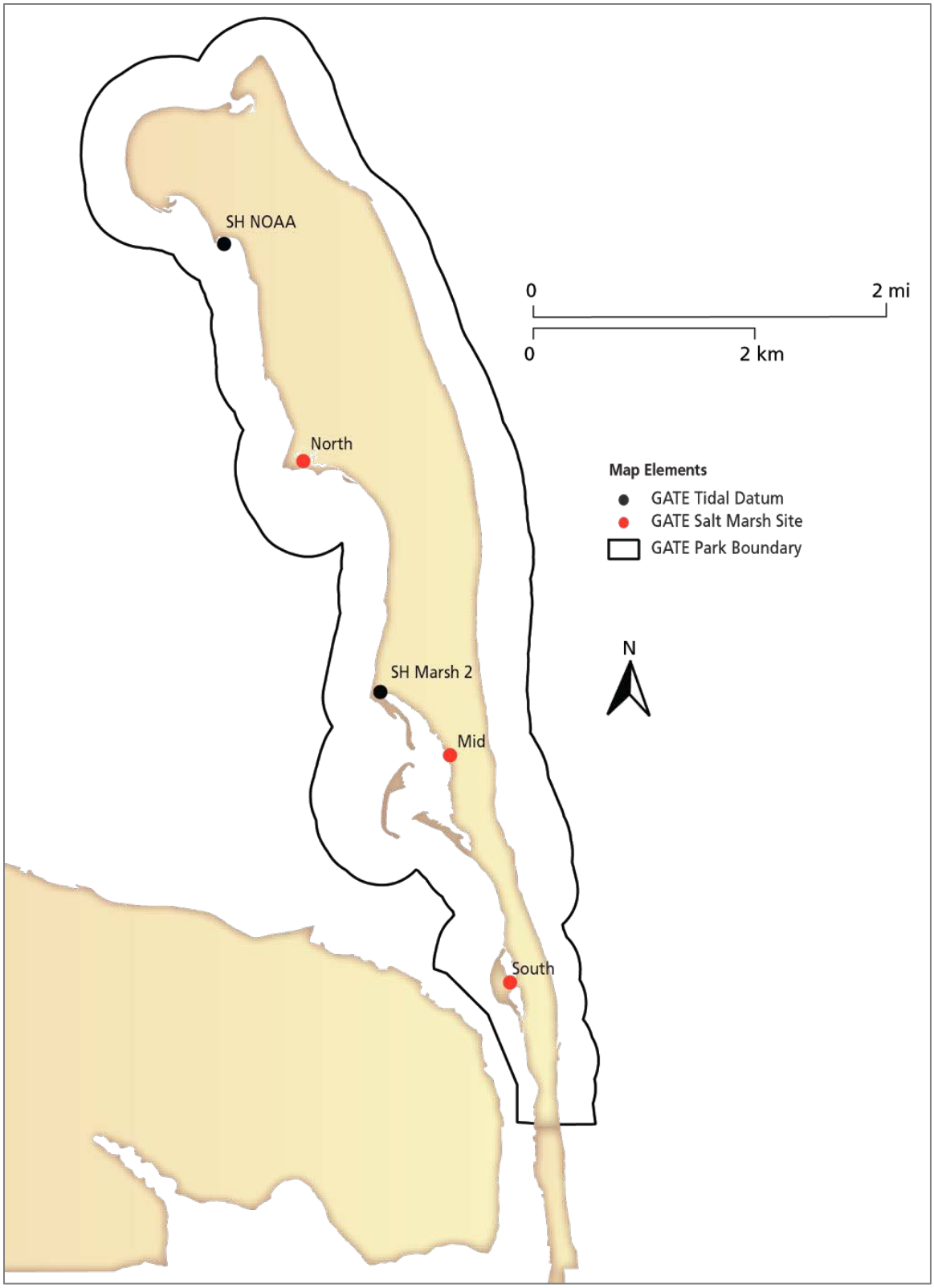


Figure 4-33. Marsh elevation surveys and tidal datum gauging stations at Sandy Hook Unit of Gateway National Recreation Area.

Table 4-9. Locations of tidal datum gauging stations and tidal measurements at Jamaica Bay Unit and Sandy Hook Unit of Gateway National Recreation Area, including mean values for Mean Tide Level (MTL) and Mean High Water (MHW) for each park unit.

Tidal datum Location	Latitude	Longitude	Mean High Water – MHW (m, NAVD88)	Mean Low Water – MLW (m, NAVD88)	Mean Tidal Level – MTL (m, NAVD88)	Mean Range MHW – MTL (m, NAVD88)	Source
Jamaica Bay – Big Egg	40.59526	-73.82665	0.886	-0.785	0.051	0.836	Jim Lynch – NPS
Jamaica Bay – Black Bank	40.62083	-73.83374	0.806	–	–	–	Jim Lynch – NPS
Jamaica Bay – Joco Reef	40.61154	-73.78523	0.905	–	–	–	Jim Lynch – NPS
Jamaica Bay – Elders East	40.63400	-73.85046	0.910	-0.754	0.078	0.832	Jolene Willis – NPS
Jamaica Bay – Joco	40.60954	-73.79219	0.942	-0.740	0.101	0.841	Jolene Willis – NPS
Jamaica Bay – Stoney Creek	40.60760	-73.85498	0.893	-0.784	0.055	0.839	Jolene Willis – NPS
Jamaica Bay – Yellow Bar	40.60626	-73.84067	0.915	-0.702	0.107	0.809	Jolene Willis – NPS
Sandy Hook – SH NOAA	40.46679	-74.00941	0.809	-0.698	0.056	0.754	URI EDC
Sandy Hook – SH Marsh 2	40.43031	-73.99330	0.735	-0.361	0.187	0.548	URI EDC
Jamaica Bay Mean	–	–	0.894	–	0.078	–	–
Sandy Hook Mean	–	–	0.772	–	0.121	–	–

Each measurement of marsh elevation was scored linearly based on its relative position between average MTL and average MHW for each park unit (0.078 - 0.894 m NAVD88 for Jamaica Bay; and 0.121-0.776 m NAVD88 for Sandy Hook). These tidal ranges were divided into three condition categories based on the percentiles outlined in Table 4-10. Marsh elevation was converted to a percentage score as per the relationships outlined in Figure 4-34.

Table 4-10. Tidal elevation scoring categories for marsh elevation at Jamaica Bay and Sandy Hook, Gateway National Recreation Area.

Park unit	Tidal elevation categories (m)		
	Significant concern 0-25%	**Moderate concern 25-75%**	**Good 75-100%**
Jamaica Bay	0.078 - 0.282	0.282 - 0.690	0.690 - 0.894
Sandy Hook	0.121 - 0..285	0.285 - 0.612	0.612 - 0.776

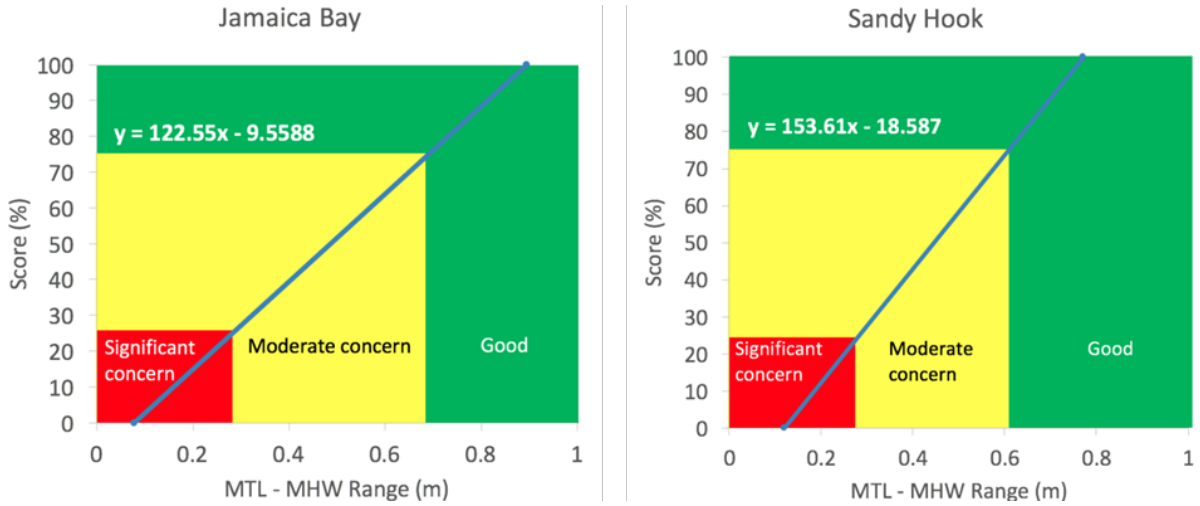


Figure 4-34. Conversion of saltmarsh elevation (in relation to tidal range between Mean Tide Level (MTL) and Mean High Water (MHW) to a percentage score for Jamaica Bay (left) and Sandy Hook (right), Gateway National Recreation Area.

Condition and Trend

Frequency distributions of marsh elevation measurements at Jamaica Bay and Sandy Hook are displayed in Figure 4-35 and Figure 4-36, respectively. Jamaica Bay had 40% of marsh elevation measurements fall within the “Good” condition, 21% in “Moderate” condition, and 19% within the “Significant concern” category. Sandy Hook had 38% of marsh elevations in “Good” condition, 13% in “Moderate” condition, and 25% within the “Significant concern” category.

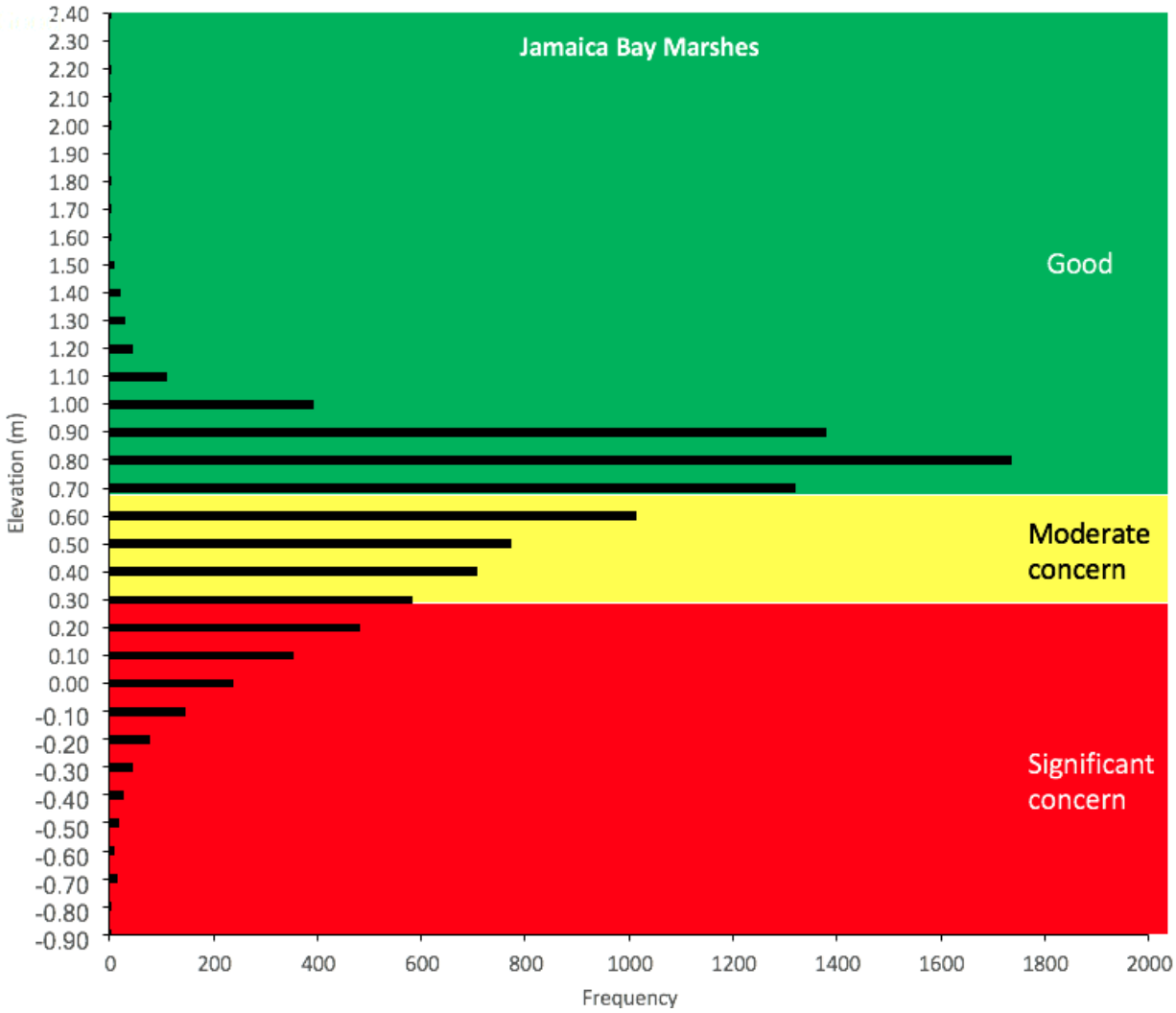


Figure 4-35. Frequency distribution of marsh elevation measurements in Jamaica Bay of Gateway National Recreation Area in 2014. Color bandings represent the three scoring bins outlined in Table 4.10.

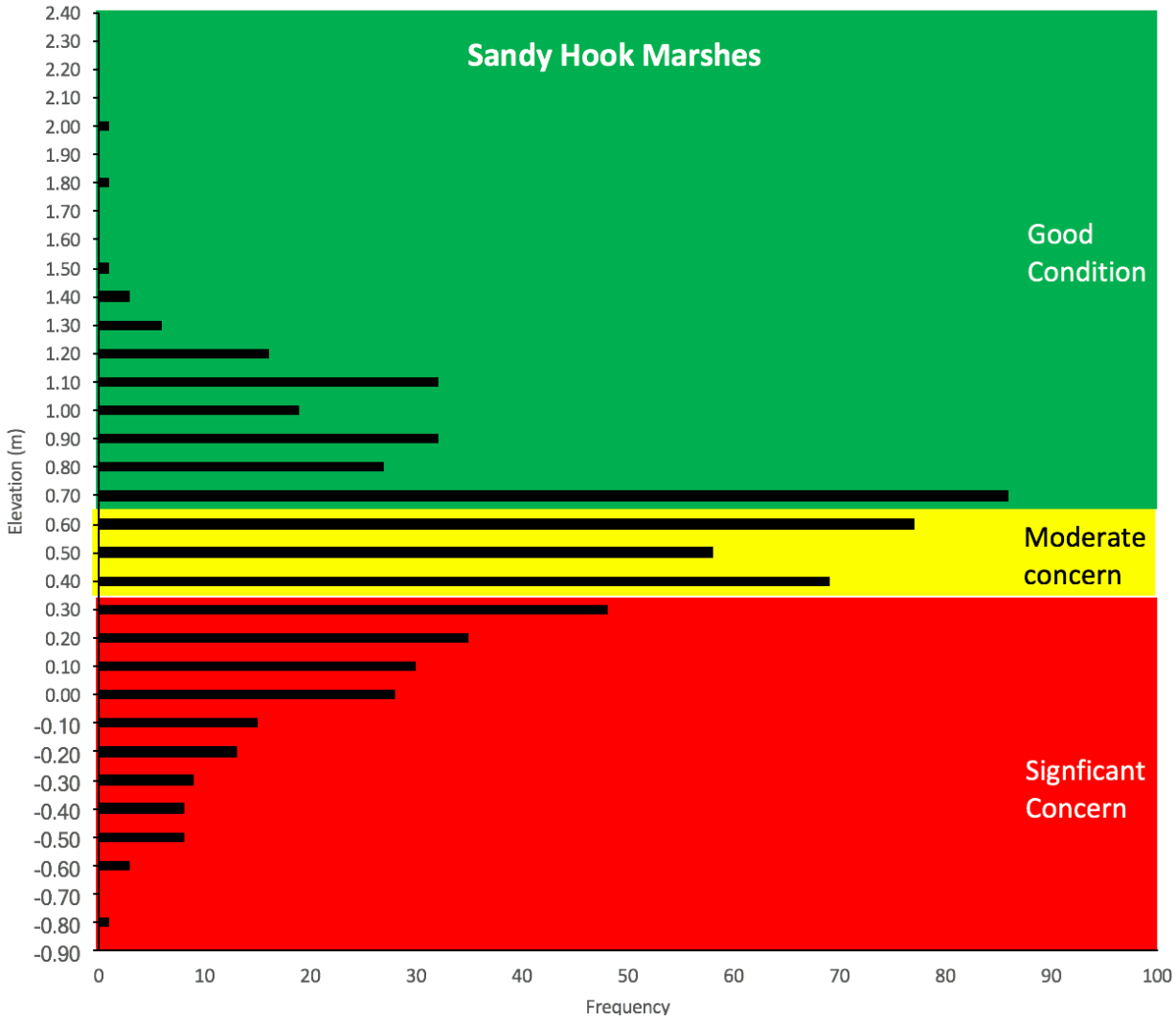


Figure 4-36. Frequency distribution of marsh elevation measurements in Sandy Hook of Gateway National Recreation Area in 2014. Color bandings represent the three scoring bins outlined in Table 4.13.

Reviewing the data by site reveals with finer detail the areas within each park unit that are most susceptible to sea level rise. Table 4-11 outlines the average elevation and score of measurements made at each site. Results ranged from “significant concern” at Big Egg, to “Good” at Bergen Beach, Breezy Point Marsh-Rocky Point, Canarsie East, Four Sparrow Marsh, Idlewild, and JoCo (Table 4-11). The highest elevation marsh in Jamaica Bay was at Breezy Point Marsh-Rocky Point at 0.9 m and the lowest at Big Egg at 0.21 m. Marsh elevations at Sandy Hook were relatively similar at all three sites ranging from 0.50 to 0.52 m.

A number of sites in “moderate” condition in Jamaica Bay were only slightly above the border of “significant concern” including Black Wall, Rulers Bar, Stoney Creek, Yellow Bar Hassock. Overall, the average elevation of all sites in Jamaica Bay was 0.55 m resulting in a score of 58% (Moderate concern). The average elevation of all sites in Sandy Hook was 0.45 m resulting in a score of 58% (Moderate concern).

Table 4-11. Number of elevation measurements at each site (n), average elevation, average scores, and condition of saltmarshes in Jamaica Bay and Sandy Hook of Gateway National Recreation Area based on elevation between Mean Tide Level (MTL) and Mean High Water (MHW).

Park unit	Sites	N	Average elevation (m)	Average score (%)	Condition
Sandy Hook	Sandy Hook North	112	0.49	57	Moderate concern
	Sandy Hook Mid	443	0.43	57	Moderate concern
	Sandy Hook South	81	0.51	61	Moderate concern
	Sandy Hook Overall	**626**	**0.45**	**58**	**Moderate concern**
Jamaica Bay	Bergen Beach	138	0.70	76	Good condition
	Big Egg	514	0.21	16	Significant concern
	Black Bank North	894	0.41	41	Moderate concern
	Black Bank South	244	0.50	51	Moderate concern
	Black Wall	271	0.33	31	Moderate concern
	Breezy Point Marsh-Rocky Point	19	0.90	100	Good condition
	Broad Creek	56	0.45	46	Moderate concern
	Canarsie East	55	0.85	94	Good condition
	Canarsie West	91	0.58	62	Moderate concern
	East High	494	0.57	60	Moderate concern
	Elders East	62	0.58	61	Moderate concern
	FBF Fringe Marsh	21	0.60	64	Moderate concern
	Four Sparrow Marsh	235	0.78	85	Good condition
	Gerritsen Creek	410	0.56	59	Moderate concern
	GNRA Spring Creek	62	0.67	73	Moderate concern
	Idlewild	261	0.70	76	Good condition
	JoCo	3141	0.69	75	Good condition
	NYCP Spring Park	187	0.67	72	Moderate concern
	Plumb Beach	129	0.46	46	Moderate concern
	Rulers Bar	134	0.37	35	Moderate concern
	Silver Hole	492	0.46	47	Moderate concern
	Stoney Creek	238	0.36	35	Moderate concern
	Yellow Bar Hassock	609	0.31	29	Moderate concern
	Yellow Bar Hassock Restoration	543	0.52	55	Moderate concern
	Jamaica Bay Overall	**9547**	**0.55**	**58**	**Moderate concern**

Sources of Expertise

- Jim Lynch, National Park Service
- Dennis Skidds, National Park Service

4.4.3 Impervious surface

Description

Impervious surface is a representation of human impact on the landscape and directly correlates to land development (Conway 2007). It includes roads, parking lots, rooftops, and transport systems that decrease infiltration, water quality, and habitat, while increasing runoff. Many ecosystem components such as wetlands, floral and faunal communities, and streambank structure show signs of impact when a landscape exceeds 10% impervious surface (Arnold and Gibbons 1996). Recent studies on stream macroinvertebrates continue to show shifts to more pollution tolerant species and reductions in biodiversity at around this same threshold (Lussier et al. 2008). A study of nine metropolitan areas in the United States demonstrated measurable effects of impervious surface on stream macroinvertebrate assemblages at impervious surface cover below 5% (Cuffney et al. 2010).

Data and Methods

Combined GIS layers of roadways, buildings and parking lots (layers sourced and provided by NPS, data from 2015 and 2016) were used to calculate the area of impervious surface within GATE, as a percentage of total land area for each park unit and the park as a whole. Percent impervious area was converted to an attainment score with good conditions assigned for impervious surface area less than the 10% threshold, as outlined in Figure 4-37.

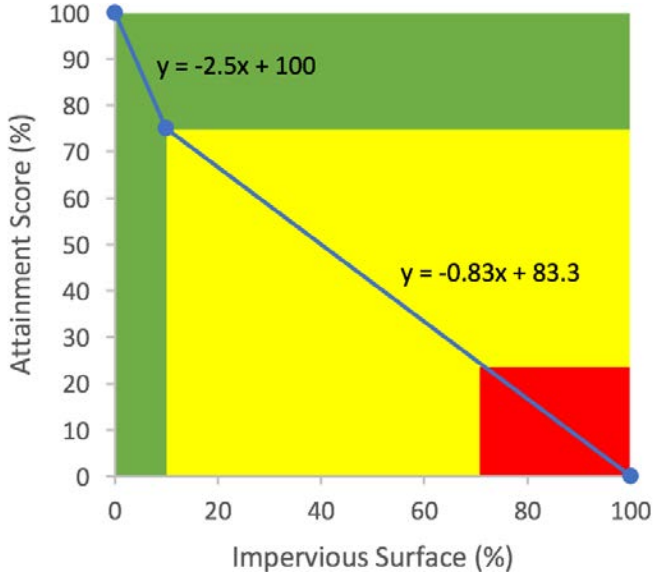


Figure 4-37. Conversion of impervious surface to percentage score (based on <10% impervious surface threshold).

Condition and Trend

The amount of impervious surface, the calculated attainment score, and condition for each park unit at GATE are outlined in Table 4-12. Jamaica Bay and Staten Island had a similar percentage of impervious surface to total area, both greater than the 10% threshold (Figure 4-38, Figure 4-39). Sandy Hook was the only park unit not to exceed the 10% threshold (Figure 4-40). This resulted in a "Good condition" for Sandy Hook and "Moderate concern" for Staten Island and Jamaica Bay units, and the park as a whole.

No trend analysis was possible with the current data set.

Table 4-12. Impervious surface area (by surface type), attainment score, and condition for each park unit and overall for Gateway National Recreation Area.

Park unit	Paved roads and parking lots area (km2)	Buildings area (km2)	Total impervious surface area (km2)	Total land area (km2)	% Impervious surface	Attainment score (%)	Condition
Sandy Hook	0.59	0.12	0.71	8.45	8.4	76	Good condition
Jamaica Bay	3.50	0.68	4.17	25.14	16.6	70	Moderate concern
Staten Island	0.72	0.14	0.86	5.15	16.7	69	Moderate concern
Overall	**4.80**	**0.94**	**5.74**	**38.74**	**14.8**	**71**	**Moderate concern**



Figure 4-38. Impervious surfaces throughout the Jamaica Bay Unit of Gateway National Recreation Area.

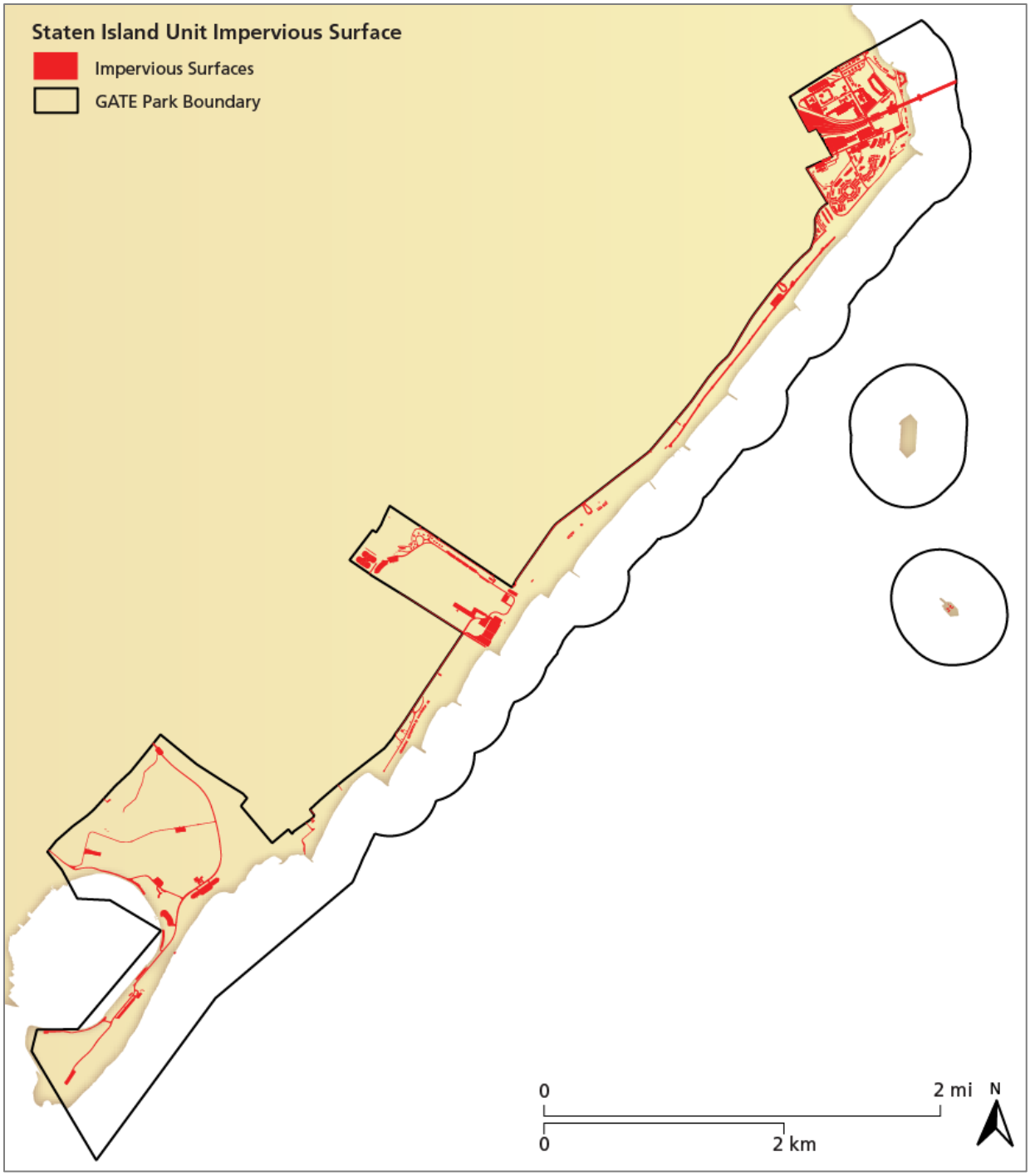


Figure 4-39. Impervious surfaces throughout the Staten Island Unit of Gateway National Recreation Area.

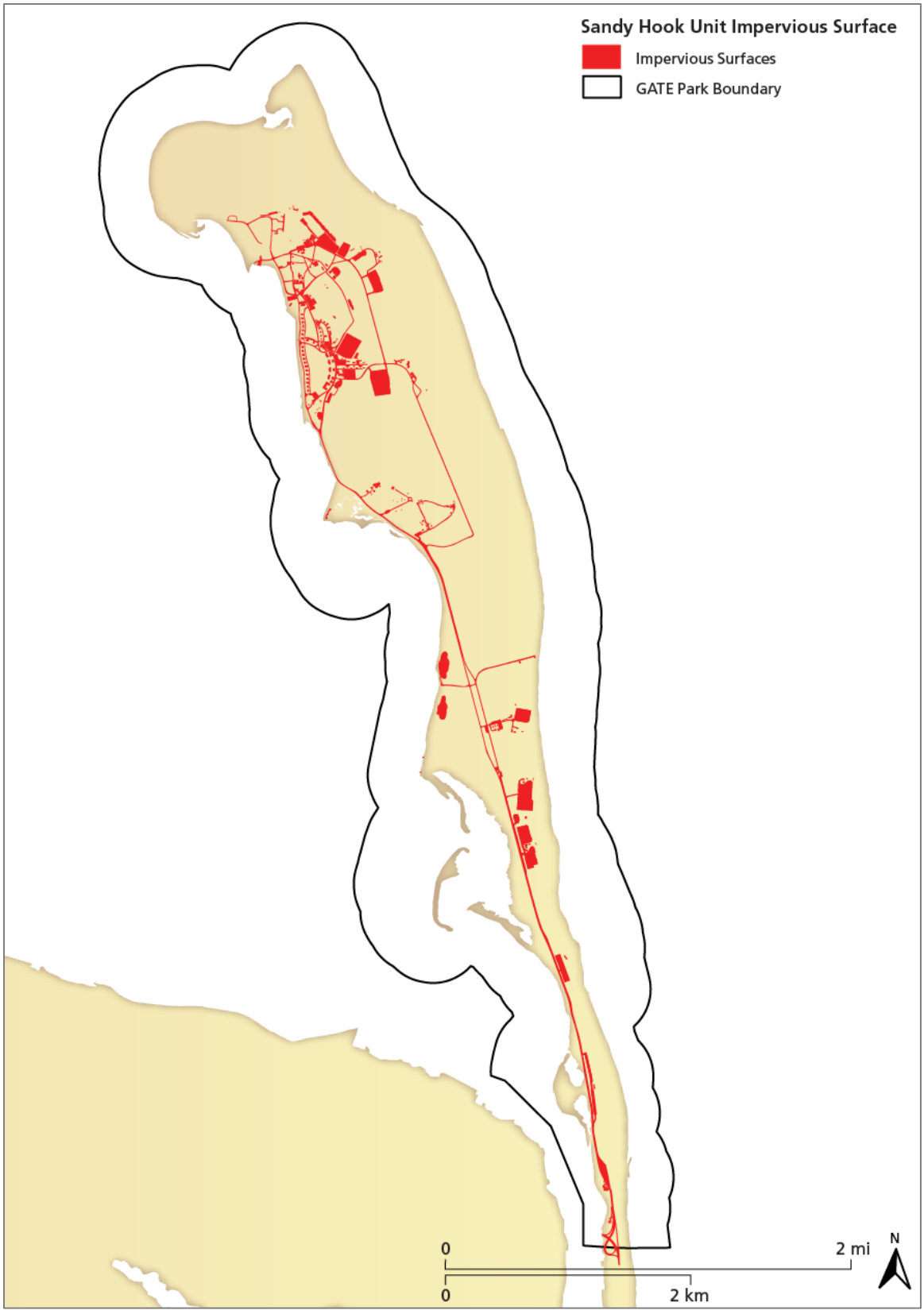


Figure 4-40. Impervious surfaces throughout the Sandy Hook Unit of Gateway National Recreation Area.

Sources of Expertise

- Dennis Skidds, National Park Service

4.4.4 Shoreline erosion and accretion

Description

Gateway National Recreation Area is composed of coastal areas directly exposed to ocean processes (e.g. Sandy Hook and Breezy Point), and other areas shielded from the direct exposure to ocean conditions (e.g. Great Kills, Miller Field, Fort Wadsworth, and Plumb Beach). Each is shaped by varied ocean energetics associated with their position, and to available sediment supply related to their location (Psuty et al., 2010b). Changes in the shoreline occur in response to seasonal weather patterns and storm events, but are also affected by sea-level rise and increased manipulations by humans, such as dredging, jetty creation, and beach and dune manipulation. Shoreline change can impact the structure and function of park natural resources, including the extent and distribution of specific wildlife habitats, as well as groundwater quality and quantity. The dynamic nature of the shoreline also poses challenges to the administration and protection of cultural resources and park infrastructure. It is difficult to make judgment on the impact of shoreline erosion and accretion on natural resources, so this assessment focuses on threats to key cultural resources and park infrastructure identified by park staff throughout the park.

Data and Methods

Two dimensional surveys of shoreline position and dune/beach profiles have been conducted throughout Gateway since the spring of 2010 (Psuty et al., 2010a, Psuty et al., 2012). Coastal profile surveys are conducted at low water during spring tides to expose as much of the beach profile as possible and to facilitate the collection of the profile to at least the North American Vertical Datum of 1988 (NAVD88 datum) position (near mean sea level). On the basis of the Psuty et al. 2012 protocol, the surveys occur at the end of the winter stormy period and at the end of the summer calm period, recording the seasonal variation of the dune/beach geomorphological system.

At the time of monitoring, NAVD88 and mean sea level are at similar elevations and the dune/beach topography has a similar relationship to these two elevations (Figure 4-41). Referencing a constant elevation and position with a fixed monument permits the monitoring of spatial and elevation evolution as the profile responds to changes in sediment supply, seasonal storminess, and increased water level.

For the purpose of this assessment, the percent change in shoreline distance (measured from fixed monuments to NAVD88) from Spring 2010 to Spring 2016 was assessed for individual profiles closest to important infrastructure at Sandy Hook, Breezy Point, Plumb Beach and Great Kills (Figures 4-41 through 4-45).

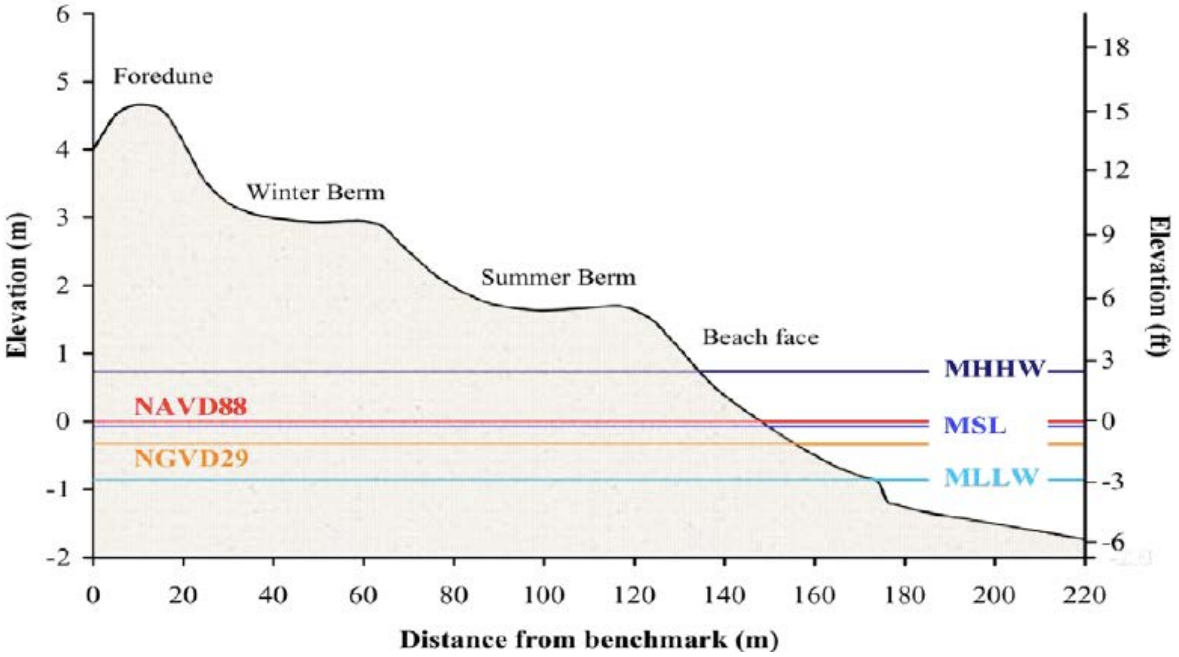


Figure 4-41. Relationship of 1983-2001 tidal epoch water levels to the North American Vertical Datum of 1988, to the 1929 National Geodetic Vertical Datum, and to a representative beach profile at Sandy Hook, Gateway National Recreation Area. All values are portrayed relative to NAVD88. Other terms are: MLLW = mean lower low water; NGVD29 = National Geodetic Vertical Datum of 1929; MSL = mean sea level; and MHHW = mean higher high water. (Extracted from Psuty et al., 2012).



Figure 4-42. Location of 16 monuments and their accompanying azimuths at Sandy Hook Unit, Gateway National Recreation Area, used in recording the 2D beach/dune profiles collected as part of the Northeast Coastal and Barrier Network monitoring program. Orthophotography provided by NOAA Office for Coastal Management Digital Coast Partnership, 2014. (Extracted from Psuty et al., 2012). Green circle highlights profile (SH3) used in this assessment closest to the Sandy Hook Visitor Center.



Figure 4-43. Location of 11 monuments and their accompanying azimuths on Breezy Point, Jamaica Bay Unit, Gateway National Recreation Area, used in running the 2D beach/dune profiles. Orthophotography provided by NOAA Office for Coastal Management Digital Coast Partnership, 2014. (Extracted from Psuty et al., 2012). Green circle highlights profile (BP3) used in this assessment closest to the Riis Park Beach House.



Figure 4-44. Location of five monuments and their accompanying azimuths at Plumb Beach, Jamaica Bay Unit, Gateway National Recreation Area, used in running the 2D beach/dune profiles. Orthophotography provided by NOAA Office for Coastal Management Digital Coast Partnership, 2014. (Extracted from Psuty et al., 2012). Green circle highlights profile (PB2) used in this assessment closest to the Belt Parkway at Plumb Beach.



Figure 4-45. Location of nine monuments and their accompanying azimuths at Great Kills, Staten Island Unit, Gateway National Recreation Area, used in running the 2D beach/dune profiles. Orthophotography provided by the U.S. Geological Survey, 2014; orthophotography reflects 2014 dredging of Great Kills Harbor (Extracted from Psuty et al., 2012). Green circle highlights profile (GK2) used in this assessment closest to Great Kills parking lot.

Condition and Trend

Distances from monitoring monuments and NAVD88 increased by over 200% (good condition) at both locations in Jamaica Bay between 2010 and 2016 (Table 4-13). Shoreline distances at the Sandy Hook location (SH3) were variable over time, but the distance in 2016 was 66% of the shoreline distance recorded in 2010 (moderate concern) (Table 4-13). Shoreline at Staten Island (GK2) showed a smaller decline over the monitoring period with shoreline distance in 2016 being 89% of the shoreline distance recorded in 2010 (good condition) (Table 4-13).

Source of Expertise

- Norb Psuty, Rutgers
- Dennis Skidds, National Park Service

Table 4-13. Condition and percent change in distances from monitoring monuments and NAVD88 benchmark at SH3, BP3, PB2, and GK2 from spring 2010 to spring 2016.

Park unit	Transect	2011 Spring distance from benchmark (m) NAVD88	2012 Spring distance from benchmark (m) NAVD88	2013 Spring distance from benchmark (m) NAVD88	2014 Spring distance from benchmark (m) NAVD88	2015 Spring distance from benchmark (m) NAVD88	2016 Spring distance from benchmark (m) NAVD88	% change between 2011 and 2016	Condition
Sandy Hook	SH3	223.49	234.77	180.06	208.88	223.49	147.21	66%	Moderate concern
Jamaica Bay	BP3	93.21	-	182.19	185.91	192.97	225.5	242%	Good
Jamaica Bay	PB2	19.52	20.26	66.52	64.28	63.77	65.39	335%	Good
Staten Island	GK2	85.44	83.81	87.12	83.14	79.39	76.03	89%	Good

5. Discussion

Bordering the greater New York and New Jersey metropolitan region, Gateway National Recreation Area encompasses some of the last remaining open space surrounding New York Harbor. Habitats stretch across open bays, ocean, marsh islands, shoreline, dunes, maritime and successional forests, grasslands, mudflats, and other open spaces. The park includes marinas, greenways, campgrounds, trails, beaches, and picnic grounds within historic landscapes, the remains of important coastal defense works, rare structures from U.S. aviation history, and the oldest continuously operating lighthouse in the United States. Each year millions come to experience the recreational, natural, and cultural opportunities that stretch throughout the coastline of three New York City boroughs and into northern New Jersey.

It is widely recognized that GATE adds critical open space in an increasingly urbanized region, provides refuge for many species, serves as a migration stop for wildlife, and is an important cultural landscape in the country's history.

Overall, natural resources in Gateway National Recreation Area are in a condition of moderate concern.

5.1 Air resource summary

Air quality was identified as a condition of "significant concern," (Table 5-1) however, air quality indicators are showing an overall improvement over recent decades, which will have positive implications for the park's natural ecosystems. Degraded air quality is a problem throughout the eastern United States and while the causes of degraded air quality are out of the park's control, the specific implications to the habits and species in the park are less well known. Gaining a better understanding of how reduced air quality is impacting sensitive habitats and species within the park would help prioritize management efforts (Table 5-2). Park management efforts to directly improve regional air quality are likely to have minimal impacts, however the park can play a leading role in regional education of the causes and effects of air pollution. These include human health issues, plant defoliation, water acidification, and altered nutrient cycling.

Despite a lack of sound and light pollution information, GATE NPS staff recognize their proximity to development, and associated air and vehicular traffic. Data collection priorities also could include the implementation of a noise and light pollution monitoring protocol. Each of these poses challenges to the park's soundscape and infrastructure, and understanding the ecological impacts should be further explored.

Table 5-1. Condition assessment of air quality resources within Gateway National Recreation Area.

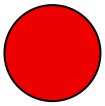
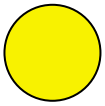
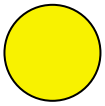
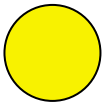
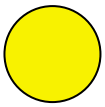
Resource	Indicator	Status	Rationale and Reference Conditions
Air quality	Total sulfur (wet deposition in kg/ha/yr)		Estimated sulfur wet deposition was 2.7 kg/ha/yr (2008-12); condition elevated to significant concern due to sensitive ecosystems; NPS ARD advises against using interpolated values for trends (Data Source: NADP-NTN via AirAtlas)
	Total nitrogen (wet deposition in kg/ha/yr)		Estimated nitrogen wet deposition was 2.9 kg/ha/yr (2008-12); moderate sensitivity to nutrient-enrichment effects; NPS ARD advises against using interpolated values for trend (Data Source: NADP-NTN via AirAtlas)
	Mercury deposition		Mercury/toxics deposition warrants moderate concern. Given that landscape factors influence the uptake of mercury in the ecosystem, the status is based on estimated wet mercury deposition and predicted levels of methylmercury in surface waters. The 2011-2013 estimated wet mercury deposition is moderate at the park, ranging from 8.0 to 8.7 micrograms per square meter and predicted methylmercury concentrations in surface waters is high, ranging from .068 to .079 nanogram per liter.
	Ozone (ppb)		Interpolated fourth-highest daily maximum eight-hour ozone concentration between 2009 and 2013 for GATE was 76.4 ppb, which resulted in 0% attainment of reference condition.
	Ozone W126		Interpolated W126 value between 2009 and 2013 for GATE was 11.1 ppm-hours, which resulted in 30% attainment of the reference condition, or a condition of moderate condition.
	Atmospheric visibility		Interpolated haze index between 2009 and 2013 for GATE was 6.2 dv, which resulted in 25% attainment of the reference condition, or a condition of moderate concern

Table 5-2. Key findings, management implications, and recommended next steps for air quality in Gateway National Recreation Area.

Key findings	Management implications	Recommended next steps
Air quality is very degraded and is a regional problem	• Impacts of poor air quality on park natural resources are largely unknown. • Other Parks (e.g. Shenandoah NP) exhibit clear ecological impacts of poor air quality (i.e. acid rain impacts).	• Investigate effects of poor air quality on sensitive habitats and species within the park (e.g. ozone damage to vegetation). • Stay engaged with the wider community in terms of air quality education and activities.
High nitrogen deposition values	• May promote establishment and growth of invasive/non-native species.	• Understanding the ecological impacts of air quality.
Visibility	• Impacts scenic vistas.	• High visibility vs. low visibility day education.
Soundscape	• May impact breeding/feeding/nesting behavior of e.g. resident and migratory birds. • Impacts visitor experience.	• Conduct a noise/soundscape study to determine if management is required.
Lightscape/night sky	• May impact breeding/feeding/nesting behavior of e.g. resident and migratory birds/turtles. • Impacts visitor experience.	• Change lighting design/timing restrictions. Collaborate with regional partners to reduce existing, and prevent new impacts to night sky darkness.
Lack of park specific air quality data	• Reduced confidence of current conditions within the park.	• Implementation of park-scale air quality monitoring would give better insights into park-level air quality condition and possible effects on park habitats and species.

5.2 Water resources summary

The condition of water resources in Gateway National Recreation Area are of moderate concern. Water resources were characterized by good pH, secchi depth, dissolved oxygen, and *Enterococcus*. A higher overall attainment was however offset by degraded conditions for chlorophyll *a*, total phosphorus, and total nitrogen (Table 5-3). Because many of the water resources within the park originate outside of park boundaries, and due to a lack of water quality data for the Staten Island and Sandy Hook Units, it is difficult to identify and manage environmental impacts from pollution within GATE. The park should aim to work collaboratively with local, state, and federal partners to undertake a comprehensive water quality monitoring program. Management implications and recommended next steps are outlined in Table 5-4.

Table 5-3. Condition assessment of water resources within Gateway National Recreation Area.

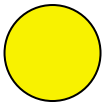
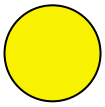
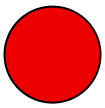
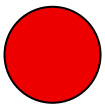
Resource	Indicator	Status	Rationale and Reference Conditions
Water resources	Dissolved oxygen		The condition of dissolved oxygen within bottom waters in GATE was very good with 95% attainment of the reference condition.
	Water clarity (secchi depth)		Water clarity condition within GATE is of moderate concern with 65% attainment of the reference condition.
	Chlorophyll *a*		Chlorophyll *a* is in moderate condition, with 54% attainment of the reference condition. The discharge of several large wastewater treatment plants and high nutrient inputs, in conjunction with long residence times, allows for the proliferation of phytoplankton populations.
	Total nitrogen		Total nitrogen had a score of 19% attainment of reference condition, a condition of significant concern.
	Total phosphorus		Total phosphorus had a score of 7% attainment of reference condition, a condition of significant concern.
	pH		Condition of pH within GATE was good with 98% of data points attaining the reference condition.
	Enterococcus		Current condition of *Enterococcus* parkwide for 2010-2015 is good condition, with 94% attainment of reference condition over all samples.

Table 5-4. Key findings, management implications, and recommended next steps for water resources in Gateway National Recreation Area.

Key findings	Management implications	Recommended next steps
Limited water quality data for Staten Island and Sandy Hook Units	• Difficult to identify and manage environmental impacts from pollution	• Work collaboratively with local, state, and federal partners to undertake water quality monitoring.
Nutrients, water clarity, and Chlorophyll *a* all had scores of moderate or condition of significant concern	• Impacts on benthic habitats and organisms.	• Work with local partners and neighbors to improve pollutant loads to Jamaica Bay. • Educate the public on causes of degraded water quality and what can be done at the local and regional scale to improve water quality conditions.
Lack of understanding on how water quality is impacting park resources	• Impedes prioritization of resource allocation and management actions.	• Undertake monitoring program focusing on park species and habitats susceptible to changes in water quality.
Enterococcus values highest at Staten Island	• Potential threat to public health and may also suggest other contaminant issues (e.g. nutrients).	• Undertake focused microbiological study to identify sources and timing of elevated bacterial levels.
Thresholds may not be appropriate for all water quality indicators	• Hinders interpretation of water quality data and subsequent decision making.	• Develop site specific water quality thresholds.
Data storage and management is not coordinated between different agencies monitoring water quality within park boundaries.	• Difficulty in collating and analyzing data. Different methods and timing of data collection potentially leads to problems with interpreting results.	• Expand Jamaica Bay Water Quality Data Visualization and Access Tool (http://www.ciesin.columbia.edu/jbwq/) to include Sandy Hook and Staten Island.

5.3 Biological integrity summary

Biological integrity was assessed as a condition of moderate concern. Horseshoe crabs, and American holly forest extent had a condition of moderate concern. Overall, piping plover, and seabeach amaranth were assessed as significant concern (Table 5-5). Due to a lack of spatial monitoring across all park units, these indicators are all presented with low confidence. Future recommendations involve establishing a standard biological inventory, selecting species and habitats that are important to park management goals. Management implications and recommended next steps are outlined in Table 5-6.

Table 5-5. Condition assessment of biological integrity resources within Gateway National Recreation Area.

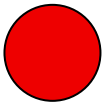
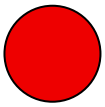
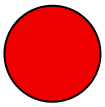
Resource	Indicator	Status	Rationale and Reference Conditions
Biological integrity	Seabeach amaranth abundance		Condition of seabeach amaranth within GATE was assessed as a significant concern. Sites in Jamaica Bay attained the reference condition in zero of six (0%) sampled years (2010-2015). In Sandy Hook, there was a 33.3% attainment of the reference condition, with two of six years attaining the reference condition. Note that abundances are much higher in the Sandy Hook Unit (median of 1220.5) than in the Jamaica Bay Unit (median of 63.5).
	Piping plover		Overall piping plover productivity within GATE had a 16.5% attainment of the reference condition, or a condition of significant concern. At Breezy Point, productivity was below the conservation goal of 1.5 in all years sampled. In the Sandy Hook Unit, productivity two of the six sampling years (2010 and 2011) scored above the conservation goal.
	Diamondback terrapin		Condition of the diamondback terrapin population within the Jamaica Bay unit of GATE was assessed as being of significant concern, as all sampling years between 2010 and 2015 failed to attain the reference condition (0% attainment). Over the past 10 years of survey data, the population of nesting female diamondback terrapins has decreased by almost 50% (Figure 4.22).
	American holly		Holly forest in Sandy Hook has been assessed at 91% of the historic state, or good condition. It is important to note that the current condition of whole forest is unknown, as only the portion studied by Stalter and McArthur could be assessed in this report.

Table 5-6. Key findings, management implications, and recommended next steps for biological integrity in Gateway National Recreation Area.

Key findings	Management implications	Recommended next steps
Seabeach amaranth and piping plover have specific habitat needs	• Habitat is susceptible to anthropogenic (human) and natural (erosion, storms) disturbances which could affect long-term survival within GATE.	• Explore options to limit human disturbance of potential seabeach amaranth and piping plover habitat by closing park areas for conservation. • Add parameters into data collection to help assess if management is allowing for success (# of individuals, area survey, exact area protected by enclosure every summer).
Spatially limited diamondback terrapin data for all park units	• Difficult to plan and manage suitable habitat.	• Undertake spatially intense monitoring program followed by an ongoing monitoring program in each park unit.
Comprehensive invasive species monitoring is lacking	• Difficult to allocate resources for invasive species management.	• Develop an invasive species management plan for GATE that includes an ongoing mapping of invasive species within the park.
Detailed landscape analysis of community change (grasslands, holly forest) is lacking.	• Impedes prioritization of resource allocation and management actions.	• Undertake review of historical landscape data in park units, and develop current/future landscape monitoring program to identify changes to park landscapes and communities.
Need to implement monitoring of important park species: eelgrass area, filter feeding organisms, invasive cover, deer, raccoons	• Impedes prioritization of resource allocation and management actions.	• Develop a biological monitoring plan for GATE that includes ongoing mapping of park habitats.

5.4 Landscape dynamics summary

Landscape dynamics was assessed as being of moderate concern. Condition was good for percent shoreline change, and moderate concern for saltmarsh elevation and impervious surfaces. Confidence in the assessment was moderate, and would be increased by developing a time-series of high-resolution, classified land cover imagery specific to the park. Management implications and next steps are outlined in Table 5-8.

Table 5-7. Condition assessment of landscape dynamics indicators within Gateway National Recreation Area.

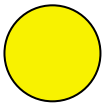
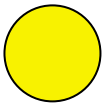
Resource	Indicator	Status	Rationale and Reference Conditions
Landscape dynamics	Saltmarsh elevation		• Sandy Hook - Average marsh elevation was 0.45 m in 2014 in comparison to the reference tidal datum mean high water elevation of 0.776 m and mean tidal level of 0.249 m, resulting in a 58% attainment score. • Jamaica Bay - Average marsh elevation was 0.55 m in 2014 in comparison to the reference tidal datum mean high water elevation of 0.886 m and mean tidal elevation of 0.886 m and mean tidal level of 0.078 m, resulting in a 58% attainment score.
	% impervious surfaces		• Percent impervious surfaces was 14.8%, a condition of moderate concern.
	% shoreline change		• Sandy Hook - Moderate Condition - Shoreline distance from benchmark in 2016 was 66% of distance in 2011 (net erosion). • Jamaica Bay - Good Condition - Shoreline distance from benchmark in 2016 was >100% of distance in 2011 (net accretion). • Staten Island - Good Condition - Shoreline distance from benchmark in 2016 was 89% of distance in 2011 (net erosion).

Table 5-8. Key findings, management implications, and recommended next steps for landscape dynamics in Gateway National Recreation Area.

Key findings	Management implications	Recommended next steps
Lack of benthic landscape data.	• Unable to assess the condition of benthic habitats or future changes.	• Develop and implement a benthic habitat monitoring program and set baseline conditions.
Need for understanding fill materials that park was built on.	• May have implications for park resources.	• Develop and implement assessment of ground fill materials.
Shoreline accretion was occurring at chosen sites within the Jamaica Bay unit, whereas shoreline erosion was evident within the Sandy Hook and Staten Island units.	• Infrastructure vulnerable to erosion.	• Conduct a vulnerability assessment of infrastructure and habitat susceptible to erosion at all park units.
Saltmarsh elevation assessment identified specific locations that were most susceptible to sea level rise. Includes: Big Egg, Black Wall, Rulers Bar, Stoney Creek, Yellow Bar Hassock	• Prioritization of resource allocation and management actions due to marsh loss and sea level rise.	• Conduct a vulnerability assessment of marsh habitat susceptible to sea level rise within Jamaica Bay. Examine options for protection of marsh habitat. • Continue sea-level monitoring to increase confidence in tidal datum information in both Jamaica Bay and Sandy Hook Units.

Literature Cited

Abouelezz, H. 2014. Summary of the 2014 Species status species management at the Jamaica Bay unit, GATE, NY.

Arnold Jr, C. L., and C. J. Gibbons. 1996. Impervious surface coverage. *Journal of the American Planning Association* 62:243-269.

Bornstein, R. D. 1968, Observations of the Urban Heath Island Effect in New York City. *Journal of Applied Meteorology and Climatology* 7:575-582.

Benotti, M. J., M. Abbene, and S. A. Terracciano. 2007. Nitrogen loading in Jamaica Bay, Long Island, New York: Predevelopment to 2005: U.S. Geological Survey Scientific Investigations Report 2007–5051, 17 p. Available at: https://pubs.usgs.gov/sir/2007/5051/SIR2007-5051.pdf (accessed 17 September 2018).

Bologna, P. A. X., M. S. Sinnema. 2012. Restoration of seagrass habitat in New Jersey, United States. *Journal of Coastal Research* 28:99. West Palm Beach, Florida.

Boyle, S. A., and F. B. Samson. 1985. Effects of nonconsumptive recreation on wildlife. *A Review. Wildlife Society Bulletin* 13(2):110-116.

Bricker, S. B., C. G. Clement, D.E. Pirhalla, S. P. Orlando, and D. R. G. Farrow. 1999. National estuarine eutrophication assessment: Effects of nutrient enrichment in the nation's estuaries. NOAA, National Ocean Service, Special Projects Office and the National Centers for Coastal Ocean Science. Silver Spring, MD: 71 pp.

Cabelli, V. J., A. P. Dufour, L. J. McCabe, and M. A. Levin. 1983. A marine recreational water quality criterion consistent with indicator concepts and risk analysis. *Journal of Water Pollution Control Federation* 55:1306-1314.

Caldwell, J. M., M. E. Nixon, H. A. Neckles, and P. S. Pooler. 2015. Estuarine water quality in parks of the Northeast Coastal and Barrier Network: Vital signs estuarine nutrient-enrichment monitoring, 2006-11. Natural Resource Report NPS/NCBN/NRR--2015/902. National Park Service, Fort Collins, Colorado.

City of New York. 2017. Deer impact management plan. Available at: http://www1.nyc.gov/site/wildlifenyc/animals/management-plan.page (accessed 17 September 2018).

Conway, T. M. 2007. Impervious surface as an indicator of pH and specific conductance in the urbanizing coastal zone of New Jersey, USA. *Journal of Environmental Management* 85:308-316.

Cornell University Law School Legal Information Institute 2016. 16 U.S. Code Subchapter LXXXVII - Gateway National Recreation Area. Available at:

https://www.law.cornell.edu/uscode/text/16/chapter-1/subchapter-LXXXVII (accessed 17 September 2018).

Cote, S. D., T. P. Rooney, J. Tremblay, C. Dussault, and D. M. Waller. 2004. Ecological impacts of deer overabundance. *Annual Review of Ecology, Evolution, and Systematics* 35:113-47.

Cuffney, T. F., R. A. Brightbill, J. T. May, and I. R. Waite. 2010. Responses of benthic macroinvertebrates to environmental changes associated with urbanization in nine metropolitan areas. *Ecological Applications* 20:1384-1401.

Davey, C. A., K. T. Redmond, and D. B. Simeral. 2006. Weather and climate inventory, National Park Service, Northeast Coastal and Barrier Network. Natural Resource Technical Report NPS/NCBN/NRTR—2006/008. National Park Service, Fort Collins, Colorado.

Driscoll, C. T., G. B. Lawrence, A. J. Bulger, T. J. Butler, C. S. Cronan, C. Eagar, K. F. Lambert, G. E. Likens, J. L. Stoddard, and K. C. Weathers. 2001. Acidic deposition in the northeastern United States: sources and inputs, ecosystem effects, and management strategies. *Bioscience* 51(3):180-198.

Dutzik, T., and D. O'Malley. The shore at risk: The threats facing New Jersey's coastal treasures, and what it will take to address them. Environment New Jersey Research and Policy Center.

EcoCheck. 2011. Sampling and data analysis protocols for Mid-Atlantic tidal tributary indicators. Wicks EC, Andreychek ML, Kelsey RH, Powell SL (eds). IAN Press, Cambridge, Maryland, USA. Available at http://ian.umces.edu/pdfs/ian_report_313.pdf (accessed 17 September 2018).

EPA 2017. Current Nonattainment Counties for All Criteria Pollutants. Available at: https://www3.epa.gov/airquality/greenbook/ancl.html (accessed 17 September 2018).

Fancy, S. G., J. E. Gross, and S. L. Carter. 2008. Monitoring the condition of natural resources in U.S. national parks. Environmental Monitoring and Assessment. Electronically published May 29, 2008.

Fenn, M. E., R. Haeuber, G. S. Tonnesen, J. S. Baron, S. Grossman-Clarke, D. Hope, D. A. Jaffe, S. Copeland, L. Geiser, H. M. Rueth, and J. O. Sickman. 2003. Nitrogen emissions, deposition, and monitoring in the Western United States. *BioScience* 53(4):391-403.

Forman, R. T. T., and A. M. Hersperger. 1996. Trends in addressing transportation related wildlife mortality: Proceedings of the transportation related wildlife mortality seminar. Florida DOT, FL-ER-58-96.

Forman, R. T. T., D. S. Friedman, D. Fitzhenry, J. D. Martin, A. S. Chen, and L. E. Alexander. 1995. Ecological effects of roads: Toward three summary indices and an overview for North America. In: Canters, K (ed). Habitat fragmentation and infrastructure. Ministry of Transport, Public Works and Water Management: Maastricht and The Hague, Netherlands.

Forrester, J., D. Leopold, and H. Underwood. 2006. Isolating the effects of white-tailed deer on the vegetation dynamics of a rare maritime American holly forest. *The American Midland Naturalist* 156(1):135-150. Available at: https://www.jstor.org/stable/4094676 (accessed 17 September 2018).

Gibbs, J. P., and W. G. Shriver. 2002. Estimating the effects of road mortality on turtle populations. *Conservation Biology* 16:1647-1652.

Gobler, C. 2016. Controls and consequences of algal blooms in Jamaica Bay, NY, USA.

Gregg, J. W., C. G. Jones, and T. E. Dawson. 2003. Urbanization effects of tree growth in the vicinity of New York City. *Nature* 424:183-187.

Greller, A. M., C. Durando, L. F. Marcus, D. Siril, A. Wijesundara, M. D. Byer, R. Cook, J. T. Tanacredi. 2000. Phytosociological analysis of restored and managed grassland habitat within an urban national park. *Urban Ecosystems* 4:293. doi:10.1023/A:1015755832045

Ginsburg, R. 1987. Holly forest feels pressure of poachers. New York Times. Available at: http://www.nytimes.com/1987/12/13/nyregion/holly-forest-feels-pressure-of-poachers.html?pagewanted=all (accessed 17 September 2018).

Haile, R. W., J. S. Witte, M. Gold. 1999. The health effects of swimming in ocean water contaminated by storm drain runoff. *Epidemiology* 10(4):355-63.

Hartig, E. K., A. Kolker, and V. Gornitz. 2001. Investigations into recent salt marsh losses in Jamaica Bay, New York. In: A. L. Gordon, R. E. Bell, S. M. Carbotte, R. D. Flood, E. K. Hartig, A. S. Kolker, V. Gornitz, D. M. Peteet, L. Lieberman, R. W. Houghton, B. A. Huber, J. L. Rubenstone, R. Takesue, A. van Geen, C. Langdon, R. N. Sambrotto. 2001. Integrated reconnaissance of the physical and biogeochemical characteristics of Jamaica Bay, Columbia University Academic Commons. Available at: http://hdl.handle.net/10022/AC:P:13051 (accessed 17 September 2018).

Hartig, E. K., V. Gornitz, A. Kolker, F. Mushacke, and D. Fallon. 2002. Anthropogenic and climate-change impacts on salt marshes of Jamaica Bay, New York City. *Wetlands* 22:71-89.

Jamaica Bay Watershed Protection Plan Advisory Committee. 2006. Planning for Jamaica Bay's future: Preliminary recommendations on the Jamaica Bay Watershed Protection Plan. Available at: http://www.ciesin.org/jamaicabay/jbwppac/JBAC_Recommendations_Report_062906.pdf (accessed 17 September 2018).

Kheirbek, I., S. Johnson, K. Ito, K. Anan, C. Huskey, T. Matte, D. Kass, H.Eisl, J. Gorczynski, S. Markowitz. 2014. The New York City community air survey: Neighborhood air quality 2008-2014. New York City Department of Health and Mental Hygiene and Queens College, City University of New York.

Kirchhoff, K., L. Stokes, A. Bahena Cuevas, L. Chan, M. Filipovic, G. Goodrich, J. Haller, K. Kasman, M. Miller, C. Orr, T. Sinnickson. 2009. Gateway National Recreation Area long-term

resource management under a changing climate. Prepared by the Columbia University, School of International & Public Affairs.

Lane, B. 1995. Beetlemania sweeps the hook: federally threatened northeastern beach tiger beetle on comeback at Sandy Hook Unit of Gateway National Recreation Area. Park Science: Integrating research and resource management Volume 15: No. 3. National Park Service.

Longcore, T., and C. Rich. 2004. Ecological light pollution. *Frontiers in Ecology and the Environment* 2(4):191-198.

Lussier, S. M., S. N. da Silva, M. Charpentier, J. F. Heltshe, S. M. Cormier, D. J. Klemm, M. Chintala, and S. Jayaraman. 2008. The influence of suburban land use on habitat and biotic integrity of coastal Rhode Island streams. *Environmental Monitoring and Assessment* 139:119-136.

Lynch, J. C., P. Hensel, and D. R. Cahoon. 2015. The surface elevation table and marker horizon technique: A protocol for monitoring wetland elevation dynamics. Natural Resource Report NPS/NCBN/NRR—2015/1078. National Park Service, Fort Collins, Colorado.

Mahan, H. 2015. Fulfilling the promise of "Parks to People" in a changing environment: the Gateway National Recreation Area Experience. *The George Wright Forum* 32(1):51-58.

Ner, S. E., R. L. Burke. February 2005. Preliminary assessment of diamondback terrapins (*Malaclemys terrapin*) nesting ecology at Sandy Hook, NJ, Gateway National Recreation Area: July – September 2002. Technical Report NPS/NER/NRTR—2005/014. National Park Service. Boston, Massachusetts.

New York City Audubon. Floyd Bennett Field and Dead Horse Bay. Available at: http://www.nycaudubon.org/brooklyn-birding/floyd-bennett-field-and-dead-horse-bay (accessed 17 September 2018).

New York City Department of Health. April 2017. New York City Region Fish Advisories. Available at: https://www.health.ny.gov/environmental/outdoors/fish/health_advisories/regional/new_york_city.htm (accessed 17 September 2018).

New York City Department of Planning 2013. New York City Population Projections by Age/Sex & Borough 2010-2040. Available at: https://www1.nyc.gov/site/planning/data-maps/nyc-population/current-future-populations.page (accessed 17 September 2018).

New York Natural Heritage Program. 2015. NYNHP Conservation Guide. Available at: http://www.acris.nynhp.org/communities.php (accessed 17 September 2018).

Nicosia, E. L. 2013. Monitoring salt marsh vegetation and nekton at Gateway National Recreation Area's Sandy Hook Unit: 2012 summary report. Natural Resource Data Series NPS/NCBN/NRDS—2013/458. National Park Service, Fort Collins, Colorado.

NOAA 2012. pH. NOAA Ocean Service Education. Available at: https://oceanservice.noaa.gov/education/kits/estuaries/media/supp_estuar10f_ph.html (accessed 17 September 2018).

Nordstrom, K. F., and N. L. Jackson. 2016. Facilitating migration of coastal landforms and habitats by removing shore protection structures: An adaptation strategy for Northeast Region units of the National Park Service. Natural Resource Report NPS/NER/NRR—2016/1240. National Park Service, Fort Collins, Colorado.

NPCA 2016a. National Parks Conservation Association. Gateway National Recreation Area Available at: https://www.npca.org/parks/gateway-national-recreation-area (accessed 17 September 2018).

NPS 2016b. Designations of National Park System Units. Available at: https://www.nps.gov/goga/planyourvisit/designations.htm (accessed 17 September 2018).

NPS 2016c. History and Culture. Available at: https://www.nps.gov/gate/learn/historyculture/index.htm (accessed 17 September 2018).

NPS 2016d. Laws and Policies. Available at: http://www.nps.gov/gate/learn/management/lawsandpolicies.htm (accessed 17 September 2018).

NPS 2016e. GATE Visitation Statistics Viewer. Available at: https://irma.nps.gov/Stats/SSRSReports/Park%20Specific%20Reports/Park%20YTD%20Version%201?Park=GATE (accessed 17 September 2018).

NPS 2016f. Inventory and Monitoring at Gateway National Recreation Area. Available at: https://www.nps.gov/im/ncbn/gate.htm (accessed 17 September 2018).

NPS 2016g. Reference Manual Chapter 4: Planning. RM #47. Available at: https://www.nps.gov/subjects/sound/rm47-part-4-planning.htm.

NPS 2015. NPS comments on the visibility study conducted for a hypothetical wind energy project on the outer continental shelf, offshore New York. Available at: https://www.boem.gov/National-Park-Service-Comments-on-Visibility-Study-NY/ (accessed 17 September 2018).

NPS 2015a. Grassland bird survey. Gateway National Recreation Area Division of Natural Resource Management.

NPS 2015b. The starting gate: Where the journey begins (web). Available at: https://www.nps.gov/gate/learn/management/the-starting-gate-where-the-journey-begins.htm (accessed 17 September 2018).

NPS 2015c. Places (web). Available at: https://www.nps.gov/gate/learn/historyculture/places.htm (accessed 17 September 2018).

NPS 2014a. Great Kills Park Environmental Cleanup Project. Available at: https://www.nps.gov/gate/learn/management/greatkillscleanup.htm (accessed 17 September 2018).

NPS 2014b. 2014 resource report- invasive plant removal. Gateway National Recreation Area, Division of Natural Resource Management.

NPS 2014c. A new vision for a great urban National Park: Gateway National Recreation Area final general management plan environmental impact statement. Gateway National Recreation Area. Available at: https://parkplanning.nps.gov/document.cfm?parkID=237&projectID=16091&documentID=59051. (accessed 17 September 2018).

NPS 2014d. Visitation Historic and Top 10 Sites. Available at: https://www.sciencedirect.com/science/article/pii/S2352485516301001 (accessed 17 September 2018).

NPS 2014e. Shifting sands of Sandy Hook. Available at: http://njseagrant.org/wp-content/uploads/2014/03/nature_shifting_sands.pdf (accessed 17 September 2018).

NPS 2013a. 2013 Resource report - invasive plant removal. Jamaica Bay Institute Gateway National Recreation Area.

NPS 2013b. Shorelines of GATE. Available at: https://www.nps.gov/gate/learn/management/upload/Shoreline_Map_03_28_2013.pdf (accessed 17 September 2018).

NPS 2013c. Soil Survey of Gateway National Recreation Area, New York and New Jersey. Available at: http://www.soilandwater.nyc/uploads/7/7/6/5/7765286/gateway_soil_survey_report.pdf (accessed 17 September 2018).

NPS 2012a. Gateway begins phragmites mowing program in high risk brushfire areas on Staten Island. Available at: https://www.nps.gov/gate/learn/news/mow-phrag.htm (accessed 17 September 2018).

NPS 2012b. Horseshoe Crabs at Gateway (Video). Available at: https://www.nps.gov/media/video/view.htm?id=2AF2D9AA-155D-451F-67BA6BE2BC4B6CF4 (accessed 17 September 2018).

NPS 2012c. Growth of Light Pollution. Available at: https://www.nps.gov/subjects/nightskies/growth.htm (accessed 17 September 2018).

NPS 2009. Gateway National Recreation Area: Long-term resource management under a changing climate. Available at https://www.nps.gov/gate/learn/news/upload/climatechangeoptimized.pdf (accessed 19 September 2018).

NPS 2008a. Cultural Landscape Report for the Battery Weed Headland. Olmsted Center for Landscape Preservation. Boston, Massachusetts, 2008.

NPS 2008b. Research opportunities in the natural and social sciences at the Jamaica Bay unit of Gateway National Recreation Area. Jamaica Bay Institute. Available at: https://www.nps.gov/gate/learn/nature/upload/JBAY-Research%20Opportunities.pdf (accessed 19 September 2018).

NPS 2007. Sandy Hook: Environmental Assessment of Proposed Updated of the 1992 Management Plan for the Threatened Piping Plover on Sandy Hook Unit Gateway National Recreation Area New York-New Jersey. Prepared for the National Park Service by Terwilliger Consulting, Inc. Locustville, VA. Pp. 121.

NPS 2005. Jamaica Bay Institute Natural Resources. Available at: https://www.nature.nps.gov/jbi/NSD.htm (accessed 17 September 2018).

NPS 1992. Water quality survey report. Division of natural resources and compliance.

NPS 1978. Assessment of long range alternatives for the reestablishment and maintenance of the South Beach Area, Sandy Hook Unit.

NPS 1976. Gateway National Recreation Area Statement for management and environmental assessment.

NPS ARD 2017. Effects of air toxics/mercury on ecosystems. Available at: https://www.nps.gov/subjects/air/nature-toxics.htm (accessed 17 September 2018).

NPS ARD. 2016. Air Quality Conditions and Trends by Park: GATE. Available at: https://www.nature.nps.gov/air/data/products/ (accessed 17 September 2018).

NPS ARD 2015. Draft National Park Service Air quality analysis methods: September 2015. Natural Resource Report NPS/NRSS/ARD/NRR-2015/XXX. National Park Service, Denver, Colorado.

NPS ARD. 2013. Air quality in national parks: Trends (2000-2009) and conditions (2005-2009). Natural Resource Report NPS/NRSS/ARD/NRR-2013/683. National Park Service, Denver, Colorado.

NPS ARD 2011. Rating air quality conditions. National Park Service, Denver, Colorado. https://nature.nps.gov/air/Planning/docs/20111122_Rating-AQ-Conditions.pdf

NPS ARD. 2010. Air quality in national parks: 2009 annual performance and progress report. Natural Resource Report NPS/NRPC/ARD/NRR—2010/266. National Park Service, Denver, Colorado.

NPS ARD 2004. Northeast Coastal and Barrier Island Network: Assessing the risk of foliar injury from ozone on the vegetation in parks in the Northeast Coastal and Barrier Island Network. http://www.nature.nps.gov/air/pubs/pdf/03Risk/ncbnO3RiskOct04.pdf

NYCDEP 2016. Air pollution. Available at: http://www.nyc.gov/html/dep/html/air/index.shtml (accessed 17 September 2018).

NYCDEP 2013. A stronger, more resilient New York. Available at: https://www1.nyc.gov/site/sirr/report/report.page (accessed 17 September 2018).

NYCDEP 2012. The State of the harbor 2012. Available at: http://www.nyc.gov/html/dep/pdf/hwqs2012.pdf (accessed 17 September 2018).

NYCDEP 2007. Draft Jamaica Bay Watershed Protection Plan. New York City Department of Environmental Protection. New York, NY.

NYHP 2016a. Jamaica Bay Wildlife Refuge. Available at: https://nyharborparks.org/visit-parks/ (accessed 17 September 2018).

NYHP 2016b. Gateway National Recreation Area. Available at: https://nyharborparks.org/visit-parks/#Gateway-sites (accessed 17 September 2018).

NYHP 2016c. Sandy Hook. Available at: https://nyharborparks.org/visit-parks/#Gateway-sites (accessed 17 September 2018).

NYHP 2016d. Fort Hancock. Available at: https://nyharborparks.org/visit-parks/#Gateway-sites (accessed 17 September 2018).

NY/NJ Harbor Estuary Program 2010. Narrative description of historical dissolved oxygen improvements in NY/NJ harbor related to previous nutrient reduction activities. Prepared by HydroQual Inc. Mahwah, New Jersey. Available at: http://www.harborestuary.org/reports/nutrient/HydroQual-DOImprovements0910.pdf (accessed 17 September 2018).

NYS DEC. 2017a. Jamaica Bay/Rockaway Inlet Watershed. Available at: http://www.dec.ny.gov/docs/water_pdf/wiatllisjbri.pdf (accessed 17 September 2018).

NYS DEC 2017b. Ocean Action Plan 2017-2027. Available at: http://www.dec.ny.gov/docs/fish_marine_pdf/nyoceanactionplan.pdf (accessed 17 September 2018).

NYS DEC 2017c. Spring Creek South Storm Resilience and Ecosystem Restoration Project. http://www.dec.ny.gov/about/104426.html (accessed 17 September 2018).

NYS DEC 2016. New York Codes, Rules, and Regulations. Available at: https://govt.westlaw.com/SiteList (accessed 17 September 2018).

NYS DEC 2014. Nitrogen pollution and adverse impacts on resilent tidal marshes. NYS DEC technical briefing summary. Available at: http://www.dec.ny.gov/docs/water_pdf/impairmarshland.pdf (accessed 17 September 2018).

NYS Department of Health. 2016. Fish: Health advice on eating fish you catch. Available at: https://www.health.ny.gov/environmental/outdoors/fish/health_advisories/ (accessed 17 September 2018).

O'Neil, J. M., D. Taillie, B. Walsh, W. Dennison, E. K. Bone, D. J. Reid, R. Newton, D. L. Strayer, K. Boicourt, L. B. Birney, S. Janis, P. Malinowski, M. Fisher. 2016. New York Harbor: Resilience in the face of four centuries of development. *Regional Studies in Marine Science* 8(2): 274-286.

Porter, E., and S. Johnson. 2007. Translating science into policy: Using ecosystem thresholds to protect resources in Rocky Mountain National Park. *Environmental Pollution* 149:268-280.

Porter, E., and K. Morris. 2007. Wet deposition monitoring protocol: Monitoring atmospheric pollutants in wet deposition. Natural Resource Technical Report NPS/NRPC/ARD/NRTR—2007/004. National Park Service, Fort Collins, Colorado.

Pover, T., and C. Davis. 2015. Piping plover nesting results in New Jersey: 2015. Avaialble at https://www.state.nj.us/dep/fgw/ensp/pdf/plover15.pdf (accessed 17 September 2018).

Pruss, A. 1998. Review of epidemiological studies on health effects from exposure to recreational water. *International Journal of Epidemiology* 27(1):1-9.

Psuty, N. P., W. Schmelz, J. Greenberg, and A. Spahn. 2017. Development of the geomorphological map for Gateway National Recreation Area (post-Hurricane Sandy): (1) Principal characteristics and components and (2) metrics of change. Natural Resource Report NPS/NRSS/GRD/NRR—2017/1416. National Park Service, Fort Collins, Colorado.

Psuty, N. P., W. Schmelz, A. Spahn, D. Riddell, K. Ames, and K. Nicholas. 2016. Northeast Coastal and Barrier Network shoreline position (1D) and coastal topographic (2D) change monitoring: 2013-2014 annual summary report for Gateway National Recreation Area. Natural Resource Data Series NPS/NCBN/NRDS—2016/1000. National Park Service, Fort Collins, Colorado.

Psuty, N. P., J. Schmelz, M. Towle, and A. Spahn. 2016. Shoreline change monitoring at Gateway National Recreation Area: 2007-2012 trend report. Natural Resource Data Series NPS/NCBN/NRDS—2016/1030. National Park Service, Fort Collins, Colorado.

Psuty, N. P., T. M Silveira, A. Spahn, and D. Skidds. 2012. Northeast Coastal and Barrier Network geomorphological monitoring protocol: Part II – coastal topography. Natural Resource Report NPS/NCBN/NRR —2012/591. National Park Service, Fort Collins, Colorado.

Psuty, N. P., P. Dennehy, T. Silveira, and N. Apostolou. 2010. Coastal geomorphology of the ocean shoreline, Gateway National Recreation Area: natural evolution and cultural modifications, a synthesis. Natural Resource Report NPS/NER/NRR—2010/184. Fort Collins, Colorado.

Renfro, A., J. K. Cochran, D. J. Hirschberg, and S. L. Goodbred. 2010. Natural radionuclides (234Th, 7Be and 210Pb) as indicators of sediment dynamics in Jamaica Bay, New York. Natural Resource Technical Report NPS/NERO/NRTR—2010/324. Fort Collins, Colorado.

Rich, C., and T. Longcore. (eds). 2006. Ecological consequences of artificial night lighting. Island Press. Washington, D.C.

Rosenzweig, C., and W. Solecki. 2015: New York City panel on climate change 2015 report: Introduction. *Annals of the New York Academy of Sciences* 1336:3-5, doi:10.1111/nyas.12625.

RPA 2012. Regional Plan Association. Turning trash into nature on Jamaica Bay. October 16 2012.

Sanderson, E.W., W. D. Solecki, J. R. Waldman, and A. S. Parris. 2016. Prospects for resilience: Insights from New York City's Jamaica Bay. Island Press, Washington.

Sikora, E., and A. H. Chapelka. 2004. Air Pollution damage to plants. ANR-913. The Alabama Cooperative Extension System.

Stalter, R., and J. McArthur-Heuser. 2015. Survival and growth of *Ilex opaca* following Superstorm Sandy, Sandy Hook, New Jersey.

Stalter, R., and J. McArthur-Heuser. 2004. Twenty-five years of stability in an *Ilex opaca* Maritime Forest, Sandy Hook, New Jersey. *Holly Society Journal* 22(2):3-13

Steen, D. A., and J. P. Gibbs. 2004. Effects of roads on the structure of freshwater turtle populations. *Conservation Biology* 18:1143-1148.

Stoffer, P., and P. Messina. 1996. Introduction to the geologic history of the New York Bight. Available at: http://www.geo.hunter.cuny.edu/bight/highland.html (accessed 17 September 2018).

Sullivan, T. J., G. T. McPherson, T. C. McDonnell, S.D. Mackey, and D. Moore. 2011a. Evaluation of the sensitivity of inventory and monitoring national parks to acidification effects from atmospheric sulfur and nitrogen deposition: Northeast Coastal and Barrier Network (NCBN). Natural Resource Report NPS/NRPC/ARD/NRR--2011/364. National Park Service, Denver, Colorado.

Sullivan, T. J., G. T. McPherson, T. C. McDonnell, S. D. Mackey, and D. Moore. 2011b. Evaluation of the sensitivity of inventory and monitoring national parks to acidification effects from atmospheric sulfur and nitrogen deposition: main report. Natural Resource Report NPS/NRPC/ARD/NRR--2011/349. National Park Service, Denver, Colorado.

Thomas, J. E., P. S. Bell, J. P. Campbell, S. D. Costanzo, W. C. Dennison, L. Donaldson, M. Lehman, R. Loncosky, and M. Nortrup. 2013. Catoctin Mountain Park natural resource condition assessment: National Capital Region. Natural Resource Report NPS/CATO/NRR—2013/745. National Park Service, Fort Collins, Colorado.

Thornberry-Ehrlich, T. L. 2011. Geologic resources inventory and scoping summary Gateway National Recreation Area. October 19, 2011.

US Army Corp of Engineers, 2016. FACT SHEET- Jamaica Bay marsh islands. Beneficial Use of Dredged Material. Available at: http://www.nan.usace.army.mil/Media/Fact-Sheets/Fact-Sheet-Article-View/Article/487604/fact-sheet-jamaica-bay-marsh-islands/ (accessed 17 September 2018).

U.S. Census Bureau 2016. State and County QuickFacts. Accessed 13 October 2016. https://www.census.gov/quickfacts/fact/table/US/PST045217

U.S. Department of Agriculture, National Resources Conservation Service (USDA NRCS) 2001. Soil Survey of Gateway National Recreation Area, New York and New Jersey. U.S. Department of Agriculture, National Resources Conservation Service and U.S. Department of the Interior, National Park Service, Gateway National Recreation Area in partnership with Cornell University Agricultural Experiment Station and New York City Soil and Water Conservation District.

U.S. EPA 2016a. Criteria air pollutants. Available at: https://www.epa.gov/criteria-air-pollutants (accessed 17 September 2018).

U.S. EPA 2016b. National listing of fish advisories. Available at: https://fishadvisoryonline.epa.gov/ (accessed 17 September 2018).

U.S. Climate Data 2017. Monthly precipitation for New York, New York. Available at: https://www.usclimatedata.com/climate/new-york/united-states/3202 (accessed 17 September 2018).

U.S. Fish and Wildlife Service. 2015. National Wildlife Refuge System: Permit applications, PSD Overview. Available at: https://www.fws.gov/refuges/airquality/permits.html (accessed 17 September 2018).

U.S. Fish and Wildlife Service. 1997. Significant habitats and habitat complexes of the New York Bight Watershed. Southern New England - New York Bight Coastal Ecosystems Program. Available at: https://nctc.fws.gov/pubs5/web_link/text/toc.htm (accessed 17 September 2018).

U.S. Geological Survey. 2015a. Geology of the National Parks, 3D and photographic tours. Available at: https://3dparks.wr.usgs.gov/nyc/common/contents.htm (accessed 17 September 2018).

U.S. Geological Survey. 2015b. Last modified February 20, 2015. “Predicted surface water methylmercury concentrations in National Park Service Inventory and Monitoring Program Parks”. U.S. Geological Survey. Wisconsin Water Science Center, Middleton, WI. Accessed June 30, 2016. Available at: https://wi.water.usgs.gov/mercury/NPSHgMap.html (accessed 17 September 2018).

U.S. Geological Survey. 2013. Dissolved oxygen, from USGS Water Science for Schools: All about water.

Waldman, J. 2008. Research opportunities in the natural and social sciences at the Jamaica Bay Unit of Gateway National Recreation Area. Prepared for the National Park Service and Jamaica Bay Institute. April, 2008.

Wallace, R. B., H. Baumann, J. S. Grear, R. C. Aller, C. J. Gobler. 2014. Coastal ocean acidification: The other eutrophication problem. *Estuarine, Coastal, and Shelf Science* 148:1-13.

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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