Shoreline changes in Jamaica Bay, Gateway National Recreation Area, 1924–2006: Implications for shoreline restoration

By Rebecca Boger, Joseph Essrog, and Mark Christiano

Figure 1. East Pond, Jamaica Bay National Wildlife Refuge.

Abstract

Using aerial photos taken in 1924 and 2006, an analysis of shoreline changes over the past 82 years was conducted within Jamaica Bay, an urban estuary associated with Gateway National Recreation Area, located in the New York City metropolitan area. We applied a 15-category land cover/land use classification scheme of the shoreline. The analysis provides a long-term perspective of how the shoreline has changed in this highly urbanized locality before and after Gateway became a national recreation area in 1972. Gateway has been successful in minimizing changes to the shoreline when compared with nonpark areas. Further, park managers can use this shoreline inventory to identify sections of shoreline that may be appropriate for restoration by allowing former protective structures to deteriorate or by removing them, thereby enhancing the ability of shoreline habitats to migrate landward with sea-level rise.

Key words

land cover/land use changes, national park–college partnerships, shoreline, urban estuary

GATEWAY NATIONAL RECREATION AREA (GATEWAY) is one of the few national park areas in the United States that is located in a highly urbanized area and accessible to a large population by public transportation. The Jamaica Bay estuary, located within Gateway, has a long history of development pressure, with 43% of the 103 miles (165 km) of shoreline occupied by a variety of structures (e.g., bulkheads [seawalls] and riprap; Boger et al. 2012). Despite this intensive development, the bay supports diverse coastal habitats and large numbers of migratory species (fig. 1, above, and fig. 2, next page).

The bay's islands and fringing salt marshes are rapidly declining and are converting to mudflat and open water. Numerous factors associated with the urban environment are thought to be contributing to the salt-marsh loss, including nutrient enrichment, dredging, sediment depletion, increased tidal ranges, and sea-level rise, among others (Benotti et al. 2007; Hartig et al. 2002; Swanson and Wilson 2008; Wigand et al., *in press*). Shoreline development likely contributes to marsh loss in Jamaica Bay because the landward migration of marshes, a natural response to sea-level rise, is halted by shoreline structures (e.g., Donnelly and Bertness 2001).

Figure 2. Jamaica Bay is the largest of three units comprising Gateway National Recreation Area. The study involved analyzing changes in land use/land cover along the shoreline of Jamaica Bay, both within and outside the national recreation area.

Gateway has identified a more natural shoreline as a goal in the draft General Management Plan/Environmental Impact Statement (GMP/EIS) in order to "maximize ecosystem functions such as habitat for wildlife, connectivity between the bay and upland habitats, and natural processes such as sediment transport and shoreline migration" (NPS 2013, chapter 2, p. 60). Given the extensive development, Gateway proposes the removal of selected hard structures and restoration of natural shoreline features.

Monitoring the status and trends of resources is critical to achieving the goal of creating a more natural shoreline in a highly modified estuary. Of particular interest for this study is the type of land use/land cover (LULC) along the shoreline, the interface between aquatic and terrestrial habitats. Given the extensive modification of natural environments since European colonization of the area in the 1600s, Gateway inherited a legacy of infrastructure and other land use changes that compound the problems park managers face today from environmental pressures such as pollution, sediment depletion, and invasive species. Boger et al. (2012) documented LULC along the shoreline in Jamaica Bay in 2006 and compared it with periods before and after the creation of Gateway in 1972. The classification techniques they developed are being used to help assess the extent of human impacts on the shoreline and ultimately to assist in planning for mitigation projects. The purpose of this article is to expand the historical analysis of the shoreline to 1924 in order to give park managers a longer-term perspective of shoreline changes to assist in the identification and prioritization of suitable sites for restoration and rehabilitation of natural shoreline features.

Methods

Shoreline position and LULC classification based on the 1924 aerial photos followed procedures described by Boger et al. (2012) for their analysis of the 1951, 1974, and 2006 imagery. The 1924 photos were acquired through the New York Bureau of Engineering and are available at the New York Public Library (http://digitalgallery.nypl.org/nypldigital/dgkeysearchresult.cfm?parent_id=855142). Using a geographic information system (GIS), we georeferenced the 1924 photos with the rectified 2006 aerial photo data set and a data set of buildings created by the New York City Department of Information Technology and Telecommunications (DOITT). The building data set has a horizontal spatial accuracy of ±2 feet (0.6 m). In addition to the 2006 aerial photos for the Boger et al. (2012) analysis, we used 2008 U.S. Geological Survey orthoimagery available at seamless.usgs.gov. Despite the great number of modifications that have been made to the shoreline since the 1924 photos, we were able to locate several common points among the 2006, 2008, and building data for use in georeferencing the 1924 photos. When georeferencing, we were not satisfied with fewer than 10 data points and worked toward identifying 20 or more in order to seek the least RMS (root-mean-square) error possible.

Once we had rectified the 1924 base imagery, we drew the shoreline and classified its segments as one of 16 possible categories (table 1, next page). We modified the Boger et al. (2012) classification scheme to include an agricultural category, an LULC classification that did not exist in the 1951, 1974, and 2006 imagery, but was present in 1924. At that time agriculture was scattered at various locations around what is now the urban New York City metropolitan area, with the entire agricultural shoreline length less than 1.2 miles (2 km). Although agriculture is an example of human modification, we included it as a natural vegetation class when comparing changes over the years.

After completing the shoreline analysis, we exported the data from GIS software to a spreadsheet program for summarization and to create charts. We then examined the LULC for the entire Jamaica Bay shoreline and for changes that have occurred (1) within the national recreation area boundary, (2) within the bay only (i.e., without the creeks), and (3) along the many creeks that feed into the bay.

Results and discussion

In 1924 a large portion (29.72%) of the Jamaica Bay shoreline had already been developed (table 2, page 73). Then, as a result of further development between 1924 and 2006, there was a large loss of vegetated shoreline while both sandy shoreline (excluding creeks) and developed shoreline made gains (fig. 3, page 73). Overall, undeveloped shoreline (sand and vegetation combined) decreased from 1924 to 2006 by approximately 13% for the entire study area. It is important to keep in mind, though, that we mapped only the shoreline and that intense development often occurs immediately landward of the undeveloped shore, as can be seen in the 1924 and 2006 aerial photos. Within Gateway, the decrease in undeveloped shoreline is only 10%, with 70% of that change taking place from 1924 to 1951. Creeks lost more than 16% of both sand and vegetated (undeveloped) shoreline, reflecting the rapid development of the upland areas surrounding the bay that began in the late 1920s. Jamaica Bay, meanwhile, experienced a 14% rise in bulkhead construction since 1924.

The photomosaics shown in figs. 4A and 4B on page 74 present the georeferenced aerial photos taken in 1924 and 2006, respectively, and serve as examples of the final products for all years examined in this study. From 1924 to 1951, sand beaches increased in extent while vegetated shoreline decreased. This was followed

Collaboration

The Department of Earth and Environmental Sciences at Brooklyn College of the City University of New York (CUNY) works closely with Gateway staff on a variety of research and education projects. The Department of Earth and Environmental Sciences is revising many of its programs and encourages activities that involve students working with local organizations on place-based projects that have meaningful applications. Education research reveals that exposure to science research that is collaborative, place-based, and of local relevance encourages students to pursue science, technology, engineering, and mathematics (STEM) careers, particularly for under-represented groups, which comprise a large percentage of the student body at Brooklyn College (Connell et al. 1995; Lemke 2001; Roth and Tobin 2007; Rumberger 2004). By working on internships, course term projects, or individual research involving local organizations, students recognize the usefulness of their skill development (Edelson et al. 2006) and become motivated by being exposed to career opportunities. This in turn improves student recruitment and retention (Miele and Powell 2010). The National Park Service is also interested in attracting qualified science students to pursue careers in resource stewardship and fosters collaboration with educational institutions that develop students with STEM skills. Thus project collaborations such as that described here are a win-win situation in which both collaborators are able to fulfill their respective goals and objectives.

Table 1. Classification scheme for land use/land cover analysis of Jamaica Bay shoreline, 1924

Classification	Human Modified or Undeveloped	General Class	Description
Residence	Human Modified	Structure	One or a series of residential structures directly on the shoreline
Commercial	Human Modified	Structure	One or a series of commercial buildings or lots directly on the shoreline
Parking Lot	Human Modified	Structure	Stand-alone parking lot directly on the shoreline
Bridge	Human Modified	Structure	Base of a bridge that extends out over water
Dock	Human Modified	Structure	Dock or boardwalk built directly on the shoreline
Pier	Human Modified	Structure	Base of a pier that extends out over water
Road	Human Modified	Road	Paved or unpaved road built along the shoreline
Beach Developed	Human Modified	Structure	Bare sand beach within 50 meters (164 ft) of development
Steel Concrete Bulkhead Vegetation*	Human Modified	Bulkhead	Steel or concrete bulkhead or riprap in front of vegetated area
Steel Concrete Bulkhead Developed	Human Modified	Bulkhead	Steel or concrete bulkhead or riprap in front of developed site
Rock Bulkhead Vegetation	Human Modified	Bulkhead	Rock bulkhead in front of vegetation
Rock Bulkhead Developed	Human Modified	Bulkhead	Rock bulkhead in front of developed area
Other	Human Modified	Structure	Other human modification
Undeveloped Sand	Undeveloped	Sand	Bare sand beach in front of vegetation
Undeveloped Vegetation	Undeveloped	Vegetation	Vegetation growing directly on the shoreline
Agriculture	Human Modified	Vegetation	Vegetation grown for food production

* Bulkheads are also called seawalls, a form of coastal defense.

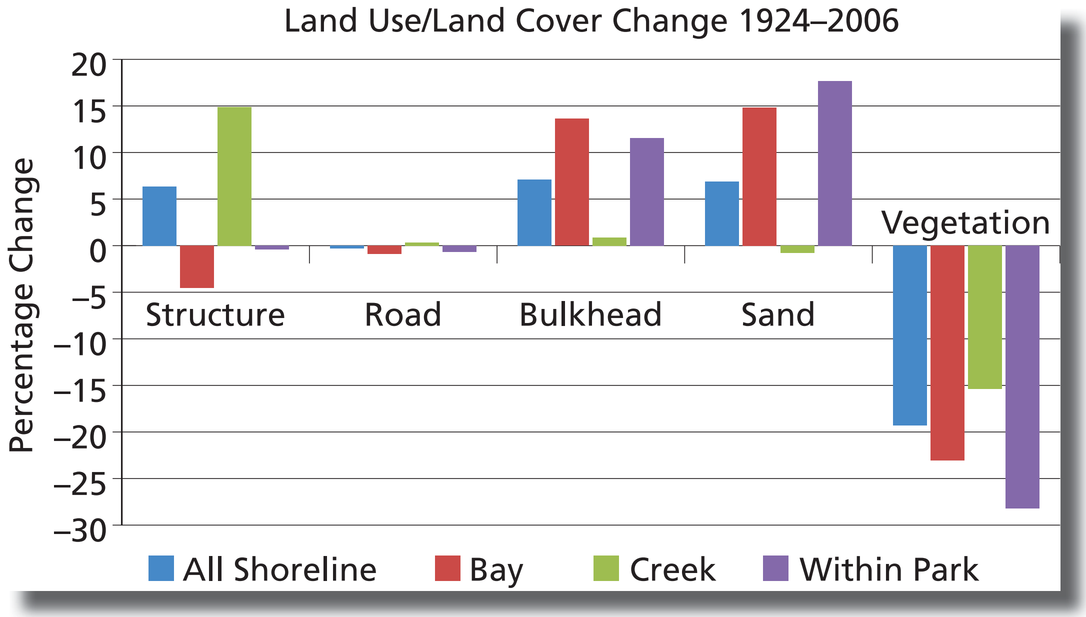

Figure 3. Land use/land cover change 1924–2006.

Table 2. Percentages of LULC for 1924 and 2006

Classification	1924 All Shoreline (%)	1924 Within Park (%)	2006 All Shoreline (%)	2006 Within Park (%)
Human Modified*	29.72	19.91	42.87	30.42
Residence	10.18	8.30	10.14	8.98
Commercial	2.84	1.64	12.02	2.11
Bridge	0.38	0.38	0.48	0.31
Dock	0.56	0.25	0.34	0.12
Pier	0.23	0.10	0.23	0.40
Paved Road	3.14	0.65	2.86	0.00
Beach Developed	3.84	4.45	1.05	2.71
Steel or Concrete Bulkhead (Vegetation)	3.36	2.37	0.78	1.33
Steel or Concrete Bulkhead (Developed)	1.55	0.65	4.00	5.70
Rock Bulkhead (Vegetation)	1.74	0.25	1.07	1.93
Rock Bulkhead (Developed)	1.08	0.34	8.97	6.21
Other	0.85	0.53	0.34	0.00
*Human Modified (reclassified)				
Structure	18.85	15.65	25.19	15.24
Road	3.14	0.65	2.86	0.00
Bulkhead	7.73	3.61	14.82	15.18
Subtotal	29.72	19.91	42.87	30.42
Undeveloped				
Sand	8.79	15.98	15.67	33.67
Vegetation	60.75	64.11	41.47	35.91
Agriculture	0.74	0.00		
Subtotal	70.28	80.09	57.14	69.58
Total	100.00	100.00	100.01	100.00

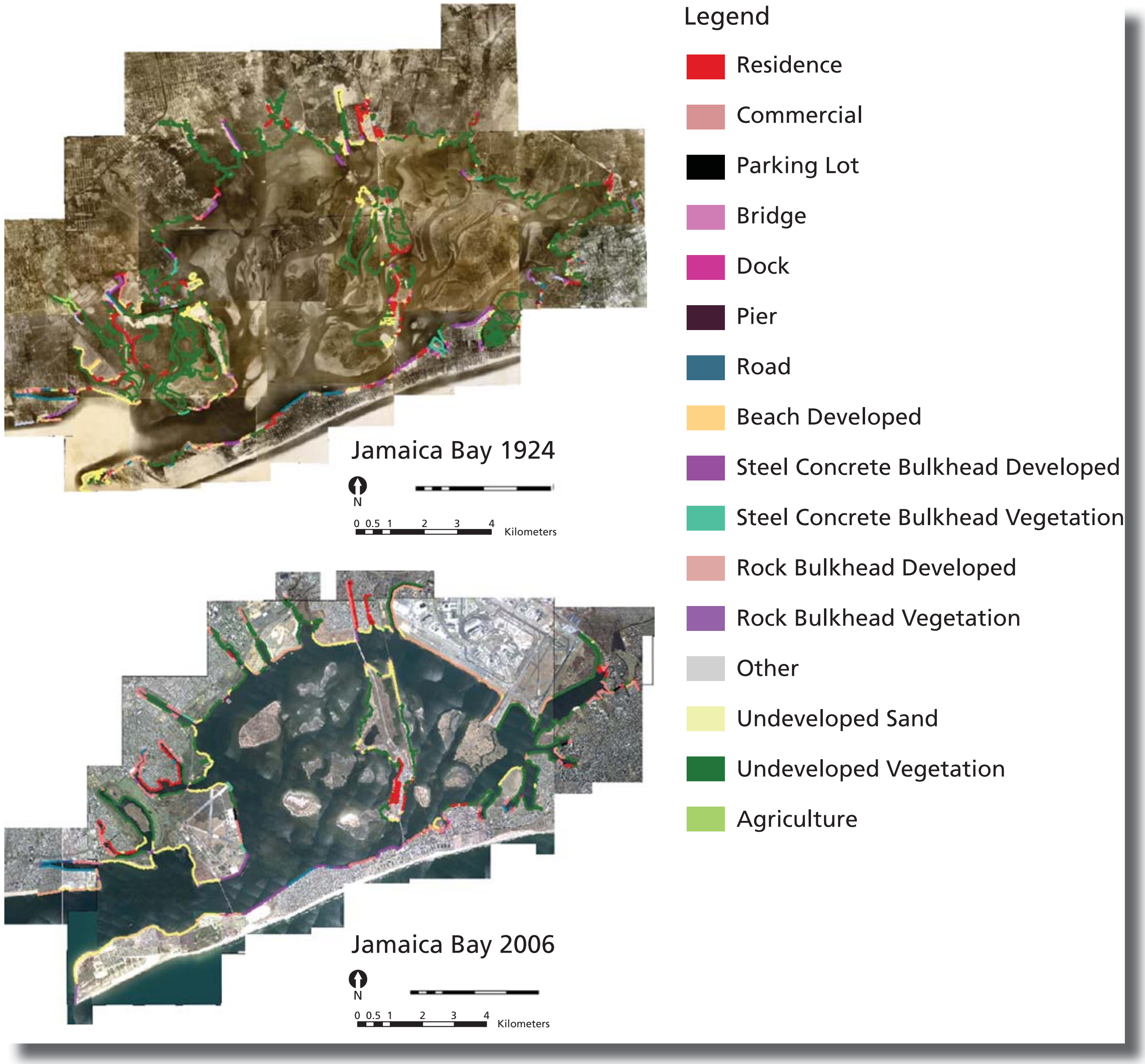

Figure 4A (top) and 4B (bottom). Aerial photomosaics of the Jamaica Bay shoreline in 1924 (A, top) and 2006 (B, bottom).

by the opposite effect, an increase in vegetation and a decrease in sand beaches, from 1951 to 1974. Finally, vegetated shoreline decreased and sandy shore (except in creeks) increased from 1974 to 2006. Major construction projects, such as the building of two airports, have changed the appearance of Jamaica Bay considerably since 1924; however, despite construction of John F. Kennedy International Airport and a number of landfills rimming the bay, relatively little change has occurred in the proportion of human-made features other than bulkheads over the period 1924–2006.

The next phase of the research will delineate historical land use/land cover change along the shoreline of Staten Island, starting with recent aerial photography and then working backward in time as we did with the Jamaica Bay analysis. Additionally, we will develop protocols applicable to more detailed analysis of the changes occurring on the vegetated shorelines. Instead of classifying all natural vegetation as one group, we will differentiate the fringing marshes from other forms of vegetated shorelines. The conversion of sandy beaches to vegetated areas may indicate loss of fringing marshes. A time perspective of fringing marshes along the shoreline can assist in the identification of historical marsh extent and rates of marsh loss. With the expectation of future extreme events like Hurricane Sandy, vegetation may make the shoreline and areas farther landward more resilient by lessening erosion, habitat loss, and damage to human-built structures. As noted by Nordstrom and Jackson (2013), an assessment of the condition of shoreline structures would identify which structures should be left as is, removed, or allowed to deteriorate naturally. As sea level rises, landforms migrate inland, although the urbanized area surrounding Jamaica Bay limits this natural process. Armed with a historical shoreline analysis and a structural assessment, park managers will be better informed to reach their goal of maximizing ecosystem functions (NPS 2013).

References

Benotti, M. J., M. Abbene, and S. A. Terracciano. 2007. Nitrogen loading in Jamaica Bay, Long Island, New York: Predevelopment to 2005. Scientific Investigations Report 2007–5051. U.S. Geological Survey, Reston, Virginia, USA. Available online only from http://pubs.usgs.gov/sir/2007/5051/SIR2007-5051.pdf.

Boger, R., J. Connolly, and M. Christiano. 2012. Estuarine shoreline changes in Jamaica Bay, New York City: Implications for management of an urban national park. Environmental Management 49:229–241.

Connell, J. P., B. L. Helpem-Felsher, E. Clifford, W. Crichlow, and P. Usinger. 1995. Hanging in there: Behavioral, psychological, and contextual factors affecting whether African American adolescents stay in high school. Journal of Adolescent Research 10:41–63.

Donnelly, J. P., and M. D. Bertness. 2001. Rapid shoreward encroachment of salt marsh cordgrass in response to accelerated sea-level rise. Proceedings of the National Academy of Sciences 98(25):14218–14223.

Edelson, D. C., A. Tarnoff, K. Schwille, M. Bruozas, and A. Switzer. 2006. Learning to make systematic decisions. The Science Teacher 73:40–45.

Hartig E. K., V. Gornitz, A. S. Kolker, F. Mushacke, and D. Fallon. 2002. Anthropogenic and climate-change impacts on salt marshes of Jamaica Bay, New York City. Wetlands 22(1):71–89.

Lemke, J. L. 2001. Articulating communities: Sociocultural perspectives on science education. Journal of Research in Science Teaching 38:296–316.

Miele, E., and W. Powell. 2010. Science and the city: Community cultural and natural resources at the core of a place-based science teacher preparation program. Journal of College Science Teaching 40:18–22.

National Park Service (NPS). 2013. New vision for a great urban national park: Gateway National Recreation Area's general management plan. National Park Service, Gateway National Recreation Area, New York, USA. Available online from http://www.nps.gov/gate/parkmgmt/planning.htm.

Nordstrom, K. F., and N. L. Jackson. 2013. Removing shore protection structures to facilitate migration of landforms and habitats on the bayside of a barrier spit. Geomorphology 199:179–191.

Roth, W.-M., and K. Tobin, editors. 2007. Science, learning, identity: Sociocultural and cultural historical perspectives. Sense Publishers, Rotterdam, the Netherlands.

Rumberger, R. 2004. Why students drop out of school. Pages 131–155 *in* G. Orfield, editor. Dropouts in America: Confronting the graduation rate crisis. Harvard Education Press, Cambridge, Massachusetts, USA.

Swanson, R. L., and R. E. Wilson. 2008. Increased tidal ranges coinciding with Jamaica Bay development contribute to marsh flooding. Journal of Coastal Research 24(6):1565–1569.

Turner R. E., B. L. Howles, J. M. Teal, C. S. Milan, E. M. Swenson, and D. D. Goehringer-Toner. 2009. Salt marshes and eutrophication: An unsustainable outcome. Limnology and Oceanography 54:1634–1642.

Wigand, C., C. T. Roman, E. Davey, M. Stolt, et al. Below the disappearing marshes of an urban estuary: Historic nitrogen trends and soil structure. Ecological Applications, *in press*.

About the authors

Rebecca Boger *(rboger@brooklyn.cuny.edu) is an assistant professor in the Department of Earth and Environmental Sciences, Brooklyn College, CUNY, in Brooklyn, New York.* ***Joseph Essrog*** *(joseph.essrog@email.com) has a BS degree from the Department of Earth and Environmental Sciences at Brooklyn College.* ***Mark Christiano*** *(mark_christiano@nps.gov) is a GIS specialist with the National Park Service, Gateway National Recreation Area, in Staten Island.*

PS