

3.4 New York City, the Lower Hudson River, and Jamaica Bay

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Species and habitats in the region encompassing New York City, the lower Hudson River, the East River, and Jamaica Bay are potentially at risk because of sea level rise. Although the region is one of the most heavily urbanized areas along the U.S. Atlantic Coast, there are nonetheless regionally significant habitats for fish, shellfish, and birds in the area, and a great deal is known about the ecology and habitat needs of these species.

Based on existing literature and the knowledge of local scientists, this brief literature review discusses those species that could be at risk because of further habitat loss resulting from sea level rise and shoreline protection (see Map 3.2). Although it is possible to make qualitative statements about the ecological implications if sea level rise causes a total loss of habitat, our ability to say what the impact might be if only a portion of the habitat is lost is more limited. A total loss of habitat might be expected if shores are protected with hard structures and the wetlands are unable to keep pace with sea level rise.

Most shorelines in the New York metropolitan area are heavily modified. Because the remaining coastal land is at a premium, planners indicate that most of the shoreline is almost certain to be protected. The remaining undeveloped land along the shore continues to be developed and armored.²⁵¹ Where protection occurs, New York City's Waterfront Revitalization Program (WRP) requires the use of nonstructural alternatives

such as beach nourishment, dune construction, and vegetation wherever possible. Planners expect that the only sizeable areas in the New York City metropolitan area that are unlikely to be protected are portions of the three Special Natural Waterfront Areas (SNWAs) designated by the city: Northwest Staten Island/Harbor Heron SNWA; East River–Long Island Sound SNWA; and Jamaica Bay SNWA.

TIDAL WETLANDS

Staten Island. Hoffman Island and Swinburne Island are National Park Service properties lying off the southeast shore of Staten Island; the former has important nest habitat for herons, and the latter is heavily nested by cormorants.²⁵² The Northwest Staten Island/Harbor Herons SNWA is an important nesting and foraging area for herons, ibises, egrets, gulls, and waterfowl.²⁵³ The so-called Harbor Herons Complex includes three island heronries of regional significance, including Shooters Island, Pralls Island, and Isle of Meadows (see subsequent section on islands). Several tidal emergent, salt, brackish, and fresh water marshes provide foraging areas for the birds of the island heronries, including Arlington

²⁵¹ George Frame, National Park Service, in email entitled Comments on NYHarbor&RaritanBay papers EPA feb07, to Karen Scott, EPA, 2/20/07, suggests that "many urban planners are not preserving undeveloped lands along the shores of the estuary; even today they are building and hardening in many areas."

²⁵² George Frame, 2/20/07 email (see note 251).

²⁵³ USFWS, 1997, p. 578 in Arthur Kill Complex, Complex #18 (see note 172).

Marsh, Sawmill Creek Marsh, Gulfport Marsh, Merrill's Marsh, Old Place Creek, Neck Creek Marsh, and Fresh Kills.²⁵⁴ With the exception of Fresh Kills, shoreline protection is considered almost certain in these areas. Loss of these marshes could have a significant negative impact on the island heronries because of a lack of alternative foraging sites nearby.

The Fresh Kills wetland system is one of the largest tidal wetland systems in the region, covering an estimated 405 ha (1,000 acres).²⁵⁵ Local planners expect that these wetlands will probably be allowed to respond naturally to sea level rise, but migration may not be possible because of the relatively steep slopes that have formed near the shore as a result of landfilling activities.

Manhattan. Most of the shoreline of Lower Manhattan and the Battery has been bulkheaded and filled. An exception is the natural shoreline and wetlands at the mouth of the Harlem River at New York City's Inwood Hill Park.²⁵⁶ The park contains low salt marsh and a broad mudflat that runs from the marsh to the channel of the Harlem River Ship Canal. Great blue herons are found along the flat in winter and snowy and great egrets are common from spring through fall.²⁵⁷

The Lower Hudson River. Although the tidal Hudson River extends upstream to the dam at Troy, New York State's tidal wetland regulations apply to the Hudson River shoreline only up to the Tappan Zee Bridge. This is the estuarine portion of the tidal river. Along this stretch of the river there is relatively little marsh, with the exception of brackish marshes at the mouth of the Croton River, in Piermont Marsh, and in a

network of marshes behind Grassy Point near Haverstraw Bay.²⁵⁸

Piermont Marsh is a 411.6 ha (1,017 acre) brackish wetland on the western shore of the lower Hudson River just below the Tappan Zee Bridge, in the town of Orangetown, in Rockland County.²⁵⁹ The New York State Department of State has designated the marsh a Significant Coastal Fish and Wildlife Habitat, and it has been designated part of the Hudson River National Estuarine Research Reserve by the National Oceanic and Atmospheric Administration and the New York State Department of Environmental Conservation (NYDEC).²⁶⁰

Piermont Marsh is dominated by common reed and narrow-leaved cattail, along with some salt marsh species that include smooth cordgrass, salt-meadow cordgrass, and spike grass, making it the location of the northernmost occurrence of salt marsh species on the Hudson. Breeding birds known to use the marsh for nesting include relatively rare species such as Virginia rail, swamp sparrow, black duck, least bittern, and sora rail. A small number of osprey sometimes gather in the marsh, particularly during spring migration. Anadromous and freshwater fish use the marsh's tidal creeks as a spawning and nursery area. Killfish, mummichog, fiddler crab, and blue crab use shallow marsh areas. Diamondback terrapin, a federal species of concern, reportedly nest in upland areas along the marsh.²⁶¹

Jamaica Bay, located between the boroughs of Brooklyn and Queens, is the largest area of protected wetlands in a major metropolitan area along the U.S. Atlantic Coast. The bay includes

²⁵⁴USFWS, 1997, p. 579 in Arthur Kill Complex, Complex #18 (see note 172).

²⁵⁵USFWS, 1997, p. 580 in Arthur Kill Complex, Complex #18 (see note 172).

²⁵⁶USFWS, 1997, p. 630 in Lower Hudson River Estuary, Complex #21 (see note 172).

²⁵⁷Fact sheet by New York City Department Of Parks and Recreation, Inwood Hill Park—Salt Marshes in New York City Parks. Accessed December 4, 2007 at: http://www.nycgovparks.org/sub_your_park/historical_signs/hs_historical_sign.php?id=12864.

²⁵⁸USFWS, 1997, p. 631 in Lower Hudson River Estuary, Complex #21 (see note 172).

²⁵⁹Fact sheet on Piermont Marsh Component of the Hudson River Reserve by the Hudson River Reserve Program, National Estuarine Research Reserve System. Accessed December 4, 2007 at: <http://nerss.noaa.gov/HudsonRiver/PiermontMarsh.html>.

²⁶⁰USFWS, 1997, pp. 629, 633 in Lower Hudson River Estuary, Complex #21 (see note 172).

²⁶¹USFWS, 1997, p. 633 in Lower Hudson River Estuary, Complex #21 (see note 172).

the Jamaica Bay Wildlife Refuge,²⁶² which has been protected since 1972 as part of the Jamaica Bay Unit of the Gateway National Recreation Area, administered by the National Park Service. The refuge includes numerous salt marsh islands that are sheltered from the Atlantic Ocean by the Rockaway Peninsula.

Despite extensive disturbance from dredging, filling, and development, Jamaica Bay remains one of the most important migratory shorebird stopover sites in the New York Bight region.²⁶³ The bay provides overwintering habitat for brant, mallards, American black duck, canvasback duck, and other waterfowl, and intertidal mudflats for foraging migrants such as black skimmer, plovers, and knots.²⁶⁴ The refuge and Breezy Point, at the tip of the Rockaway Peninsula, support populations of 214 species that are state or federally listed or of special emphasis, including 48 species of fish and 120 species of birds. These areas combined have been designated as a Significant Coastal Fish and Wildlife Habitat by the New York State Department of State and as a Critical Environmental Area by the NYDEC.²⁶⁵

Spring Creek Park²⁶⁶ is one of only two remaining areas of salt marsh in the northern tributaries of Jamaica Bay. Yellow-crowned night heron, little blue heron, and willet are

found in these marshes.²⁶⁷ The nearby Four Sparrow Marsh is the other remaining salt marsh in this part of the bay. It is a particularly noteworthy as an undisturbed nesting habitat for four native species of sparrows that are in decline, the sharp-tailed, seaside, swamp, and song sparrows, and as a stopover site for some 326 species of migrating birds. Several species of ducks, gulls, and wading birds also nest in Four Sparrow Marsh and feed on marsh mollusks and crustaceans.²⁶⁸

Because of its importance as an area of significant biodiversity and its uniqueness as a wildlife sanctuary in a highly developed urban setting, planners expect that Jamaica Bay's wetlands will be allowed to respond naturally to sea level rise. However, wetlands in some parts of the bay are currently showing substantial losses. Researchers studying the salt marsh islands near the John F. Kennedy International Airport (including Yellow Bar Hassock, Black Wall Marsh, Big Egg Marsh, East High Meadow Marsh, Elders Point Marsh, and Jo Co Marsh) estimated that marsh loss in the area averaged 12 ha (29.7 acres) per year from 1974 to 1999, even though the area is a national park.²⁶⁹ This represents an increase in marsh loss of 8 ha (19.8 acres) per year over preceding decades when the area was not yet part of the Gateway National Recreation Area. The estimated rate of loss has been increasing, averaging 18 ha (44.5 acres) per year over the period 1994 to 1999.²⁷⁰ The reasons for this accelerating trend in marsh loss aren't completely clear, though sea level rise has been implicated as one possible cause.^{271,272} However, the Jamaica Bay researchers noted that the significant marsh loss that is already occurring "implies that accretion rates in Jamaica Bay may

²⁶²Jamaica Bay Wildlife Refuge is managed by the National Park Service, as part of the Jamaica Bay Unit of the Gateway National Recreation Area. The refuge was originally created by the New York City Parks department in 1951. See "Brochure: The Jamaica Bay Wildlife Refuge", National Park Service, accessed November 27, 2006 at:

http://www.nps.gov/archive/gate/jbu/jbu_nature.htm. Many people mistakenly call the refuge "Jamaica Bay *National* Wildlife Refuge," but national wildlife refuges are managed by the US Fish and Wildlife Service, not the National Park Service.

²⁶³USFWS, 1997, p. 532 in Jamaica Bay and Breezy Point, Complex #16 (see note 172).

²⁶⁴Hartig, 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. p. 74, citing Wells (1998).

²⁶⁵USFWS, 1997, p. 532 in Jamaica Bay and Breezy Point, Complex #16 (see note 172).

²⁶⁶See fact sheet on Spring Creek Park by the New York City Department of Parks and Recreation at http://nycgovparks.org/sub_your_park/historical_signs/hs_historical_sign.php?id=11227.

²⁶⁷USFWS, 1997, p. 532 in Jamaica Bay and Breezy Point Complex #16 (see note 172).

²⁶⁸See fact sheet on the Four Sparrow Marsh Preserve by the New York City Department of Parks and Recreation, available at: http://www.nycgovparks.org/sub_about/parks_divisions/nrg/forever_wild/site.php?FWID=21.

²⁶⁹Hartig, et al., 2002 (see note 264).

²⁷⁰Hartig et al., 2002, p. 71 (see note 264).

²⁷¹Hartig et al., 2002, p. 75 (see note 264).

²⁷²George Frame, 2/20/07 email (see note 251), suggests that "the catastrophic loss of salt marshes in Jamaica Bay could be due mainly to input of nutrients and contaminants from wastewater treatment plants. Also, past dredging and subaqueous borrow pits may act as a sediment sink, starving salt marshes. Sea level rise might be less important."

be insufficient, even at present rates of sea level rise, to compensate for losses due to erosion and other factors.²⁷³

There are significant ecological implications of marsh loss in this area. Annual marsh primary production ranges from 700 to 1,500 g/m² in Jamaica Bay marshes.²⁷⁴ This primary production is essential for the larger estuarine food web, including the production of commercially and recreationally valuable fish species that use marshes as nursery areas.²⁷⁵ Kneib (2003) developed models of marsh nekton production resulting from marsh primary production in Georgia marshes and estimated that nekton production ranges from 15 to 42 kg/ha/yr, a third of which represents the production of commercial and recreational species that use the marshes as nursery areas.²⁷⁶ Thus, loss of these wetlands, even if the current rate of 18 ha/yr does not increase as sea level rise increases, would have an important impact, not just on marsh primary production but also on the production of fish and shellfish within both the marsh and the surrounding estuary. In fact, state and federal governments with holdings in the area indicate that some form of protection may be necessary to protect the significant ecological value of the bay, including applying sediment to raise the marsh surface.

Estuarine Beaches

Among the relatively few areas of beach remaining in the New York City Metropolitan Area are the beaches of the Rockaways, Coney Island, and the South Shore of Staten Island. Beach nourishment is planned or under way for all of these areas.

Jamaica Bay has been designated and mapped as a protected beach unit pursuant to the federal

²⁷³Hartig et al., 2002 p. 82 (see note 264).

²⁷⁴Hartig et al., 2002, p. 71 (see note 264).

²⁷⁵Teal, 1986 (see note 10).

²⁷⁶Kneib, R.T., 2003, "Bioenergetics and landscape considerations for scaling expectations of nekton production from intertidal marshes," *Marine Ecology Progress Series* 264:279–296. (The modeled nekton production estimates were based on an estimated annual above ground primary production of 1,250 grams dry weight per square meter derived from field data, which is within the range of the annual primary production estimated for Jamaica Bay marshes.)

Coastal Barrier Resources Act.²⁷⁷ Much of the bay's shoreline has been hardened with seawalls and bulkheads, so estuarine sandy beach habitat is now uncommon.²⁷⁸ Remaining estuarine beaches occur off Belt Parkway (e.g., Plumb Beach) and on the bay islands.²⁷⁹

Several islands in Jamaica Bay contain mountains of dredged sand (on top of salt marshes), so they now have sandy beaches. Sandy beach also exists from Breezy Point tip to Fort Tilden (at Flatbush Avenue). Floyd Bennett Field is entirely on top of former saltmarsh and estuarine beach; this artificial island now has sandy beach along more than half of its shoreline, although portions have a bulkhead farther inland.²⁸⁰

Mud snails are common throughout this habitat, up to the high tide mark. The snails graze on sea lettuce and old horseshoe crab shells. Beach wrack, consisting primarily of straw from smooth cordgrass and common reed, with small proportions of sea lettuce, contains insects, isopods, and amphipods that also provide forage for shorebirds.²⁸¹ The abundance of shorebird species is positively correlated with the abundance of beach wrack and associated invertebrates.²⁸²

Horseshoe crabs lay their eggs on the small pockets of beach in the bay, many of which are found on the bay islands. The shore of Plumb Beach is a popular horseshoe crab nesting site.²⁸³

Diamondback terrapin also nest on sandy habitats. Diamondback terrapins are the only

²⁷⁷USFWS, 1997, pp. 531–532 in Jamaica Bay and Breezy Point, Complex #16 (see note 172).

²⁷⁸Don Riepe, American Littoral Society. August 20, 2006 email to E. Strange, Stratus Consulting, entitled "Notes from phone conversation," in which he confirmed his visual observations of intertidal beaches and shoreline armoring along Jamaica Bay as discussed in an earlier phone call with E. Strange on August 11, 2006. (Mr. Riepe has served as director of the Northeast Chapter of the American Littoral Society for 25 years. He is also the organization's "Jamaica Bay Guardian," and has personally observed most of the estuarine shores in this area.)

²⁷⁹Ibid.

²⁸⁰George Frame, personal visual observations, 2/20/07 email (see note 251).

²⁸¹Don Riepe, 2006 email (see note 278).

²⁸²Dugan et al., 2003 (see note 127).

²⁸³USFWS, 1997, p. 535 in Jamaica Bay and Breezy Point, Complex #16 (see note 172).

turtles found in brackish waters. In general, nesting terrapins show a strong preference for sandy back-barrier beaches compared to the ocean-facing beaches of barrier islands.^{284,285} One reason for this may be that the back-barrier beaches are closer to the *Spartina* marshes where terrapins feed and grow.²⁸⁶ In Jamaica Bay, terrapins nest in uplands, usually above the beaches; the filled wetlands of Jamaica Bay provide most of the nest sites for terrapins in this area.²⁸⁷

Nesting and migrating shorebirds feed on the invertebrates of the beaches in the study region. Many of these species nest along the marine barrier beach at Breezy Point, including the federally threatened piping plover, the state endangered least tern, and the state threatened common tern. These species feed on the small invertebrates of estuarine and ocean beaches as well as area mudflats. Breezy Point is also a concentration area for raptors, waterfowl, and landbirds passing through the area. Migrating raptors include the federally endangered peregrine falcon and the state threatened northern harrier and osprey.²⁸⁸

Because of the importance of beach species for estuarine food webs, scientists have raised concerns about the ecological implications of the loss of estuarine beaches.²⁸⁹ In addition to the forage provided by the abundant mud snails and the small organisms of beach wrack, horseshoe crab eggs are a critical food source for migrating shorebirds.²⁹⁰ In addition, continued loss of the few remaining sandy habitats in the study region would be particularly serious for diamondback

terrapin, which only nest in these habitats. Because so few beaches remain, local planners indicate that beach nourishment in the face of sea level rise is likely for most remaining beach habitat in this area.

Tidal Flats

Relatively few tidal flats remain along the highly modified shorelines of the study region. There is only a narrow band of shallow subtidal flats along Lower Manhattan and the Battery.²⁹¹ However, tidal mudflats are increasing as salt marshes disappear.²⁹²

Large concentrations of shorebirds, herons, and waterfowl use the shallows and tidal flats of Piermont Marsh along the lower Hudson River as staging areas for both spring and fall migrations.²⁹³ Tidal flats provide substrate for algae such as sea lettuce (*Ulva lactuca*), an important food for brants.²⁹⁴

Tidal flats in Jamaica Bay are frequented by shorebirds and waterfowl, and an intensive survey of shorebirds in the mid-1980s estimated more than 230,000 birds of 31 species in a single year, mostly during the fall migration.²⁹⁵ The most abundant shorebirds feeding on Jamaica Bay's tidal flats in fall include plovers, sandpipers, ruddy turnstone, sanderling, dunlin, short-billed dowitcher, and greater yellowlegs. In addition to these species, red knot is seen during the spring migration. Area mudflats are also important for waterfowl in winter.²⁹⁶

Inundation with rising seas will eventually make flats unavailable to short-legged shorebirds,

²⁸⁴Roosenburg, W.M., 1991, "Nesting habitat of diamondback terrapin: A geographic comparison," *Wetland Journal* 6:8–11.

²⁸⁵Dr. Russell Burke, 2006 email to E. Strange (personal visual observation) (see note 226).

²⁸⁶Feinberg, and Burke, 2003, "Nesting ecology and predation of diamondback terrapins, *Malaclemys terrapin*, at Gateway National Recreation Area, New York," *Journal of Herpetology* 37:517–526, p. 520.

²⁸⁷George Frame, 2/20/07 email (personal visual observations) (see note 251).

²⁸⁸USFWS, 1997, p. 536 in Jamaica Bay and Breezy Point, Complex #16 (see note 172).

²⁸⁹Jackson, et al., 2002 (see note 139), reviewing the findings of J.K. Sullivan, 1994, "Habitat status and trends in the Delaware estuary," *Coastal Management* 22:49–79; and Dove and Nyman, 1995, pp. 441–447 (see note 14).

²⁹⁰Karpanty et al., 2006 (see note 160).

²⁹¹USFWS, 1997, p. 630 in Lower Hudson River Estuary, Complex #21 (see note 172).

²⁹²George Frame, 2/20/07 email (personal visual observations) (see note 251).

²⁹³USFWS, 1997, p. 633 in Lower Hudson River Estuary, Complex #21 (discussing the ecological significance and uniqueness of Piermont Marsh) (see note 172).

²⁹⁴George Frame, 2/20/07 email (personal visual observations) (see note 251).

²⁹⁵1984 study by Joanna Burger of Rutgers University, cited on p. 3 in New York State Department of State and USFWS, 1998 (see note 221).

²⁹⁶USFWS, 1997, p. 537 in Jamaica Bay and Breezy Point Complex #16 (discussing the significance of Jamaica Bay, in particular the bay islands, as a stopover site for migratory shorebirds) (see note 172).

unless they can shift feeding to marsh ponds and pannes.²⁹⁷ At the same time, disappearing saltmarsh islands in the area are transforming into intertidal mudflats.²⁹⁸ This increases habitat for shorebirds at low tide, but leaves less habitat for refuge at high tide.

Shallow Nearshore Waters and Submerged Aquatic Vegetation (SAV)

There is extensive shallow water habitat and high biological productivity in the part of the Hudson River from Stony Point south to Piermont Marsh, just below the Tappan Zee Bridge in Rockland County. This wide, shallow area is where the estuary's seasonal (and annual) salt front occurs, which is the area of greatest mixing of ocean and freshwater. The salt front functions to concentrate nutrients and plankton, resulting in a high level of both primary and secondary productivity. Thus, this part of the Hudson is a major habitat area for numerous fish and bird species. It is a major nursery area for striped bass, white perch, tomcod, and Atlantic sturgeon and a wintering area for the federally endangered shortnose sturgeon. Waterfowl also feed and rest here during spring and fall migrations. Some SAV is also found here, dominated by water celery, sago pondweed, and horned pondweed.²⁹⁹ Sea level rise will affect this productive area through salinity changes that will influence the composition and diversity of nearshore vegetation and associated fauna. However, changes in the upstream extent of the salt wedge as a result of sea level rise have not been analyzed, nor has anyone considered the ecological implications of such a change.

Marsh and Bay Islands

Regionally important populations of egrets, herons, and ibises are located on North and South Brother islands in the East River and on Shooter's Island, Prall's Island, and Isle of Meadows in Arthur Kill and Kill van Kull. North

and South Brother islands have the largest black crowned night heron colony in New York State, along with large numbers of snowy egret, great egret, cattle egret, and glossy ibis.³⁰⁰ The population of the heronries of Shooter's Island, Prall's Island, and Isle of Meadows, known collectively as the Harbor Herons Complex, constitutes about 25 percent of all nesting wading birds in New York, New Jersey, and Connecticut.³⁰¹ The available research provides no basis for expecting that these colonial nesting birds could survive if these islands were inundated.

Since 1984, an average of 1,000 state threatened common tern have nested annually in colonies on seven islands of the Jamaica Bay Wildlife Refuge, including Canarsie Pol, Jo Co Marsh, and Silver Hole Marsh, with smaller numbers at Duck Creek Marsh, East High Meadow, Ruffle Bar, and Subway Island. The heronry on Canarsie Pol also supports nesting by great black-backed gull, herring gull, and American oystercatcher. The only colonies of laughing gull in New York State, and the northernmost breeding extent of this species, occur on the islands of East High Meadow, Silver Hole Marsh, Jo Co Marsh, and West Hempstead Bay.³⁰²

Hoffman Island and Swinburne Island are National Park Service properties lying off the southeast shore of Staten Island; the former has important nest habitat for herons, and the latter is heavily nested by cormorants.³⁰³

Diamondback terrapin nest in large numbers along the sandy shoreline areas of the islands of Jamaica Bay, primarily Ruler's Bar Hassock.³⁰⁴ Local experts have reported observing about

²⁹⁷Erwin et al., 2004, p. 901 (see note 16). (Discussing mudflats at Forsythe National Wildlife Refuge, New Jersey, and other northeastern Atlantic coast sites.)

²⁹⁸George Frame, 2/20/07 email (personal visual observation) (see note 251).

²⁹⁹USFWS, 1997, p. 630 in Lower Hudson River Estuary, Complex #21 (see note 172).

³⁰⁰USFWS, 1997, p. 614 in The Narrows, Complex #20 (see note 172).

³⁰¹Steinberg, N. D.J. Suszkowski, L. Clark, and J. Way, 2004, Health of the Harbor: The First Comprehensive Look at the State of the NY/NJ Estuary, a report to the NY/NJ Harbor Estuary Program, Hudson River Foundation, New York, pp. 12–13.

³⁰²USFWS, 1997, p. 537 in Jamaica Bay and Breezy Point, Complex #16 (see note 172).

³⁰³George Frame, 2/20/07 email (personal visual observation) (see note 251).

³⁰⁴USFWS, 1997, p. 538 in Jamaica Bay and Breezy Point, Complex #16 (see note 172).

2,000 females nesting in the area.³⁰⁵ Although bay islands may offer more protection from predators than the mainland, in recent years a large percentage of terrapin eggs have been depredated.³⁰⁶ Other possible causes of low egg survivorship include so-called “root predation,” whereby the roots of beach plants “invade” a nest and penetrate the eggs and absorb their nutrients.³⁰⁷

It is estimated that between 1974 and 1994, the smaller islands of Jamaica Bay lost nearly 80 percent of their vegetative cover.³⁰⁸ There has been an accelerating trend in the loss of marsh

area, reaching an average annual rate of 18 ha (44.5 acres) per year between 1994 and 1999.³⁰⁹ Further loss of bay island habitat with rising seas could eliminate nesting sites for island-nesting birds, having significant impacts on the populations of these species, particularly those with already diminished population sizes such as the state threatened common tern. A local terrapin expert has speculated that marsh loss, combined with loss of beach nesting sites, could greatly reduce the remaining local population of diamondback terrapin.³¹⁰

³⁰⁵Dr. Russell Burke, 2006 email to E. Strange (see note 226). See also Feinberg, J.A., and R.L. Burke, 2003 (see note 286), and Ner, S.E., and R.L. Burke, n.d., Direct and indirect effects of urbanization on diamond-back terrapins of the Big Apple: Distribution and predation in a human-modified estuary, Unpublished manuscript, Department of Biology, Hofstra University, Hempstead, NY.

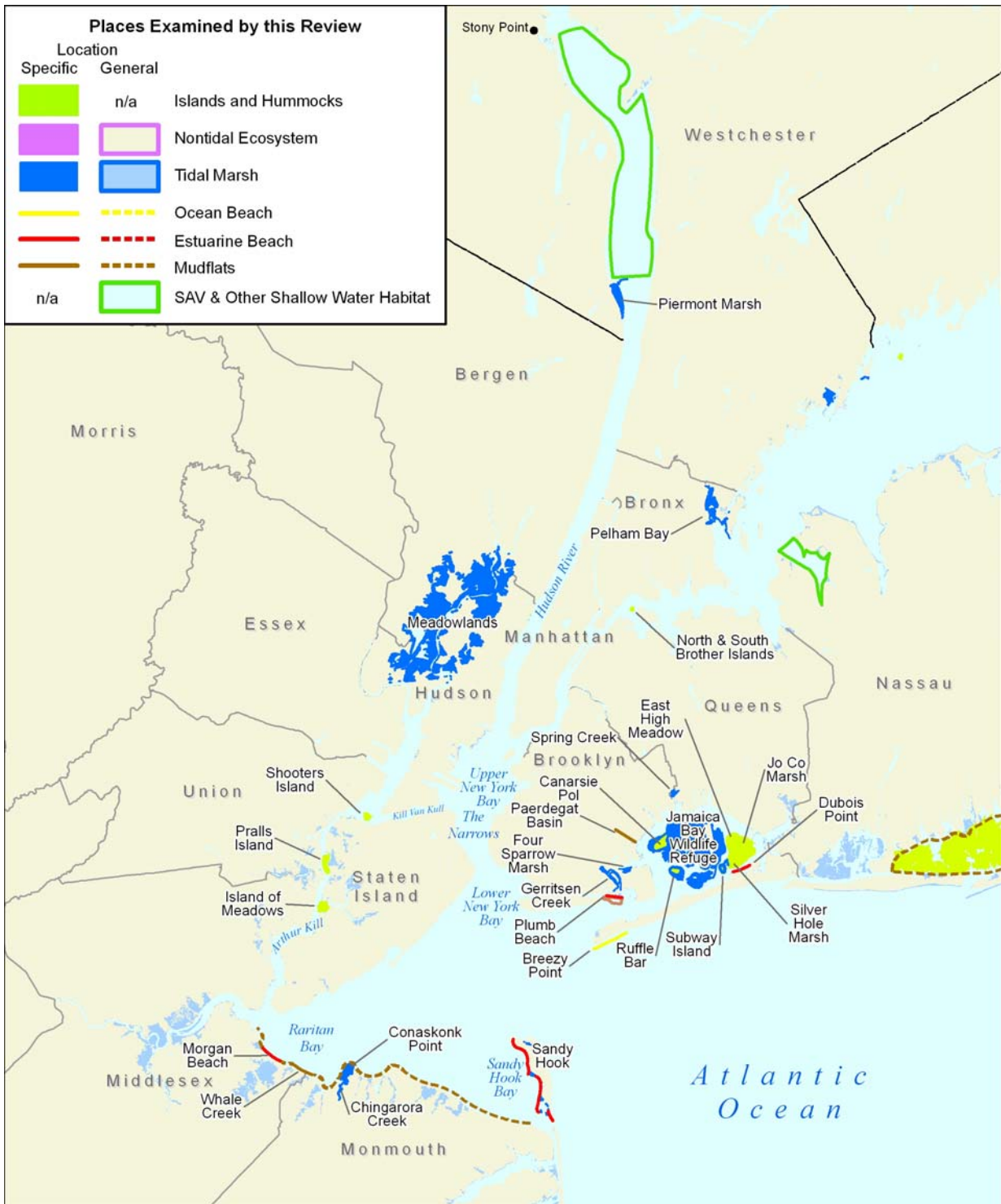
³⁰⁶Ner and Burke, n.d. (see note 305).

³⁰⁷Feinberg and Burke, 2003, pp. 517 and 523, and references therein (see note 286).

³⁰⁸Hartig et al., 2002, p. 71 (see note 264).

³⁰⁹Hartig et al., 2002, p. 78 (see note 264).

³¹⁰Dr. Russell Burke, 2006 email to E. Strange (see note 226).



Map 3.2 Locations and Types of Habitat Discussed in this Report: New York Harbor and Raritan Bay