

## 3.6 New Jersey's Coastal Bays

*Author: Elizabeth M. Strange, Stratus Consulting Inc.*

Species and habitats along the Atlantic Coast of south-central New Jersey are potentially at risk because of sea level rise. This region encompasses the barrier islands, barrier spits, and back-barrier lagoons of New Jersey's Ocean, Atlantic, and Cape May counties. The region contains important habitats for a wide variety of fish, invertebrates, terrapins, and birds, 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 summary discusses those species that could be at risk because of further habitat loss resulting from sea level rise and shoreline protection (see Map 3.3). 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.

Ocean County has two coastal barrier islands, Island Beach to the north and Long Beach Island to the south. Behind these barrier islands are the bays of the Barnegat Estuary, including Barnegat Bay, Manahawkin Bay, and Little Egg Harbor; three inlets; several tidal creeks; and numerous finger canals.<sup>346</sup> The Barnegat Bay National Estuary Program (BBNEP) includes the shoreline from the Point Pleasant Canal south to the Little Egg Harbor Inlet.<sup>347</sup>

Atlantic County has the back-barrier bays and tidal wetlands of the Brigantine Bay and marsh complex, which extends from Little Egg Inlet

south to the Great Egg Harbor Inlet,<sup>348</sup> and the Great Egg Harbor Estuary<sup>349</sup> contained within southern Atlantic County and northern Cape May County. Cape May County has the important environmental areas of the Cape May Peninsula, which include the coastal ponds of Cape May Meadows at the tip of the peninsula and a network of salt marsh islands and small, shallow bays connected by a network of channels and tidal creeks on the peninsula's Atlantic Ocean side.<sup>350</sup>

There have been many efforts to conserve and restore species and habitats in the barrier island/back-barrier lagoon system of the study region. Some of the larger parks and wildlife areas in the region are Island Beach State Park, Great Bay Boulevard State Wildlife Management Area, and the E.B. Forsythe National Wildlife Refuge (Forsythe Refuge) in Ocean and Atlantic counties. Parts of the Cape May Peninsula are protected by the Cape May National Wildlife Refuge,<sup>351</sup> the Cape May Point State Park,<sup>352</sup> and TNC's Cape May Migratory Bird Refuge.<sup>353</sup> The peninsula is renowned as one of the primary stopover sites for migrating birds along the U.S. Atlantic Coast. The North Brigantine Natural

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<sup>346</sup>See USFWS, 1997, Barnegat Bay Complex, Complex #6. pp. 317–330 (see note 172).

<sup>347</sup>The website for the Barnegat Bay National Estuary Program is <http://www.bbep.org/>.

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<sup>348</sup>See USFWS, 1997, Brigantine Bay and Marsh Complex, Complex #4. pp. 281–307 (see note 172).

<sup>349</sup>See USFWS, 1997, Great Egg Harbor Estuary, Complex #3. pp. 261–268 (see note 172).

<sup>350</sup>See USFWS, 1997, Cape May Peninsula, Complex #1. pp. 177–195 (see note 172).

<sup>351</sup>See <http://www.fws.gov/northeast/capemay/>.

<sup>352</sup>See

<http://www.state.nj.us/dep/parksandforests/parks/capemay.html>.

<sup>353</sup>See

<http://www.nature.org/wherewework/northamerica/states/newjersey/work/art17205.html>.

Area is a critical nesting area for least terns and piping plovers and a critical stopover habitat for a number of migrating shorebirds. Corson's Inlet State Park and Strathemere Natural Area, which straddle Corson's Inlet, have historically provided critical habitat area for black skimmers, least terns, and piping plovers, and in an important stopover habitat for migratory shorebirds. Stone Harbor Point and Champagne Island, part of the Hereford Inlet system, are critical nesting areas for least terns, black skimmers, piping plovers, common terns, and American oystercatchers, and provide critical resting and feeding habitat for migrating shorebirds, including red knot. Marsh islands behind this inlet system and behind Stone Harbor host the largest concentration of nesting laughing gulls in the world.<sup>354</sup> The TNC refuge alone supports an estimated 317 bird species, 42 mammal species, 55 reptile and amphibian species, finfish, shellfish, and other invertebrates.<sup>355</sup> All of these areas are likely to be placed at increased risk by rising sea levels.

### Tidal Marshes and Nearshore Nontidal Marshes

There are 18,440.7 ha (71.2 mi<sup>2</sup>), 29,344.6 ha (113.3 mi<sup>2</sup>), and 26,987.7 ha (104.2 mi<sup>2</sup>) of tidal salt marsh in Ocean, Atlantic, and Cape May counties, respectively. Based on a review of available studies, a panel of accretion experts convened for this report concluded that marshes in the study are keeping pace with current local rates of sea level rise of 4 mm/yr, but will become marginal with a 2 mm/yr acceleration, and will be lost with a 7 mm/yr acceleration except where they are near local sources of sediments (e.g., rivers such as the Mullica and Great Harbor rivers in Atlantic County) (see Section 2.1).

There is potential for wetland migration in the unprotected parts of Island Beach State Park, the

Forsythe Refuge, and other parks and wildlife management areas in Ocean County.<sup>356</sup> Wetlands may also be allowed to migrate along the undeveloped shorelines of the Mullica and Great Egg Harbor rivers in Atlantic County.<sup>357</sup>

However, with the exception of beaches and a few areas such as the Forsyth Refuge, most estuarine shorelines are hardened.<sup>358</sup> Local planners indicate that the developed mainland and barrier island shorelines of Ocean, Atlantic, and Cape May counties will almost certainly be protected. The narrow fringing salt marshes along protected shorelines north of Barnegat Inlet could be lost even with a 2 mm/yr acceleration in rate of sea level rise. Below Barnegat Inlet natural shorelines are considered likely to remain because the sea would have to rise many feet before it would reach US Highway 9.<sup>359</sup> With continued sea level rise, natural sedimentary processes will be increasingly disrupted and lead to "drowning" of marshes. Many typical back-bay areas will likely become lakes. The invasive common reed may spread into areas where higher sea levels cause groundwater discharge to migrate up slope with greater volume.<sup>360</sup>

As marshes along protected shorelines experience increased tidal flooding, there may be an initial benefit to some species. This is because as tidal creeks become wider, deeper, and more abundant, fish species may benefit because of increased access to forage on the marsh surface.<sup>361</sup> Fish species such as Atlantic silverside, mummichog, and bay anchovy move into the creeks during low tide, but have greater access and are more common on the marsh surface during high tide. Sampling of larval fishes in high salt marsh on Cattus Island, Beach

<sup>356</sup>Ibid.

<sup>357</sup>Ibid.

<sup>358</sup>Stanton Hales, Richard Stockton College, Biology & Marine Sciences Programs, Pomona, NJ. E-mail entitled Reviews of USEPA-sponsored papers, to Karen Scott of EPA 7/25/07. (personal visual observations).

<sup>359</sup>Ibid.

<sup>360</sup>Barry Truitt, The Nature Conservancy. Email entitled Review of Atlantic coast side of the VES, to Karen Scott of EPA, 7/25/07.

<sup>361</sup>Weinstein, M.P., 1979, "Shallow marsh habitats as primary nurseries for fishes and shellfish, Cape Fear River, North Carolina," *U.S. Fisheries Bulletin* 77:339-357.

<sup>354</sup>Dave Jenkins, acting chief, New Jersey Division of Fish and Wildlife, Endangered and Nongame Species Program, Trenton, NJ. E-mail entitled Opportunity to comment on a US EPA-sponsored paper concerning sea level rise, to Karen Scott of EPA, 7/18/07. (personal visual observations).

<sup>355</sup>Fact sheet by National Park Service on the New Jersey Coastal Heritage Trail Route. Accessed December 4, 2007 at: <http://www.nps.gov/archive/neje/migsites.html>.

Haven West, and Cedar Run in Ocean County showed that high marsh is important for production of mummichog, rainwater killfish, spotfin killifish, and sheepshead minnow. The flooded marsh surface and tidal and nontidal ponds and ditches appear to be especially important for the larvae of these species.<sup>362</sup> However, as sea levels continue to rise, and marshes along hardened shorelines convert to open water, marsh fishes will lose access to these marsh features and the protection from predators, nursery habitat, and foraging areas provided by the marsh.

Loss of marsh area would also have negative implications for the dozens of bird species that forage and nest in the region's marshes. Initially, deeper tidal creeks and marsh pools will become inaccessible to short-legged shorebirds such as plovers.<sup>363</sup> Long-legged waterbirds such as yellow-crowned night heron, which forages almost exclusively on marsh crabs (fiddler crab and others), will lose important food resources. High marsh nesting birds such as northern harrier, black rail, clapper rail, and willet may be most at risk.<sup>364</sup> Eventually, complete conversion of marsh to open water will affect the hundreds of thousands of shorebirds that stop in these areas to feed during their migrations. The New Jersey Coastal Management Program estimated that some 1.5 million migratory shorebirds stop over on New Jersey's shores during their annual migrations.<sup>365</sup> Waterfowl also forage and overwinter in area marshes. Midwinter aerial waterfowl counts in Barnegat Bay alone average 50,000 birds.<sup>366</sup> The tidal marshes of the Cape May Peninsula provide stopover areas for hundreds of thousands of shorebirds, songbirds, raptors, and waterfowl during their seasonal

migrations.<sup>367</sup> The peninsula is also an important staging area and overwintering area for seabird populations. Surveys conducted by the U.S. Fish and Wildlife Service from July through December 1995 in Cape May County recorded more than 900,000 seabirds migrating along the coast.<sup>368</sup>

As feeding habitats are lost, local bird populations may no longer be sustainable. For example, avian biologists suggest that if marsh pannes and pools continue to be lost in Atlantic County as a result of sea level rise, the tens of thousands of shorebirds that feed in these areas may shift to feeding in impoundments in the nearby Forsythe Refuge, increasing shorebird densities in the refuge by tenfold and reducing population sustainability because of lower per capita food resources and disease from crowding.<sup>369</sup>

Local populations of marsh-nesting bird species will also be at risk where marshes drown. This will have a particularly negative impact on rare species such as seaside and sharp-tailed sparrows, which may have difficulty finding other suitable nesting sites. According to syntheses of published studies in Greenlaw and Rising, and Poole and Gill, densities in the region ranged from 0.3 to 20 singing males per hectare and 0.3 to 4.1 females per hectare for the seaside and sharp-tailed sparrows, respectively.<sup>370</sup> Loss and alteration of suitable marsh habitats are the primary conservation concerns for these and other marsh-nesting passerine birds.<sup>371</sup> Nonpasserine marsh nesting

<sup>362</sup>Talbot, C.W., and K.W. Able, 1984, "Composition and distribution of larval fishes in New Jersey high marshes," *Estuaries* 7:434-443.

<sup>363</sup>Erwin et al., 2004 (see note 16).

<sup>364</sup>Dave Jenkins (see note 354).

<sup>365</sup>Cooper, M.J.P., M.D. Beevers, and M. Oppenheimer, 2005, *Future Sea Level Rise and the New Jersey Coast*, Science, Technology, and Environmental Policy Program, Woodrow Wilson School of Public and International Affairs, Princeton University, Princeton, NJ, p. 3, citing the New Jersey Coastal Management Program.

<sup>366</sup>USFWS, 1997, Barnegat Bay Complex, Complex #6. p. 323 (see note 172).

<sup>367</sup>See USFWS, 1997, Cape May Peninsula, Complex #1. pp. 177-195 (see note 172).

<sup>368</sup>USFWS, 1997, Barnegat Bay Complex, Complex #6. p. 324 (see note 172).

<sup>369</sup>Erwin et al., 2006 (see note 58).

<sup>370</sup>Greenlaw, J.S., and J.D. Rising, 1994, "Sharp-tailed sparrow (*Ammodramus audacutus*)," in Poole, A. and F. Gill, (eds.), *The Birds of North America*, No. 127, The Academy of Natural Sciences, Philadelphia and the American Ornithologists' Union, Washington, DC; and Post, W. and J. S. Greenlaw, 1994, Seaside sparrow (*Ammodramus maritimus*), in Poole and Gill, as cited in Chapter 6 of *The Barnegat Bay Estuary Program Characterization Report*. Prepared by the Barnegat Bay National Estuary Program (Scientific and Technical Advisory Committee), January 2001. Available at: [http://www.bbep.org/char\\_rep.htm](http://www.bbep.org/char_rep.htm)

<sup>371</sup>Chapter 7 of *The Barnegat Bay Estuary Program Characterization Report*. Prepared by the Barnegat Bay National Estuary Program (Scientific and Technical Advisory

birds may also be at risk, particularly high marsh species such as northern harrier and black rail, which are state-listed as endangered. Species that nest in other habitat but rely on marshes for foraging, such as herons and egrets, will also be affected as marshes drown.

Bulkheading is also under way to protect the vulnerable freshwater ecosystems of the Cape May Meadows (The Meadows), which is located behind the eroding dunes of the Cape May Canal. Freshwater coastal ponds in The Meadows are found within a few hundred feet of the shoreline and therefore could easily be inundated as seas rise. The ponds provide critical foraging and resting habitat for a variety of bird species, primarily migrating shorebirds.<sup>372</sup> Among the rare birds seen in The Meadows by local birders are buff-breasted sandpipers, arctic tern, roseate tern, whiskered tern, Wilson's phalarope, black rail, king rail, Hudsonian godwit, and black-necked stilt.<sup>373</sup> Because of its vulnerability to sea level rise and its status as an ecologically important area, local planners expect that The Meadows will continue to be protected in the future.

## Estuarine Beaches

Estuarine beaches could largely disappear as a result of erosion and inundation of sandy habitat as seas rise. This would eliminate the billions of invertebrates that are found within or on the sandy substrate or beach wrack along the tide line of estuarine beaches.<sup>374</sup> These species provide a rich and abundant food source for bird species. Small beach invertebrates include isopods and amphipods, blood worms, and beach hoppers, and beach macroinvertebrates include soft shell clams, hard clams, horseshoe crabs,

fiddler crabs, and sand shrimp (see details in Section 3.1).

To protect estuarine beaches, beach nourishment is being implemented in developed portions of the Ocean County shore, particularly in the northern part, while bulkheading continues to be used on the bayside shores of the county. TNC, the U.S Army Corps of Engineers (USACE), and the New Jersey Department of Environmental Protection (NJDEP) are undertaking beach replenishment to protect a mile-long stretch of sandy beach found in the Cape May Migratory Bird Refuge that provides nesting habitat for the rare piping plover and least tern.<sup>375</sup>

Loss of horseshoe crab eggs as a result of beach erosion or beach nourishment could have important implications for the 1.5 million migratory shorebirds that stop over on New Jersey's shores to refuel during their annual migrations.<sup>376</sup> Many shorebirds feed preferentially on horseshoe crab eggs in spring (e.g., red knot),<sup>377,378</sup> and loss of this food source could reduce the growth and survival of migrants if there are insufficient alternative foraging sites nearby.<sup>379</sup> Sanderling, red knot, and ruddy turnstone prefer sandy beaches for foraging.<sup>380</sup> In spring these migrants must feed nearly continuously to gain sufficient weight for nesting and to continue their long-distance migrations.<sup>381</sup>

Northern diamondback terrapin nests on estuarine beaches in the Barnegat Bay area.<sup>382</sup> Loss of these habitats will make terrapins even more dependent on areas modified by humans (roadways). Local scientists consider coastal

Committee), January 2001. Available at:

[http://www.bbep.org/char\\_rep.htm/Ch7/Chapter%207.htm](http://www.bbep.org/char_rep.htm/Ch7/Chapter%207.htm).

<sup>372</sup> Fact sheet by New Jersey Department of Environmental Protection on Cape May Point State Park. Accessed December 5, 2007 at:

<http://www.state.nj.us/dep/parksandforests/parks/capemay.html>.

<sup>373</sup> Fact sheet by Paul Kerlinger, Outdoors Columnist, entitled "Birding, The Cape May Migratory Bird Refuge." Accessed December 5, 2007 at:

<http://www.capemaytimes.com/birds/capemay-meadows.htm>.

<sup>374</sup> Bertness, 1999, pp. 256–257, gives an estimate of more than 2 billion microscopic invertebrates per square meter (see note 133).

<sup>375</sup> Fact sheet by The Nature Conservancy on the Cape May Migratory Bird Refuge. Accessed December 5, 2007 at: <http://www.nature.org/wherework/northamerica/states/newjersey/work/art17205.html>.

<sup>376</sup> Cooper et al., 2005, p.3, citing the New Jersey Coastal Management Program (see note 365).

<sup>377</sup> USFWS, 2005 (see note 232).

<sup>378</sup> Karpanty et al., 2006 (see note 160).

<sup>379</sup> Although in spring the principal food source of shorebirds is typically horseshoe crab eggs, the BBNEP reports that in Barnegat Bay shorebirds feed on invertebrates in marsh mudflats and beaches. See Chapter 7 of *The Barnegat Bay Estuary Program Characterization Report* (see note 371).

<sup>380</sup> Chapter 7 of *The Barnegat Bay Estuary Program Characterization Report* (see note 371).

<sup>381</sup> USFWS, 2005 (see note 232).

<sup>382</sup> Chapter 7 (and references therein) of *The Barnegat Bay Estuary Program Characterization Report* (see note 371).



development, which destroys terrapin nesting beaches and access to nesting habitat, one of the primary threats to diamondback terrapins, along with predation, roadkills, and crab trap bycatch.<sup>383</sup>

Loss of estuarine beach could also have negative impacts on rare tiger beetles. Two subspecies of *Cicindela dorsalis* are found on New Jersey's coastal shoreline: the northeastern beach tiger beetle, *C. dorsalis dorsalis*, which is a federally listed threatened species and a state species of special concern and regional priority, and *C. dorsalis media*, which is considered rare, though it has not been considered for state listing. In the mid-1990s, the northeastern beach tiger beetle was observed on the undeveloped ocean beaches of Holgate and Island Beach. The USFWS does not know whether this species is also found on the area's estuarine beaches, but studies indicate that it feeds and nests in a variety of habitats.<sup>384</sup> The current abundance and distribution of the northeastern beach tiger beetle in the coastal bays is a target of research.<sup>385</sup> At present, there are plans to reintroduce the species in the study region at locations where natural ocean beaches remain.<sup>386</sup>

## Tidal Flats

The tidal flats of New Jersey's back-barrier bays are critical foraging areas for hundreds of species of shorebirds, passerines, raptors, and waterfowl. Tidal flats are found in almost all of the coastal bays, and support invertebrates such as insects, worms, clams, and crabs that provide an important food source for these and other birds that forage in the study region. Some shorebirds such as semipalmated sandpiper, dunlin, and

dowitcher forage preferentially on mudflats and shallow impoundments.<sup>387</sup>

Important shorebird areas in the study region include the flats of Great Bay Boulevard Wildlife Management Area, North Brigantine Natural Area, and the Brigantine Unit of the Forsythe Refuge.<sup>388,389</sup> The USFWS estimates that the extensive tidal flats of the Great Bay alone total 1,358 ha (3,355 acres). Inundation of tidal flats with rising seas would eliminate critical foraging opportunities for the area's abundant avifauna. As tidal flat area declines, increased crowding in remaining areas could lead to exclusion and mortality of many foraging birds.<sup>390, 391</sup> Some areas may become potential sea grass restoration sites, but whether or not "enhancing" these sites as eelgrass areas is feasible will depend on their location, acreage, and sediment type.<sup>392</sup>

## Shallow Nearshore Waters and Submerged Aquatic Vegetation (SAV)

The Barnegat Estuary is distinguished from the lagoons to the south by more open water and SAV and less emergent marsh. Within the Barnegat Estuary, dense beds of eelgrass are found at depths under 1 meter (3.28 feet), particularly on sandy shoals along the backside of Long Beach Island and Island Beach, and around Barnegat Inlet, Manahawkin Bay, and Little Egg Inlet. Eelgrass is relatively uncommon from the middle of Little Egg Harbor south to Cape May,<sup>393</sup> particularly locations where water depths are above 1 meter (3.28 feet), such as portions of Great South Bay.<sup>394</sup>

Seagrass surveys from the 1960s through the 1990s revealed an overall decline in seagrass in Barnegat Estuary from 6,823 ha (16,847 acres) in

<sup>383</sup>See the website of the Wetlands Institute's terrapin conservation program at <http://www.terrapinconservation.org>.

<sup>384</sup>USFWS, 1997, Barnegat Bay Complex, Complex #6, pp. 317–330 (see note 172).

<sup>385</sup>State of New Jersey, 2005, New Jersey Comprehensive Wildlife Conservation Strategy for Wildlife of Greatest Conservation Need, August 2005 Draft, Table C1, p. 61, available at:

<http://www.njfishandwildlife.com/ensp/waphome.htm>.

<sup>386</sup>State of New Jersey, 2005 (see note 385).

<sup>387</sup>Chapter 7 of *The Barnegat Bay Estuary Program Characterization Report* (see note 371).

<sup>388</sup>See USFWS, 1997, Barnegat Bay Complex, Complex #6, p. 317 (see note 172).

<sup>389</sup>USFWS, 1997, Brigantine Bay and Marsh Complex, Complex #4, p. 281 (see note 172).

<sup>390</sup>Galbraith et al., 2002, p. 173 (see note 50).

<sup>391</sup>Erwin et al., 2004, p. 892 (see note 16).

<sup>392</sup>Stanton Hales (expert judgment based on a career largely devoted to these issues) (see note 358).

<sup>393</sup>USFWS, 1997, Barnegat Bay Complex, Complex #6, pp. 317–330 (see note 172).

<sup>394</sup>USFWS, 1997, Mullica River-Great Bay Estuary, Complex #5, pp. 295–307 (see note 172).

a 1968 survey to an average of 5,677 ha (14,029 acres) of seagrass beds from 1996 to 1998.<sup>395, 396</sup>

Numerous studies indicate that eelgrass has high ecological value as a source of both primary<sup>397</sup> and secondary production<sup>398</sup> in estuarine food webs. In Barnegat Estuary eelgrass beds provide habitat for invertebrates, birds, and fish that use the submerged vegetation for spawning, nursery, and feeding habitat. In addition, many species graze on eelgrass, including gastropods, fishes, ducks, and muskrats.<sup>399</sup>

Short and Neckles suggested that a 50 cm (19.7 in.) increase in water depth as a result of sea level rise could reduce the light available for eelgrass photosynthesis by 50 percent, resulting in a 30–40 percent reduction in seagrass growth. The researchers suggested that this will, in turn, result in reduced productivity and functional values of eelgrass beds.<sup>400</sup>

Results of a study in Barnegat Bay indicated that shoreline protection may exacerbate this problem. The study found that where shorelines are bulkheaded, SAV, woody debris, and other features of natural shallow water habitat are rare or absent. These bulkheaded areas have reduced abundances of fishes compared to sites that were not bulkheaded sites.<sup>401</sup>

The Barnegat Estuary has 14 yacht clubs, with 4 on Long Beach Island alone. Sailing and sailboat racing are less popular in Atlantic and Cape May

counties,<sup>402</sup> with their relatively small and shallow bays. One possible benefit of the conversion of marsh to open water would be increased recreational sailing in the larger barrier bays that might form. On the other hand, deeper water would make Little Egg Harbor Bay less hospitable to windsurfing.<sup>403</sup>

## Marsh and Bay Islands

Large bird populations are found on marsh and dredge spoil islands of the back-barrier bays in the study region. These islands include nesting sites protected from predators for several species of conservation concern, including gull-billed tern, common tern, Forster's tern, least tern, black skimmer, American oystercatcher, and piping plover. Diamondback terrapin, a state species of special concern and a regional priority, is also known to feed on marsh islands in the bays.<sup>404</sup>

Some of the small islands in Barnegat Bay and Little Egg Harbor are several feet above mean spring high water,<sup>405</sup> but portions of other islands are very low, and some low islands are currently disappearing. Many of these vulnerable islands are used by nesting common terns, Forster's terns, black skimmers, and American oystercatchers.<sup>406</sup> With the assistance of local governments, the Mordecai Land Trust is actively seeking grants to halt the gradual erosion of Mordecai Island, a 45-acre island just west of Beach Haven on Long Beach Island. Members of the land trust have documented a 37 percent loss of island area since 1930. The island's native salt marsh and surrounding waters and SAV beds provide habitat for a variety of aquatic and avian species. NOAA Fisheries considers the island and its waters essential fish

<sup>395</sup>Chapter 7 of *The Barnegat Bay Estuary Program Characterization Report* (see note 371).

<sup>396</sup>According to an 7/21/06 email to E. Strange, Stratus Consulting, from Dr. Paul A. X. Bologna of the Department of Biology and Molecular Biology at Montclair State University, Dr. Bologna has conducted SAV monitoring in the Barnegat Estuary since 1998, but these data are not yet analyzed.

<sup>397</sup>Thayer, G.W., W.J. Kenworthy, and M.S. Fonseca, 1984, *The Ecology of Eelgrass Meadows of the Atlantic Coast: A Community Profile*, U.S. Fish and Wildlife Service, FWS/OBS-84/02.

<sup>398</sup>Jackson, E.L., A.S. Rowden, M.J. Attrill, S. Bossey, and M. Jones, 2001, The importance of seagrass beds as habitat for fishery species, *Oceanography and Marine Biology Annual Review* 39:269–303.

<sup>399</sup>Chapter 7 of *The Barnegat Bay Estuary Program Characterization Report* (see note 371).

<sup>400</sup>Short and Neckles, 1999 (see note 91).

<sup>401</sup>Byrne, 1995 (see note 112).

<sup>402</sup>Of 32 yacht clubs in New Jersey, 14 are in Ocean County, and 6 are in Atlantic and Cape May counties combined. The other 12 are evenly divided between Delaware River, Monmouth County, and North Jersey. Don Robertson's Marine Marketplace: Yacht Clubs with Web Sites. Available at:

<http://www.yachtsales.com/yclubs/nj.html>.

<sup>403</sup>Titus, J., 1998, Windsurfing in a warmer world, *Windsurfing Magazine*, March (Windsurfing is more convenient when water is 3–4 ft deep than when over one's head.)

<sup>404</sup>USFWS, 1997, Barnegat Bay Complex, Complex #6. pp. 317–330 (see note 172).

<sup>405</sup>Personal visual observation by James G. Titus, U.S. EPA.

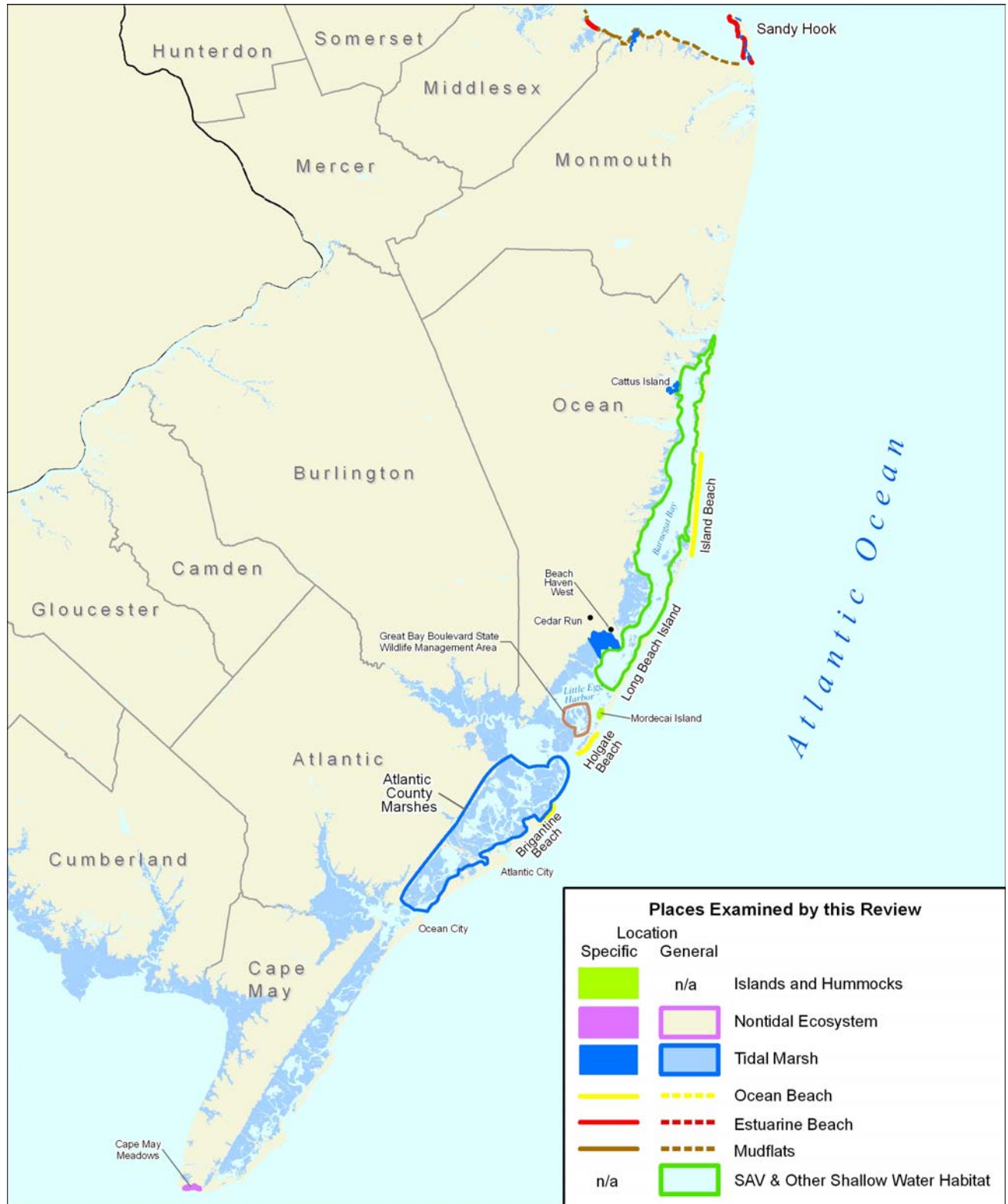
<sup>406</sup>Dave Jenkins (personal visual observation) (see note 354).

habitat for spawning and all life stages of winter flounder as well as juvenile and adult stages of Atlantic sea herring, bluefish, summer flounder, scup, and black sea bass.<sup>407</sup> The island is also a strategically located nesting island for many of New Jersey's threatened and endangered species, and it contains a moderate-size black skimmer colony, common terns, and most recently, a very small colony of royal terns.<sup>408</sup>

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<sup>407</sup>Mordecai Land Trust web site, available at:  
<http://www.mordecaimatters.org>.

<sup>408</sup>Dave Jenkins (personal visual observation) (see note 354).



Map 3.3 Locations and Types of Habitat Discussed in this Report: New Jersey Shore