INVENTORY OF HABITAT MODIFICATIONS TO SANDY OCEANFRONT BEACHES IN THE U.S. ATLANTIC COAST BREEDING RANGE OF THE PIPING PLOVER (*CHARADRIUS MELODUS*) AS OF 2015: MAINE TO NORTH CAROLINA

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INTRODUCTION

Sandy beach habitat has been modified throughout the United States (U.S.) Atlantic Coast breeding range of the piping plover (*Charadrius melodus*), from Maine to North Carolina. Threats to sandy beach ecosystems include development, hard shoreline stabilization structures, sediment placement projects, beach scraping, sand fencing, and more. Sandy beaches are a valuable habitat for piping plovers, red knots (*Calidris canutus*), other shorebirds and waterbirds for nesting, foraging, loafing, and roosting. The North Atlantic Landscape Conservation Cooperative (LCC) has designated the piping plover as a representative species in all three subregions, standing as a surrogate for other species using dynamic beach systems including American oystercatchers (*Haematopus palliatus*), least terns (*Sterna antillarum*), black skimmers (*Rynchops niger*), seabeach amaranth (*Amaranthus pumilus*) and migrating shorebirds.

Sandy beaches and/or dunes are designated as a key habitat in the state Wildlife Action Plans for all of the states in the Northeastern and Mid-Atlantic coastal states – Maine (ME), New Hampshire (NH), Massachusetts (MA), Rhode Island (RI), Connecticut (CT), New York (NY), New Jersey (NJ), Delaware (DE), Maryland (MD), Virginia (VA), and North Carolina (NC); the piping plover is listed as a species in greatest conservation need by each of those states as well (CT DEP 2005, CT DEEP 2015, DE DNREC 2006, MD DNR 2005, MDIFW 2005, NJ DEP 2008, NYDEC 2005, RDFW 2005, MDFW 2006, NC WRC 2005, NHFG 2006, VA DGIF 2015). The Long Island Sound Study lists both beach and dune habitat and the presence of piping plovers as environmental indicators for the health of the Long Island Sound ecosystem (LISS 2015). The Peconic Estuary Program also has designated piping plover nests and nesting productivity as an environmental indicator, as well as the extent of shoreline hardening from shoreline stabilization structures (Balla et al. 2005).

Recovery Task 1.2 of the U.S. Fish and Wildlife Service (USFWS) Recovery Plan for the piping plover prioritizes the maintenance of "natural coastal formation processes that perpetuate high quality breeding habitat," specifically discouraging the "construction of structures or other developments that will destroy or degrade plover habitat" (Task 1.21), "interference with natural processes of inlet formation, migration, and closure" (Task 1.22), and "beach stabilization projects including snowfencing and planting of vegetation at current or potential plover breeding sites" (Task 1.23) (USFWS 1996, pp. 65-67). The U.S. Fish and Wildlife Service's most recent 5-Year Review for the piping plover recommends increasing "efforts to restore and maintain natural coastal formation processes in the New York-New Jersey recovery unit, where threats from development and artificial shoreline stabilization are highest, and in the Southern Recovery Unit, where the plover's habitat requirements are the most stringent …. This action is also critical to reducing adverse effects of accelerating sea level rise" for the breeding range of the federally listed (threatened) Atlantic Coast population (USFWS 2009, p. 195).

A series of assessments recently filled the data need to identify such habitat modifications that have altered natural coastal processes and the resulting abundance, distribution, and condition of existing habitat in the U.S. Atlantic Coast breeding range prior to Hurricane Sandy and immediately after Hurricane Sandy in October 2012. The U.S. Atlantic Coast breeding range of the piping plover stretches from Maine to North Carolina.

Six recent reports provided these data for the U.S. continental migration and overwintering range of the piping plover (Rice 2012a, 2012b), the northern portion of the U.S. Atlantic Coast breeding range (Rice 2015a, 2015b) and the southern portion of the U.S. Atlantic Coast breeding range (Rice 2014, 2015c) prior to Hurricane Sandy. A summary report synthesized the results of these six reports to characterize tidal inlet and sandy beach habitats from Maine to North Carolina before Hurricane Sandy (Rice 2015d). Another report assessed the storm-induced habitat modifications to tidal inlets and sandy beaches from Maine to North Carolina resulting from Hurricane Sandy (Rice 2015e). Lastly, the habitat assessment for tidal inlets from Maine through North Carolina was updated to 2015 conditions in Rice (2016). Altogether this information can provide an assessment of the cumulative impacts of habitat modifications at tidal inlets and sandy beaches for piping plovers and other birds, including oceanfront beaches used by the recently listed rufa red knot (*Calidris canutus rufa*). These assessments do **not**, however, include habitat disturbances at tidal inlets or sandy beaches such as off-road vehicle (ORV) usage, pet and human disturbance, or disturbance to dunes or vegetation.

All of these previous reports, inventory data and Google Earth data layers are available online at the *Beach and Tidal Inlet Habitat Inventories Project* page of the North Atlantic LCC website at www.northatlanticlcc.org. The Google Earth data layers are also available in shapefile format in the *Inventory of Habitat Modifications to Tidal Inlets and Sandy Beach Habitat Gallery* at Data Basin, at www.databasin.org. Phase 1 of the project contains reports, data and map layers for tidal inlet and sandy beach habitats prior to Hurricane Sandy. Phase 2 of the project contains reports, data and map layers for tidal inlet and sandy beach habitat immediately following Hurricane Sandy in October 2012. Phase 3 of the project contains reports, data and may layers for tidal inlet and sandy beach habitat conditions in 2015.

This report updates the habitat inventory for sandy beach habitat three years after Hurricane Sandy, characterizing the habitat and its modifications for the entire U.S. Atlantic Coast breeding range of the piping plover, from Maine through North Carolina, as of 2015.

METHODS

This assessment updates the sandy beach inventories for the U.S. Atlantic Coast breeding range that characterized the habitat abundance, distribution and condition prior to Hurricane Sandy in October 2012, as described in Rice (2012b), Rice (2015b) and Rice (2015c). In order to evaluate the status of sandy oceanfront beaches along the coastline from Maine through North Carolina, the same methods of Rice (2015b) and Rice (2015c) were used with minor refinement. Mainland and inner estuarine beaches were not included unless no barrier islands were located offshore and thus the mainland or inner estuarine beaches were located with direct exposure to the Atlantic Ocean, Long Island Sound or the Peconic Estuary (e.g., Monmouth Beach, New Jersey, or Montauk, New York). The northern limit of the study area was Georgetown, Maine, north of which sandy beaches are rare. The southern limit of the study area was the state boundary between North Carolina and South Carolina.

Numerous reviewers provided comments on a draft of this assessment in order to verify and correct details, where necessary, and are listed in the Acknowledgements section. In order to assess the status of sandy beach habitat from ME to NC as of 2015, six habitat modifications for sandy beaches were identified and measured: 1) beachfront development, 2) beachfront lands in public and/or non-governmental organization (NGO) ownership, 3) beachfront armor, 4) locations of sediment placement activities constructed or proposed through 2015, 5) locations of beach scraping between 2012 and 2015, and 6) locations of sand fencing present between 2012 and 2015.

Development

The oceanfront shoreline was assessed by using the Google Earth imagery available for 2015, or where no 2015 imagery was available, early 2016. High-resolution imagery in Google Earth Pro was used to calculate the locations and lengths of sandy oceanfront beaches in each geographic area as well as to distinguish the lengths that were developed versus undeveloped. A Microsoft Excel database of all data was created, with the data organized by geographic area. Data were compiled on a community/municipal basis to facilitate updates and replication of the data. Line segments were created within Google Earth Pro for each undeveloped or developed beach segments. The line segments were labelled with the community name followed by "DEV" for developed or "UNDEV" for undeveloped, followed by a number representing the geographic order of the beach segment (from north to south or east to west). Thus the line labelled "Charlestown UNDEV 15" is the fifteenth beach segment from east to west in the town of Charlestown, Rhode Island, and it is an undeveloped section of beachfront. Line segments representing developed beachfront areas were colored in orange and those representing undeveloped beachfront colored in green (Figure 1). The length of each line segment in Google Earth Pro was recorded in Microsoft Excel.

In Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, and along the Long Island Sound (LIS) and Peconic Estuary shorelines of New York, sandy beaches may be directly adjacent to rocky beaches. Rocky beaches are defined as beaches composed predominantly of gravel, cobble and/or boulders. Rocky beaches may have minor amounts of sandy substrate. Solid rock outcrops are not considered rocky beaches. Beaches in the study area may convert from predominantly sandy to predominantly rocky or vice versa seasonally or yearly; for the purposes of this inventory, the substrate was categorized using the highest resolution imagery available within Google Earth for 2015 or early 2016. Where rocky beaches were directly adjacent to sandy beaches, the segments of rocky beach were delineated, measured and recorded because those areas may convert between predominantly sandy and rocky over time; these data are available within the Microsoft Excel and Google Earth data layer products associated with this habitat assessment.

The presence or absence of beachfront development was evaluated within 500 feet (ft; 152 meters [m]) landward of the first line of stable vegetation, or between the beach and a coast parallel road, whichever was nearer. Where a coast parallel road was present, the distance between the beach and the road needed to be sufficient enough to be developable with a building in order to be considered undeveloped beachfront (when no buildings were present). When development was set back less than 500 ft (152 m) but a water body such as a coastal pond separated the sandy beach from the development, the beach segment was considered undeveloped. The 500 ft (152 m) evaluation area landward of the beach was measured

Figure 1. Segments of sandy beach habitat delineated as developed (orange) and undeveloped (green) in Charlestown, RI. Narrow lime green lines represent the boundaries of beachfront parcels in public or NGO ownership. Fuchsia lines represent the locations of armor.

perpendicular to the shoreline orientation. This 500 ft (152 m) criteria is a minor revision to the methodology used in the 2012 habitat assessment (Rice 2015b, 2015c), which did not utilize a specific distance limit.

When calculating the approximate lengths of beach shoreline that were developed versus undeveloped, no distinction was made as to the level of development. Undeveloped areas were those where no structures existed adjacent to the beach and that appeared natural in the Google Earth aerial imagery. Vacant lots that were surrounded by a high number of buildings were not counted as undeveloped areas unless they were of a sufficient size to measure (e.g., greater than 200 ft [61 m] in oceanfront length). Parking lots and roads were not considered as developed areas unless they were developed on the landward side of the road and the road was close to the beach, preventing the sandy beach from migrating with rising sea level. Golf courses directly adjacent to the beach were categorized as developed beachfront. The individual dates of Google Earth imagery and eye altitude from which measurements were made were recorded; the latter was typically 1,000-1,100 feet (305-335 meters) above ground level.

The shoreline lengths used in this report are approximations for several reasons. First is the dynamic nature of the habitat. Sandy oceanfront beaches shift in space over time and may grow (accrete) or recede (erode) on a daily, weekly, seasonal or annual basis. Thus, the measured lengths are snapshots in time and are not necessarily the same lengths that would be measured today or tomorrow. Second, only the ocean-facing segments of the inlet shorelines were included, and the demarcation lines were based on professional judgment. Finally, the measurements are approximations due to mathematical rounding to the nearest hundredth of a mile.

Neither beach width nor area were measured in this assessment. The width or area of a beach changes daily and the available aerial imagery does not control for season, tide stage, etc. The beach segment lines created for the Google Earth data layer represent the presence or absence of sandy beach habitat in 2015. The lines do not represent the wet-dry line, the first line of stable vegetation, or any other physical feature; the lines are drawn on the dry beach and measure its length only.

Where sandy beach habitat was absent seaward of beachfront armor, but evidence indicates that a sandy beach would be present in the absence of the armor, those sandy shoreline segments were delineated with yellow lines and their length recorded (Figure 2). The presence or absence of dry sandy beach habitat seaward of beachfront armor is ephemeral in many areas, and could fluctuate with the construction of sediment placement projects; the delineation of their location in 2015 allows for future comparisons. The line segments were labelled with "NO BEACH" rather than "DEV" or "UNDEV" in the aforementioned naming convention. The segments of sandy shoreline lacking beach habitat seaward of armor in 2015 represent a habitat loss at the time the imagery was taken. Professional judgement was used to determine which shorelines would be predominantly sandy or rocky in the absence of armor.

Figure 2. Segments of sandy shoreline where no dry sandy beach was present seaward of beachfront armor structures in 2015 were delineated with yellow lines and their lengths recorded, as in this example from Fairfield, Connecticut.

Public and NGO Beachfront Ownership

Beachfront land parcels in public or NGO ownership were delineated from a variety of sources, including county or municipal parcel data available online to the public (see Table 1 of Rice 2015b for a full list of sources consulted for Maine to New York). Public and NGO-owned beachfront parcels are delineated with narrow, lime green lines in Google Earth Pro (Figure 1). The public / NGO line segments were delineated parallel to the beach segment lines in order to measure the length of sandy beach habitat present within the public and NGO tracts in 2015. Public/NGO land ownership may extend beyond the lines shown, which delineate the length of sandy beach within the public/NGO owned parcels. In some locations the public/NGO ownership lines include areas of rocky beach where the rocky beach is directly adjacent to segments of sandy beach because the substrate may change over time from predominantly rocky to sandy and vice versa.

The amount of sandy oceanfront beach in public and/or NGO ownership (and thus protected to some degree from development) provides an approximation of how much of sandy beach habitat may be available as sea level continues to rise and climate changes. If an area is in public or NGO ownership, then it is assumed that the habitat retains the potential to migrate inland with rising sea level and to continue to provide habitat for the piping plover and other shorebirds and waterbirds over the next several decades. [Note that public and NGO-owned lands may have been, continue to be, or may be modified in the future by shoreline stabilization structures or sediment placement projects; therefore they only retain *the potential* to provide future habitat as sea level rises.] Where sandy oceanfront beaches are developed, it is assumed that the habitat is highly susceptible to being lost or significantly degraded as sea level rises (through erosion or shoreline armoring), and thus of diminishing value to the piping plover. Undeveloped sandy oceanfront beaches that are not public or NGO-owned (i.e., private) were assumed to be developable. These beaches could provide opportunities for future conservation of adaptive capability via easements or other mechanisms.

Public and NGO lands in this assessment include the public lands of National Wildlife Refuges (NWRs) owned by the USFWS; National Seashores (NSs) and National Recreation Areas (NRAs) owned by the National Park Service (NPS); state, county and local parks and beaches; state Natural Areas, wildlife refuges and heritage preserves; and military bases. Sandy oceanfront beaches that have been protected by non-governmental conservation organizations, such as The Nature Conservancy preserves, were also included. Properties that have habitat conservation plans were not included because these properties typically have some level of development and are not protected, undeveloped spaces like refuges or parks. Data on the name, location, ownership, length of sandy beach present in 2015, and type of public or NGO land (e.g., wildlife refuge, park) were recorded in Microsoft Excel.

Where readily available information existed, notations about habitat modifications within individual public and NGO lands were noted in the Microsoft Excel database. These habitat modifications could include:

- the presence of jetties, groins or other shoreline armoring in or adjacent to the parcel;
- dredging activities at an inlet in or near the parcel;
- beach nourishment or dredge disposal activities on beaches in the parcel;

- the presence of ORV or recreational vehicle usage;
- campgrounds, recreational facilities, and/or camping allowed on the beach;
- the maintenance and protection of coastal highways;
- the artificial creation and/or maintenance of dunes;
- artificial opening or closure of inlets, including inlet relocations;
- vegetation plantings;
- the presence of feral horses, hogs or other animals that can damage vegetation and dunes;
- waterfowl impoundments;
- the presence of private inholdings or retained rights agreements that preclude some management options; and
- the presence of historic sites or structures (e.g., historic forts on the Sandy Hook peninsula in New Jersey, military batteries at Delaware Seashore State Park in Delaware or Cape May Point State Park in New Jersey).

Beachfront Armor

An assessment to estimate the length of each state's sandy oceanfront beach that has been armored with hard structures was measured by identifying and digitizing structures visible in Google Earth imagery in historic and current aerial photography. Armoring structures include shore-parallel seawalls, bulkheads, revetments, riprap, geotube and sandbag revetments, groins, offshore breakwaters, and jetties. A description of the different types of stabilization structures typically constructed on sandy beaches – terminal groins, groins, seawalls, breakwaters, revetments and others – can be found in Rice (2009) as well in the *Manual for Coastal Hazard Mitigation* (Herrington 2003, online at http://www.state.nj.us/dep/cmp/coastal_hazard_manual.pdf)), the U.S. Army Corps of Engineers' *Coastal Engineering Manual* (USACE 2002) and in *Living by the Rules of the Sea* (Bush et al. 1996).

Where existing datasets were available delineating beachfront armor, those datasets were incorporated in this assessment. Existing datasets include those of MA DCR (2009) and Fontenault et al. (2013) in Massachusetts, a 2008 inventory by the North Carolina Division of Coastal Management of sandbag revetments in NC, and coastal engineering inventories conducted for some National Park Service lands (e.g., Dallas et al. 2013). Where existing datasets were not available, beachfront armor was digitized using a heads-up approach[1] and colored fuchsia in a Google Earth data layer (Figures 1 and 2). All identifiable armoring structures were included, even if some are periodically buried, failing, in disrepair or remnant structures. Stormwater outfalls and docks were included if they were armored (typically with stone) and functioning like groins (i.e., the shoreline was offset on either side of the structure); their dual functions were noted in their labels.

The armor structures were labelled with the community name followed by the type of structure and ending with a number for that type of structure representing its geographic order (from north

[1] Heads-up digitizing is the manual digitization of a feature by tracing a computer mouse over features displayed in aerial imagery as a method to create GIS data.

Figure 3. The approximate locations of armor structures that were proposed but not constructed as of 2015 were delineated with sky blue lines in a Google Earth data layer, as in this example from Ocean Isle Beach, NC. The Town of Ocean Isle Beach has proposed to construct a terminal groin at the east end of the island near Shallotte Inlet.

to south or east to west). For example, "Rehoboth Beach groin 4" is the fourth groin in Rehoboth Beach, Delaware (DE), counted from north to south. "Dewey Beach bulkhead 1" is the first bulkhead in Dewey Beach, DE, counted from north to south. Note that some dates of aerial imagery within Google Earth are slightly offset from each other; the position of each armor structure was delineated from the same date of imagery used to identify the presence or absence of sandy beach habitat (i.e., 2015 or early 2016) and could appear offset in other imagery dates. Proposed armor structures were delineated in sky blue and prefaced with "PROPOSED" in their labels (Figure 3).

The length of shoreline modified by armoring was measured using the methodology of Coburn et al. (2010), Dallas et al (2013) and Schupp and Coburn (2015) in their recent coastal engineering inventories for the NPS, which utilized aerial imagery to identify and digitize shore protection structures within individual coastal parks. "The structure length used in calculating the percentage of shoreline armored for individual shore parallel structures was merely the length of the structure. For groin fields … the length of stabilized shore was set as the length of the groin field" (Dallas et al. 2013, p. 5). Where Dallas et al. (2013) defined a groin field as three or more groins, in this assessment a groin field was defined as two or more groins in close proximity to each other. An armoring "project was considered distinct if there was any discernible, physical separation between it and an adjacent coastal engineering project. A series of bulkheads constructed by individual interests, for example, would be classified as one structure as long as no identifiable gaps were observed between them" (Dallas et al. 2013, p. 5). The overall length of a contiguous section of seawalls, bulkheads and/or revetments was then measured and recorded as the length of shoreline armored in a given area. Digitization of the armoring structures within Google Earth allowed for overlapping armoring structures (i.e., a section of seawall with a groin field seaward of the wall) to be identified and the overall length of shoreline modified by the armoring to be measured without double counting. The lengths of sandy beach habitat modified by beach armoring were recorded in Microsoft Excel.

The lengths of shoreline affected by armoring included in this report should be considered a minimum because of the difficulty in identifying structures that still may be hidden by vegetation, dunes, or beach fill. A number of armor structures that were not visible prior to Hurricane Sandy were exposed by the storm or during the three years after the storm, for example; these structures were not included in the 2012 armor inventories of Rice (2015b, 2015c), but were newly identified and included in this 2015 update. Wherever available, published sources on hard stabilization structures armoring the coast were used to verify the types of armoring and the lengths of shoreline armored in a given area. In addition, solitary shore perpendicular structures such as jetties or solitary groins were noted but not included in the lengths of shoreline armored. Although the adjacent shoreline is impacted by the solitary structure, the length of shoreline impacted is unique to the given setting and cannot be uniformly measured. Therefore the lengths of shoreline modified with armoring identified in this assessment are minimum values.

Sediment Placement

An estimate of the length of sandy oceanfront beaches that have received or continue to receive sediment placement was also compiled. Sediment placement projects include beach fill or nourishment, artificial dune construction using fill material, inlet closure, and dredge disposal placement projects. The locations of sediment placement projects constructed as of 2015 were identified and delineated with a series of red lines in a Google Earth data layer. In this way, overlapping project areas could be identified. Each area of beach that has received sediment placement is counted only once, even if the site has repeatedly been modified by sediment placement, since the goal was to measure the spatial area of modification. Overlapping project areas were counted only once. Proposed sediment placement project areas were delineated with sky blue lines. Where project data were insufficient to identify precise project boundaries of sediment placement projects, red points (rather than lines) were delineated within the overall project area. Project details and lengths of modified beaches (with known boundaries) were recorded in Microsoft Excel.

The sediment placement information serves two purposes: 1) a basis for cumulative effects to sandy oceanfront beaches resulting from soft stabilization and dredge disposal activities (see the Discussion section), and 2) an assessment of the length of coastline where sandy beaches will attempt to be "held in place" as sea level rises. The latter increases the risk of further degrading habitat quality over time as the adverse impacts of these activities continue, perhaps in perpetuity (for a discussion of the potential adverse ecological impacts of beach nourishment and dredge disposal activities, between which "there is little to no difference" [Bush et al. 2004, p. 90], see Peterson et al. 2000, Peterson and Bishop 2005, Defeo et al. 2009, and Rice 2009). Again,

Figure 4. The known locations of sediment placement projects constructed as of 2015 were delineated with red lines in a Google Earth data layer, as shown here in Spring Lake, New Jersey. The slightly shorter red line on the left represents the location where the Town of Spring Lake periodically places dredged material from Wreck Pond. The longer red line on the right represents the federal Sandy Hook to Barnegat Inlet Beach Erosion Control Project, Asbury Park to Manasquan Beach Section.

published sources including peer-reviewed literature, government agency reports and permits, were used to compile the lengths of shoreline affected by beach nourishment and dredge disposal placement activities in each state. Where readily available published sources were absent for a geographic area, the beach nourishment database of the Program for the Study of Developed Shorelines (at http://beachnourishment.wcu.edu) was consulted and an inventory of projects in that region was added to the Excel database.

Beach Scraping

Beach scraping is the use of bulldozers to push up artificial levees or "dunes" with sediment from the beach (Figure 5). The bulldozers scrape the top layer of sand, oftentimes limited by permit conditions to one foot (0.3 m) depth, to push a mound of sand and create an artificial dune that functions like a levee at the back of a beach. Beach scraping can be conducted by individual property owners (including state agencies on state lands) or by local municipalities. This type of habitat modification is most common following storm events that have eroded the dunes. For the purposes of this assessment, beach scraping is considered distinct from the bulldozing of sediment that occurs as part of a sediment placement project. During the sediment placement projects, bulldozers and other heavy equipment shape new sediment into a predetermined, engineered profile. Beach scraping, on the other hand, uses the existing sediment on a beach to create an artificial dune or levee.

The locations and extents of beach scraping that was conducted during the three years after Hurricane Sandy, or November 2012 through December 2015, were inventoried. Beach scraping was identified both in aerial imagery and through state permits in some states (i.e., RI, NY). Aerial imagery consulted to identify beach scraping locations included Google Earth imagery covering the 3-year period as well as aerial imagery taken by the National Oceanic and Atmospheric Administration – National Geodetic Survey (NOAA-NGS) and the United States Geological Survey (USGS) following storm events during the 3 years after Hurricane Sandy. Identified areas of beach scraping are conservative, limited only to those locations documented in aerial imagery or through available coastal management permits.

The length of sandy beach habitat modified by beach scraping was calculated by delineating thick blue lines in Google Earth. The line segments are oriented parallel to the beach. The locations, dates and lengths of each beach scraping site were recorded in Microsoft Excel, along with the imagery source.

Figure 5. Beach scraping often is visible in aerial imagery, as shown here in Harvey Cedars, NJ, immediately following Hurricane Sandy, when two bulldozers are visible actively scraping the beach. The locations of beach scraping known to have modified sandy beach habitat from November 2012 through December 2015 were delineated with thick blue lines in a Google Earth data layer.

Sand Fencing

The locations of all sand fencing visible on imagery taken at any point during the three years after Hurricane Sandy, from November 2012 through December 2015, were identified using high resolution imagery available in Google Earth. Visible sand fencing may have been installed during those three years or may have been installed prior to Hurricane Sandy and was still present and identifiable in imagery from 2013 through 2015. Some sand, or snow, fencing may be installed and removed seasonally, while other sections of fencing may remain permanently and become buried in sand and vegetation. By zooming in to an eye elevation of 500 ft (152 m) or less, sand fencing is visible in high resolution imagery within Google Earth. The location of visible sand fencing was digitized using a heads-up approach in Google Earth, creating a data layer with contiguous sections of fencing delineated with thin, royal blue lines (Figures 6 and 7).

The digitized fencing lines were delineated based upon the style and orientation of the fencing. Where sand fencing was present in a solitary line, the line of fencing was traced (Figure 6A). When fencing was installed in a zigzag pattern or series of parallel rows, the centerline of the row of sand fencing was marked (Figure 6B). In locations where multiple rows of sand fencing were present, the longest contiguous section of fencing was delineated (Figure 7A). Adjacent lines of sand fencing were delineated as contiguous sections when no large gaps were present between the adjacent lines. That is, if only a narrow gap separated the two adjacent sections so private property owners could access the beach, the two sections were delineated as one contiguous line. Older sand fencing that was still visible within a vegetated dune system at the back of the beach was included if it was readily visible and identifiable because the fencing had modified the beach habitat by creating dunes in an artificially determined location and orientation; as long as the fencing was still visibly present, it was assumed that the fencing continued to modify the beach and its associated dune system.

The length of sand fencing was calculated by measuring the length of sandy beach modified by each contiguous section of sand fencing. This measurement did not measure the linear length of the fencing itself, but rather the linear length of sandy beach habitat modified by each section of fencing. These measurements were calculated by using the “ruler” or the “path” tool within Google Earth and were measured on a line parallel to the beach’s orientation (and the beach segment lines previously delineated). Where sand fencing was orientated perpendicular to the beach (Figure 7B), most often at property boundaries but also at beach access pathways, a minimum length of sandy beach habitat modified by that sand fence was considered 10 ft (3 m). Where rows of sand fencing overlap, the total length of beach modified by the sand fencing was counted without overlaps. Each sand fencing line segment was labelled with the community’s name and then a number representing the geographic order within that community, from north to south or east to west. For example, “Ocean City fence 19” is the 19th contiguous section of sand fencing in Ocean City, Maryland (MD), from north to south.

Figure 6. Sand fencing present on sandy beach habitat between November 2012 and December 2015 was identified and delineated in a Google Earth data layer, using thin royal blue lines to delineate each contiguous section of sand fencing. (6A) Where sand fencing was present in a solitary line, the line of fencing was traced. (6B) When fencing was installed in a zigzag pattern or series of parallel rows, the centerline of the sand fencing installation was traced.

Figure 7. (7A) In locations where sand fencing was present in multiple rows, the longest row, which modified the most length of sandy beach habitat, was delineated, as seen in the top image from Lido Beach in Hempstead, NY, along the South Shore of Long Island. (7B) Where sand fencing was installed perpendicular to the shoreline, as along these property boundaries at Lordship Beach in Stratford, CT, a minimum length of beach modified by the perpendicular fence was set at 10 ft (3 m).

RESULTS

As of 2015, 1,742.16 miles (2,803.73 kilometers [km]) of sandy shoreline was present between Georgetown, ME, and the North Carolina-South Carolina state boundary, with 1,650.68 miles (2,656.51 km) of sandy beach habitat present and 90.88 miles (146.26 km) where sandy beach habitat was absent seaward of hard stabilization structures, or armor (Table 1). Massachusetts (458.40 miles or 737.72 km) and North Carolina (322.26 miles or 518.63 km) had the greatest lengths of sandy beach habitat present in 2015. The total length of oceanfront shoreline, excluding inlets, is virtually the same in New Jersey and on the Long Island Sound and Atlantic Ocean shorelines of New York with approximately 127 miles (204 km) in each (Table 1). The New Hampshire (~10 miles or 16 km), Delaware (~25 miles or 40 km) and Maryland (~31 miles or 50 km) oceanfront shorelines are much shorter than the remaining states in the U.S. Atlantic Coast breeding range of the piping plover.

Table 1. The lengths of sandy oceanfront beach and shoreline in each state (from north to south) within the U.S. Atlantic Coast breeding range of the piping plover and the proportions that are developed and undeveloped as of 2015. The difference between the total shoreline length and the length of sandy beach is the length of shoreline that had no sandy beach present as of 2015 according to Google Earth imagery; therefore ~ 91 miles (~146 km) of shoreline in this area lacked sandy beaches due to the presence of armoring with hard structures.

State	Approximate Total Sandy Shoreline Length (miles)	Approximate Length of Sandy Beach (miles)	Percent of Sandy Shoreline Developed	Percent of Sandy Shoreline Undeveloped†
Maine	49.36	48.33	65%	35%
New Hampshire	10.76	9.93	86%	14%
Massachusetts	506.26	458.40	41%	59%
Rhode Island	48.76	46.48	34%	66%
Connecticut	106.41	88.29	55%	45%
NY – Long Island Sound	128.51	124.19	62%	38%
NY – Peconic Estuary	154.92	144.03	40%	60%
NY – Atlantic Ocean	125.69	122.57	44%	56%
New Jersey	127.62	125.33	65%	35%
Delaware	24.65	24.65	45%	55%
Maryland	31.10	31.10	29%	71%
Virginia	105.12	105.12	15%	85%
North Carolina	323.00	322.26	41%	59%
TOTAL	**1,742.16**	**1,650.68**	**45%**	**55%**

† Beach segments classified as "undeveloped" occasionally include a few scattered structures.

Table 2. The approximate shoreline lengths that are in public or NGO ownership in each state (from north to south) within the U.S. Atlantic Coast breeding range of the piping plover in 2015. These beaches include those in public ownership, ownership by non-governmental conservation organizations, and conservation easements. These miles of shoreline generally overlap with the miles of undeveloped beach but may also include some areas that have been developed with recreational facilities or other facilities (e.g., military bases).

State	Length of Shoreline in Public / NGO Ownership (miles)	Percentage of Shoreline in Public / NGO Ownership
Maine	13.68	28%
New Hampshire	5.31	55%
Massachusetts	241.50	53%
Rhode Island	26.13	56%
Connecticut	39.66	44%
NY – Long Island Sound	35.55	29%
NY – Peconic Estuary	62.53	43%
NY – Atlantic Ocean	61.60	50%
New Jersey	32.43	26%
Delaware	14.28	58%
Maryland	22.10	71%
Virginia	93.91†	89%
North Carolina	179.47	56%
TOTAL	**828.15**	**48%**

† An unknown portion of Cedar Island is privately owned but undeveloped. The Chincoteague NWR owns a number of island parcels. The total island length is included here.

The New Hampshire coast has the highest proportion of sandy oceanfront beaches that are developed (84%) and the Virginia coast is the least developed (15%). More than half (50%) of the sandy beach habitat in Maine, New Hampshire, the Long Island Sound shoreline of New York, and New Jersey has been modified by beachfront development (Table 1). Altogether, 775.27 miles (1,247.68 km; 45%) of sandy oceanfront shoreline from Maine through North Carolina are developed (Table 1). Nearly half of the total oceanfront sandy shoreline (828.15 miles or 1,332.78 km, 48%) is in public or NGO ownership, with Virginia (89%) and Maryland (71%) having the highest proportions (Table 2).

For every state, the length of oceanfront shoreline that has been armored with hard erosion control structures (armor) was measured (Table 3). The total length of shoreline between Georgetown, ME, and the North Carolina-South Carolina boundary that has been armored is at least 476.81 miles (767.35 km; 27% of the total shoreline length). This assessment is a minimum number because some structures are buried and not visible in aerial imagery; in addition, historical records or inventories of hard stabilization structures may be incomplete or unavailable to indicate where buried structures may exist. The Massachusetts coast has the greatest length of armored oceanfront beach by far, with 157.24 miles (253.05 km; 31%) of sandy shoreline modified by beachfront armor. The North Carolina and Maryland coasts are the least armored, with only 3% (9.05 miles or 14.56 km) and 5% (1.62 miles or 2.61 km) of their oceanfront shorelines, respectively, having beachfront armor as of 2015.

Massachusetts has the highest number of armor structures by far, with a total of 2,894 armor structures identified on sandy shoreline within the state in 2015 – 35% of all the armor structures identified from Maine to North Carolina (Table 4). As of 2015, there were 1,615 groins, 90 jetties, 21 breakwaters and 1,168 contiguous sections of seawalls, revetments and/or bulkheads along the sandy shoreline of Massachusetts. Connecticut and the Peconic Estuary shoreline of New York each have over 1,400 armor structures, both dominated by groins (944 in CT and 1,036 on the Peconic Estuary). Maryland (14) and Delaware (31) have the least number of armor structures, but they also have shorter shorelines. Altogether there were up to 5,145 groins, 235

Table 3. Approximate shoreline miles that have been modified by armoring with hard erosion control structures in each state (from north to south) within the U.S. Atlantic Coast breeding range of the piping plover in 2015. Note that these totals are minimum numbers, given missing data for some areas. Refer to the Methods section above for a description of how the lengths of armored shoreline were calculated. The percentage of sandy shoreline modified by armor (far right column) was calculated by dividing the total length of armored sandy shoreline by the total sandy shoreline length in Table 1.

State	Known Approximate Length of Armored Sandy Beach Shoreline (miles)	Approximate Length of Armored Shoreline with No Sandy Beach (miles)	Total Length of Armored Sandy Shoreline (miles)	Percentage of Sandy Shoreline Modified with Armor
Maine	14.93	1.681	16.61	33%
New Hampshire	6.91	0.833	7.74	72%
Massachusetts	109.38	47.86	157.24	31%
Rhode Island	4.62	1.895	6.51	13%
Connecticut	39.38	18.12	57.50	54%
NY – Long Island Sound	38.96	4.32	43.28	34%
NY – Peconic Estuary	37.05	10.016	47.07	30%
NY – Atlantic Ocean	32.51	3.12	35.63	28%
New Jersey	77.24	2.29	79.53	62%
Delaware	3.67	0	3.67	15%
Maryland	1.62	0	1.62	5%
Virginia	11.36	0	11.36	11%
North Carolina	8.30	0.743	9.05	3%
TOTAL	**385.93**	**90.88**	**476.81**	**27%**

Table 4. Approximate number of each type of armoring visible on the oceanfront beach in each state (from north to south) within the U.S. Atlantic Coast breeding range of the piping plover visible on Google Earth imagery between 1989 and late 2015 or early 2016 and/or reported in published documents. Note that multiple seawalls, bulkheads or revetments are counted as one structure if they are continuous with no separations; for example, if five individual properties each have an individual seawall protecting their property and the seawalls are attached to each other with no gaps, the armoring is counted as one seawall structure (Dallas et al. 2013) and its overall length is counted in Table 3 above.

State	Number of Groins	Number of Jetties	Number of Seawalls, Bulkheads and/or Revetments	Number of Breakwaters
Maine	1	7	120	0
New Hampshire	13	2	47	2
Massachusetts	1,615	90	1,168	21
Rhode Island	16	11	71	3
Connecticut	944	24	424	22
New York – Long Island Sound	594	21	280	4
New York – Peconic Estuary	1,036	50	310	14
New York – Atlantic Ocean	Up to 358	8	114	1
New Jersey	455	11	161	6
Delaware	25	2	4	0
Maryland	7	2	2	3
Virginia	Up to 47	3	33	19
North Carolina	34	4	152	1
TOTAL	**Up to 5,145**	**235**	**2,886**	**96**

jetties, 96 breakwaters, and 2,886 contiguous sections of seawalls, bulkheads and/or revetments along the sandy shoreline within the U.S. Atlantic Coast breeding range of the piping plover in 2015.

At least 398.80 miles (641.80 km; 24%)[2] of oceanfront shoreline between Georgetown, ME, and the North Carolina-South Carolina boundary have received artificial sand placement via dredge disposal activities, beach nourishment or restoration, dune construction, emergency berms, inlet bypassing, and inlet closure projects (Table 5). In most areas sediment placement projects are conducted in developed areas or adjacent to shoreline or inlet hard stabilization structures in order to address erosion, reduce storm damages, or ameliorate sediment deficits caused by inlet dredging and stabilization activities. The length of sandy shoreline modified by sediment

[2] The totals listed in Table 5 are minimum numbers due to insufficient data on the lengths and locations of several past projects in each state (see Rice 2015b and 2015c).

Table 5. The approximate lengths of authorized constructed (existing) sediment placement projects and those proposed in each state (from north to south) within the U.S. Atlantic Coast breeding range of the piping plover as of 2015; sediment placement projects include beach nourishment, artificial dune construction, inlet closure, and dredge disposal placement projects.

	Length of Shoreline Modified with Sediment Placement as of 2015 (miles)	**Length of Shoreline Proposed to be Modified with Sediment Placement (miles)**	**Percentage of Shoreline Modified with Sediment Placement as of 2015**
Maine	6.30 +	0.34	> 13%
New Hampshire	1.37 +	0	> 14%
Massachusetts	20.91 +	0.95	> 4%
Rhode Island	7.02 +	0	> 15%
Connecticut	16.27 +	2.36	> 15%
New York – Long Island Sound	6.56 +	1.94	> 5%
New York – Peconic Estuary	7.76 +	1.58	> 5%
New York – Atlantic Ocean	77.27	5.66	62%
New Jersey	80.31	17.60	63%
Delaware	12.05	0	49%
Maryland	31.10	0	100%
Virginia	30.91	0.08	39%
North Carolina	100.97	45.45	31%
TOTAL	**398.80 +**	**75.96**	**24%**

placement projects increased significantly after Hurricane Sandy. Prior to the hurricane, at least 337.98 miles (543.93 km), or 18%, of sandy shoreline was known to be modified by sediment placement (Rice 2015d). During the three years after Hurricane Sandy, approximately 50 miles (80 km) of sandy beach habitat was newly modified with sediment placement projects – a 15% increase. By the end of 2015, another 75.96 miles (122.25 km) of sandy shoreline was anticipated to be (in 2016-17) or proposed to be modified by sediment placement. If constructed, the anticipated and proposed sediment placement projects would increase the length of sandy shoreline modified by sediment placement to 474.76 miles (764.05 km), an increase from 24% to 27% of the sandy shoreline.

Although the coast of Maryland has the highest proportion of sediment placement activities its oceanfront shoreline at 100%, that percentage reflects historical activities that have not recurred in recent decades (Rice 2015c). Since 1980, sandy beach habitat in oceanfront Maryland has only been 53% modified by sediment placement. Therefore the Atlantic Ocean shoreline of New York and New Jersey have the highest proportion of sandy beach habitat modified by sediment placement in 2015, at 62-63% (Table 5). North Carolina, however, has more sandy beach habitat modified by sediment placement than any other state, with over 100 miles (160 km) modified as of 2015; because North Carolina has the second highest length of sandy shoreline within the U.S. Atlantic Coast breeding range of the piping plover, the proportion of habitat within the state of North Carolina that had been modified by sediment placement as of 2015 was 31%. Anticipated and proposed sediment placement projects would modify more sandy beach habitat in North Carolina than in any other state, by a factor of nearly 2.5.

Sandy beach habitat in the New England and Peconic Estuary states is much less modified by sediment placement projects than the states to the south, ranging from 3 to 15% (Table 5). Large scale, federally-maintained coastal storm damage reduction projects that place sediment on sandy beach habitat every few years for 50 years or more are rare north of Montauk, NY. Locally sponsored projects, particularly the placement of dredged material from nearby navigation channels, are more typical of the states north of Montauk, NY.

Beach scraping modified sandy beach habitat in each of the states within the U.S. Atlantic Coast breeding range of the piping plover during the three years after Hurricane Sandy (Table 6). The beaches of the Peconic Estuary of New York were the least modified by beach scraping, with only 0.02 miles (0.03 km) of sandy beach habitat modified by beach scraping between 2012 and 2015. Less than 1 mile (1.6 km) of sandy beach habitat in Maine, New Hampshire and Massachusetts was modified by beach scraping as well. The sandy beach habitat in New Jersey (20%) and the South Shore of Long Island (18%) were the most modified by beach scraping after Hurricane Sandy.

Table 6. The length and proportion of sandy beach within each state (from north to south) along the U.S. Atlantic Coast breeding range of the piping plover that was known to be modified with beach scraping from 2012 to 2015.

State	Length of Shoreline in Modified by Beach Scraping (miles)	Percentage of Shoreline Modified by Beach Scraping
Maine	0.10	0.20%
New Hampshire	0.18	2%
Massachusetts	0.41	0.1%
Rhode Island	3.10	7%
Connecticut	2.97	3%
NY – Long Island Sound	1.07	1%
NY – Peconic Estuary	0.02	0.01%
NY – Atlantic Ocean	22.48	18%
New Jersey	25.32	20%
Delaware	1.47	6%
Maryland	3.79	12%
Virginia	2.89	3%
North Carolina	4.84 +	> 2%
TOTAL	**68.64**	**4%**

Table 7. The length and proportion of sandy beach within each state (from north to south) along the U.S. Atlantic Coast breeding range of the piping plover that was modified with the installation of sand fencing from 2012 to 2015.

State	Length of Shoreline in Modified by Sand Fencing (miles)	Percentage of Shoreline Modified by Sand Fencing
Maine	0.95	2%
New Hampshire	0.20	2%
Massachusetts	18.50	4%
Rhode Island	8.49	18%
Connecticut	3.23	4%
NY – Long Island Sound	0.65	0.50%
NY – Peconic Estuary	0.79	0.60%
NY – Atlantic Ocean	57.85	46%
New Jersey	60.26	47%
Delaware	14.85	60%
Maryland	10.05	32%
Virginia	8.15	8%
North Carolina	62.69	19%
TOTAL	**246.66**	**15%**

Sand fencing was present in every state during the three years after Hurricane Sandy. Less than 1 mile (1.6 km) of sandy beach habitat was modified by sand fencing along the shorelines of Maine, New Hampshire, the North Shore of Long Island, and the Peconic Estuary of New York (Table 7). The sandy beach habitat of the shorelines of North Carolina, New Jersey, and the South Shore of Long Island were significantly modified by sand fencing between 2012 and 2015, with an average of ~60 miles (~97 km) of sandy beach habitat each modified by sand fencing. Sand fencing was much less common on sandy beaches that were backed by bluffs, which tend not to have dunes, than those on barrier islands or baymouth barriers where dunes are more common.

The Atlantic Coast Piping Plover Recovery Plan designates three recovery units in the U.S. portion of the breeding range (USFWS 1996). The New England recovery unit includes Maine, New Hampshire, Massachusetts, Rhode Island and Connecticut. The New York – New Jersey recovery unit includes the Long Island Sound, Peconic Estuary and Atlantic Ocean shorelines of New York plus New Jersey. The Southern Recovery Unit includes Delaware, Maryland, Virginia and North Carolina. Rice (2015d) provided a summary of the habitat modifications to both tidal inlet and sandy beach habitats within each of the recovery units and the breeding range as a whole as of 2012 conditions. Table 8 lists the lengths of sandy beach habitat present and absent within each state of the breeding range in 2015, plus the proportions of each that have been modified by development, armor, sediment placement, beach scraping and sand fencing.

As of 2015, beachfront development threatened 45% of the sandy beach habitat in the New England Recovery Unit and armor threatened 34%. While the magnitude of the threat of habitat modification due to beachfront development remained approximately the same as in 2012, the estimate of armor increased significantly with new information sources that updated the datasets used for Massachusetts in the 2012 assessment of Rice (2015d) (see the Massachusetts section for a full discussion). Sandy beach habitat was absent seaward of 70.39 miles (113.28 km) of armor in 2015 within the New England Recovery Unit, indicating a habitat loss of over 70 miles (113 km) in 2015. Sediment placement, beach scraping and sand fencing are minor but localized threats to sandy beach habitat in the New England Recovery Unit, each modifying less than 10% of the habitat in 2015 (Table 8). Approximately 45% of the sandy beach habitat present in the New England Recovery Unit in 2015 was in public or NGO ownership.

Beachfront development modified 49% of the sandy shoreline present in 2015 within the New York – New Jersey Recovery Unit. The estimated amount of habitat modification from beachfront armor increased significantly from 26% in 2012 (Rice 2015d) to 38% in 2015 due to the construction of many new armor structures as well as the identification of armor exposed by Hurricane Sandy. The magnitude of habitat modification from sediment placement on sandy beach habitat also increased significantly from 25% in 2012 (Rice 2015d) to 36% in 2015 with the construction of numerous new sediment placement projects. Habitat loss seaward of armor structures declined (at least temporarily), however, from ~27 miles (~43 km) to ~20 miles (~32 km) between 2012 and 2015 in New York and New Jersey. Sand fencing was also identified as a significant threat to sandy beach habitat, modifying ~120 miles (~193 km; 22%) of sandy beach habitat between 2012 and 2015 within the New York – New Jersey Recovery Unit. Beach scraping modified ~ 49 miles (~79 km; 9%) of sandy beach habitat between 2012 and 2015 in New York and New Jersey, making it a relatively minor but localized threat (Table 8). In 2015, over 192 miles (139 km) of sandy beach habitat was present in public or NGO owned beachfront lands, an increase of about 3 miles (5 km) from the 2012 estimate.

Beachfront development and sediment placement remained the most significant threats to sandy beach habitat within the Southern Recovery Unit in 2015. The estimated length of sandy shoreline modified by beachfront development declined from ~196 miles (~315 km) in 2012 to ~169 miles (~272 km) in 2015. However, this apparent decline is almost entirely the result of revised assessment methods used in Rice (2015b) applied to North Carolina, which resulted in an apparent decline of developed beachfront of ~26 miles (~42 km) (see the North Carolina section for a full discussion). The length of sandy shoreline modified by sediment placement in the Southern Recovery Unit increased substantially between 2012 and 2015. In 2015, ~218 miles (~351 km), or 45%, had been modified by sediment placement from Delaware to North Carolina compared with 163 miles (~262 km) of sandy shoreline, or 33%, in 2012. Although the length of sandy shoreline modified by sediment placement in Virginia increased slightly, nearly all of the increase in habitat modified by sediment placement in the three years after Hurricane Sandy occurred in North Carolina. Sand fencing modified 20% of the sandy beach habitat present in the Southern Recovery Unit between 2012 and 2015. Sixty percent (60%) of the sandy beach

Table 8. The proportion of sandy beach habitat modified by each type of habitat modification in each state (from north to south) within the U.S. Atlantic Coast breeding range of the piping plover as of 2015, or between November 2012 and 2015 in the cases of beach scraping and sand fencing.

	Length of Sandy Beach Habitat Present in 2015 (miles)	Length of Armored Shoreline with No Sandy Beach (miles)	Total Length of Sandy Shoreline in 2015 (miles)	Percentage of Shoreline Modified with Beachfront Development in 2015	Percentage of Shoreline Modified with Armor in 2015	Percentage of Shoreline Modified with Sediment Placement as of 2015	Percentage of Shoreline Modified with Beach Scraping Between 2012-2015	Percentage of Shoreline Modified with Sand Fencing Between 2012-2015
ME	48.33	1.681	49.36	64%	33%	> 13%	0.20%	2%
NH	9.93	0.833	10.76	84%	72%	> 14%	2%	2%
MA	458.40	47.86	506.26	41%	31%	> 4%	0.10%	4%
RI	46.48	1.895	48.76	31%	13%	> 15%	7%	18%
CT	88.29	18.12	106.41	46%	54%	> 15%	3%	4%
NY – LIS	124.19	4.32	128.51	61%	34%	5%	1%	0.50%
NY – Peconic	144.03	10.016	154.92	35%	30%	> 5%	0.01%	0.60%
NY – Atlantic	122.57	3.12	125.69	43%	28%	62%	18%	46%
NJ	125.33	2.29	127.62	64%	63%	61%	20%	47%
DE	24.65	0	24.65	45%	15%	49%	6%	60%
MD	31.10	0	31.10	29%	5%	100%	12%	32%
VA	105.12	0	105.12	15%	11%	39%	3%	8%
NC	322.26	0.743	323.00	41%	3%	31%	> 2%	19%
TOTAL	**1,650.68**	**90.878**	**1,742.16**	**44%**	**27%**	**23%**	**4%**	**14%**

habitat in Delaware was modified by sand fencing, and 32% in Maryland (Table 8). North Carolina had more sandy beach habitat modified by sand fencing than any other state, with nearly 63 miles (101 km) of habitat modified by sand fencing between 2012 and 2015. Beachfront armor and beach scraping, while relatively minor threats for the entire Recovery Unit at 5% and 3% respectively, remain a localized threat.

State-specific Results

Maine

Beachfront Development

In 2015 there were 50.45 miles (81.19 km) of sandy shoreline on the oceanfront shoreline of Maine, including 48.77 miles (78.49 km) of sandy beaches and 1.68 miles (2.70 km) of armored shoreline where no sandy beach was present (Table B-1). Where sandy beaches were present, the beachfront was 64% developed and 36% undeveloped. When sections of shoreline where sandy beaches were absent due to hard shoreline stabilization structures are included, the beachfront that was developed increases to 65% and the beachfront that was undeveloped decreases to 35%.

Prior to Hurricane Sandy, there were 48.88 miles (78.66 km) of sandy beach and 0.48 miles (0.77 km) of armored shoreline with no sandy beach along the Atlantic Ocean shoreline of Maine, for a total of 49.36 miles (79.44 km) of shoreline (Rice 2015b). The slight increase to 50.45 miles (17.32 km) of sandy shoreline is due to changes in the distribution of predominantly sandy beaches in areas that were previously predominantly rocky and changes in the length of armored, sandy shoreline with and without beach present. In 2012, 0.48 miles (0.77 km) of armored shoreline lacked sandy beaches where evidence indicated sandy beaches would be present in the absence of the armor. In 2015, the length of armored shoreline where sandy beaches were absent seaward of the armor increased to 1.68 miles (2.70 km).

While the overall length of sandy beach present in southern Maine remained relatively the same at ~49 miles (~79 km), its distribution changed slightly. The most significant changes in sandy beach habitat between 2012 and 2015 were in Biddeford and Wells. In Biddeford, immediately south of the Saco River dual jetties the shoreline curves and forms an embayment between the south jetty, Basket Island and Stage Island. In 2014-15, a tombolo fully emerged and connected Basket Island with the mainland with dry sandy beach. Extensive shoals also formed on both the east and west sides of the tombolo, including the full emergence of an islet located 600 - 700 ft (183 - 213 m) to the southeast of Basket Island. Historical imagery in Google Earth indicates that the tombolo, shoals and emergent islets are ephemeral features that periodically emerge. Their presence with dry sandy beach habitat in 2015 increased the length of sandy beach habitat in Biddeford by 0.69 miles (1.11 km) between 2012 and 2015. In Wells, on the other hand, the length of sandy beach habitat decreased by 0.60 miles (0.97 km) due to an increase in the length of sandy shoreline that was armored with no beach present in 2015.

The proportion of sandy shoreline that was modified by development prior to Hurricane Sandy was 68% (Rice 2015b). In 2015 this estimate declined slightly to 65%. The decline is due to due to (1) changes in the distribution of predominantly sandy beaches at the base of rock outcrops; (2) the shifting positions of inlets and their adjacent barrier spits, including the emergence of a tombolo to Basket Island and an adjacent islet in Biddeford; (3) an increase in the length of armored, sandy shoreline with no beach present; and (4) a revision to the methodology for identifying developed versus undeveloped beachfront. That is, the distance from the beach in which development was evaluated was limited to the area from the vegetation line to a shore parallel road or 500 ft (152.4 m), whichever was closer to the beach (see the Methods section for more information). This refinement resulted in slight changes to the proportions of beachfront classified as developed or undeveloped in Harpswell, on Chebeague Island and in Wells near the dual jetties at Wells (Webhannet River) Inlet.

The length of beachfront in public and/or NGO ownership did not significantly change in the three years following Hurricane Sandy (Table B-2). In 2012, 13.89 miles (22.35 km), or 28%, of the southern Maine oceanfront was in public or NGO ownership (Rice 2015b). No new sandy beachfront lands are known to have been placed in public or NGO-ownership in the three years after Hurricane Sandy. In 2015, 13.68 miles (22.02 km) of sandy beach were present within public or NGO-owned beachfront lands, a slight decrease due to the shifting of unstabilized inlets and their adjacent barrier spits. The proportion of sandy beach within public or NGO-ownership was unchanged at 28% in 2015.

Beach Armor Modifications

In 2012, prior to Hurricane Sandy, 31% of the sandy shoreline in southern Maine was modified by armor, or hard shoreline stabilization structures (Rice 2015b). One new section of armor was constructed in the three years after Hurricane Sandy, from 2012 through 2015; a small gap between two pre-existing revetments in Phippsburg was filled with a new revetment. One section of private bulkhead was repaired in Saco in 2014. In addition, 6 bulkheads or revetments that were buried in sediment and/or vegetation in 2012 were exposed in the three years after Hurricane Sandy, revealing a total of 0.68 miles (1.09 km) of armor in Scarborough, Saco, Biddeford and Kennebunkport that was not identified in Rice (2015b).

In 2015, 14.93 miles (24.03 km) of sandy beach habitat in southern Maine was modified by armor and another 1.68 miles (2.70 km) of armored shoreline had no beach present in early 2016 (Table B-3). The total length of sandy shoreline modified by armor in southern Maine as of early 2016 was 16.45 miles (26.47 km), or 33%. There were 7 jetties, 1 groin, and 120 contiguous sections of seawalls, bulkheads and/or revetments present along the southern Maine sandy oceanfront in late 2015 / early 2016[3] (Table 9). No breakwaters were present along sandy beach habitat in southern Maine in late 2015 / early 2016.

[3] Google Earth imagery available for the Maine coast from Georgetown to Wells for 2015 is dated September 7, 2015. From southern Wells south to Kittery, 2015 imagery is not available but imagery dated April 27, 2016, is available and was used for that section of coast.

Table 9. Approximate number of each type of armoring visible on the oceanfront beach in each community in southern Maine visible on Google Earth imagery between April 1998 and April 2016. Note that multiple seawalls, bulkheads or revetments are counted as one structure if they are continuous with no separations; for example, if five individual properties each have an individual seawall protecting their property and the seawalls are attached to each other with no gaps, the armoring is counted as one seawall structure and its overall length is counted in Table B-3 in Appendix B.

Community	Number of Groins	Number of Jetties	Number of Seawalls, Bulkheads and/or Revetments	Number of Breakwaters
Georgetown	0	0	0	0
Phippsburg	0	0	3	0
Harpswell	0	0	0	0
Chebeague Island	0	0	1	0
Little Chebeague Island	0	0	0	0
Long Island	0	0	0	0
Portland	0	0	6	0
Cape Elizabeth	1	0	3	0
Scarborough	0	1	5	0
Old Orchard Beach	0	0	25	0
Saco	0	1	10	0
Biddeford	0	1	15	0
Kennebunkport	0	1	9	0
Kennebunk	0	1	12	0
Wells	0	2	22	0
Ogunquit	0	0	3	0
York	0	0	6	0
Kittery	0	0	0	0
TOTAL	**1**	**7**	**120**	**0**

The communities with the most sandy beach habitat modified by armor remain Saco (40%), Old Orchard Beach (46%), Biddeford (47%), Kennebunk (52%), Kennebunkport (64%), Wells (81%) and York (83%). In contrast, the communities or islands of Georgetown, Harpswell, Little Chebeague Island, Long Island, Great Diamond Island, Little Diamond Island, Cushing Island, Kittery and Gerrish Island had no hard stabilization structures identified on their sandy beaches. Hard stabilization structures can also be found on the non-sandy sections of shoreline in Maine, but those structures were not included in this assessment.

The length of sandy shoreline where sandy beaches were absent seaward of armor structures increased from 0.48 miles (0.77 km) to 1.68 miles (2.70 km) in southern Maine between 2012 and late 2015 or early 2016. In 2012, the 0.48 miles (0.77 km) of armored shoreline where sandy beach habitat was absent were located entirely in Saco (Rice 2015b). In 2015, the length of armored shoreline lacking beaches in Saco decreased to 0.33 miles (0.53 km) and new sections of armored shoreline where beaches were absent were identified in Portland, Biddeford, Kennebunk and Wells (Table B-3).

Proposed and Anticipated Habitat Modifications
In 2013 the USACE proposed a shoreline damage mitigation project in the Camp Ellis section of Saco, immediately north of the Saco River inlet jetties (USACE 2013l, 2013m). The proposed project includes the construction of a new spur jetty on the north jetty that would extend 750 ft (229 m) north from a point 1,475 ft (450 m) offshore of the shoreline. Modifications to reinforce the 400 ft (122 m) of the north jetty extending offshore from the new jetty spur were also proposed. The proposed Camp Ellis Beach Shoreline Damage Mitigation Project would also place sediment along the shoreline immediately north of the north jetty (see the Sediment Placement section below).

Sediment Placement Modifications

Sediment placement has modified sandy beach habitat in only limited locations on southern Maine's oceanfront coast, primarily through the placement of dredged material from navigation channels. Sediment dredged from the inlets and associated channels at the Scarborough River, Saco River, Kennebunk River, Webhannet River (Wells Harbor) and Ogunquit River have been placed on adjacent beaches (Rice 2015b). Prior to Hurricane Sandy, at least 6.30 miles (10.13 km), or 13%, of the state's sandy beach habitat was known to be modified by sediment placement. The precise length and location of the dredged material placement at Biddeford was not available (Rice 2015b).

In the three years after Hurricane Sandy, sediment (150,000 cubic yards [cy], or 114,683 cubic meters [m^3]) dredged from the Wells (Webhannet River) inlet and its associated channels was placed on an unknown length of sandy beach in Drakes Island Beach (north of the inlet) and Wells Beach (south of the inlet) in late 2013 (Town of Wells 2013, USACE New England District website). The USACE also placed 114,300 cy (87,389 m^3) of sediment dredged from the Scarborough River inlet and its associated channels on an unknown length of Western Beach in Scarborough in 2014-15.

As of 2015, the length of sandy beach habitat in southern Maine modified by sediment placement remains the same at more than 6.30 miles (10.13 km), with the length of sandy beach habitat modified in Biddeford unknown (Table B-4). At least 13% of Maine's oceanfront sandy beach habitat has been modified by sediment placement.

Proposed and Anticipated Habitat Modifications
In 2013 the USACE and the City of Saco proposed a shoreline damage mitigation project at Camp Ellis beach that would place 365,000 cy (279,062 m^3) of sediment from an upland source along 3,250 ft (991 m) of shoreline as mitigation for erosion caused by the federal navigation project at the Saco River. The proposed Camp Ellis Beach Shoreline Damage Mitigation Project would modify the north jetty on the Saco River and place sediment along the shoreline immediately north of the north jetty, which would restore sandy beach habitat to ~1,760 ft (536 m) of armored shoreline where sandy beaches were absent in 2015. Approximately 1,800 ft (549 m) of the proposed sediment placement area would modify sandy shoreline that has not

previously been modified by sediment placement. If constructed, beach renourishment is proposed to place 116,000 to 236,000 cy (88,688 to 180,435 m^3) of sediment on the beach every 12 years (USACE 2013l, 2013m).

In 2016 the USACE proposed to place 150,000 cy (114,683 m^3) of sediment dredged from the Saco River and its associated inlet channels on 450 ft (137 m) Camp Ellis beach in Saco as beneficial use of the material dredged from the federal navigation project “to alleviate on-going erosion of the beach area” (USACE 2016e, p. 2). The proposed sediment placement area has previously been modified by sediment placement.

Lastly, in late 2015 the USACE proposed to place 375,000 cy (386,708 m^3) of sediment dredged from the Piscataqua River and its associated inlet channels in a nearshore placement site off Wells Beach. Sediment dredged from Wells Harbor has previously been placed in the nearshore off Wells Beach in 2002, 2005 and 2012 (Town of Wells Beach 2013, Wigglesworthy 2015). The proposed project would relocate sediment from one river system to another, which would be highly uncommon.

Beach Scraping Modifications

The threat from beach scraping on the Atlantic Ocean shoreline of southern Maine is minimal, limited to 0.10 miles (0.16 km) of sandy beach, or 0.2%, from late 2012 to 2015 (Table B-5). Only 2 sections of beach scraping were identified in imagery for the three years after Hurricane Sandy, modifying a total of 507 ft (154 m), or 5%, of sandy beach in Saco on Seaside Avenue and Surf Street. The general absence of beach scraping is due to the predominantly rocky shoreline for most of the Maine oceanfront – dunes are uncommon and protected by the Maine Natural Resources Protection Act.

Sand Fencing Modifications

The threat from sand fencing on the southern Maine oceanfront shoreline is minimal, limited to 0.95 miles (1.53 km) of sandy beach, or 2%, from late 2012 to 2015 (Table B-6). Only 11 sections of sand fencing were identified in imagery for the three years after Hurricane Sandy, modifying a total of 5,037 ft (1,535 m) of sandy beach habitat. The 11 sections of sand fencing all were located in Scarborough, Saco and Ogunquit, modifying 4% of Scarborough and Saco’s beaches but 45% of Ogunquit’s sandy beach habitat. The general absence of sand fencing is due to the predominantly rocky shoreline for most of the Maine oceanfront – wide, sandy beaches lacking armor where sand fencing would be most successful to trap windblown sand are uncommon.

Summary

Only about 2% of Maine’s 3,500 mile (5,633 km) shoreline has sandy beaches (Slovinsky and Dickson 2003). The remaining coast is composed mostly of mud flats and salt marshes and to a lesser degree of rocky cliffs (Kelley et al. 1989). Nearly all of Maine’s sandy beaches are in the southern part of the state south of Georgetown within Sagadahoc, Cumberland and York Counties (Kelley et al. 1989, Beach Stakeholders Group 2006). Because Maine's tidal range is 12 to 24 ft (3.66 to 7.32 m), some of the highest in the world (MDIFW 2005), sandy beaches may be quite narrow at high tide but very wide at low tide.

The length of sandy beach habitat in southern Maine was approximately the same in 2012 and 2015, at ~49 miles (~79 km). The Beach Stakeholders Group (2006) found approximately 75 miles (120.70 km) of beaches in Maine, with less than 40 miles (64.37 km) of sandy beaches and the remaining portion coarser gravel and/or boulder beaches. The Maine Geological Survey recently identified approximately 37.5 miles (60.35 km) of sandy beaches from Georgetown south (Peter Slovinsky, Maine Geological Survey, pers. communication, May 15, 2015). The inclusion of some mixed substrate beaches, as described in Rice (2015b), is the most likely reason why these 2012 and 2015 inventories identified a greater length of sandy beaches in southern Maine than these other sources.

Sandy beach habitat in southern Maine is minimally threatened by beach scraping (0.2%), sand fencing (2%), and sediment placement (>13%). Beachfront development (65%) and armor (33%) are significant threats to sandy beach habitat in Maine, however.

New Hampshire

Beachfront Development

In 2015 there were 10.76 miles (17.32 km) of sandy shoreline on the oceanfront shoreline of New Hampshire, with 9.93 miles (15.98 km) of sandy beaches and 0.83 miles (1.34 km) of armored shoreline where no sandy beach was present (Table C-1). Where sandy beaches were present, the beachfront was 84% developed and 16% undeveloped. When sections of shoreline where sandy beaches were absent due to hard shoreline stabilization structures are included, the beachfront that was developed increases to 86% and the beachfront that was undeveloped decreases to 14%.

Prior to Hurricane Sandy, there were 9.58 miles (15.41 km) of sandy beach and 0.19 miles (0.31 km) of armored shoreline with no sandy beach along the Atlantic Ocean shoreline of New Hampshire, for a total of 9.77 miles (15.72 km) of shoreline (Rice 2015b). The slight increase to 10.76 miles (17.32 km) of sandy shoreline is due to changes in the distribution of predominantly sandy beaches in areas that were previously predominantly rocky and changes in the length of armored, sandy shoreline with and without beach present.

Rice (2015b) estimated that the proportion of sandy shoreline that was modified by development prior to Hurricane Sandy was 87%. In 2015 this estimate declined slightly to 86%. The apparent decline is due to a revision to the methodology for identifying developed versus undeveloped beachfront. That is, the distance from the beach in which development was evaluated was limited to the area from the vegetation line to a shore parallel road or 500 ft (152.4 m), whichever was closer to the beach (see the Methods section for more information). This refinement resulted in slight changes to the proportions of beachfront classified as developed or undeveloped in New Castle, Rye and North Hampton.

The length of beachfront in public and/or NGO ownership did not significantly change in the three years following Hurricane Sandy along the New Hampshire oceanfront (Table C-2). In 2012, 5.11 miles (8.22 km), or 53%, of the New Hampshire beachfront was in public or NGO ownership (Rice 2015b). No new sandy beachfront lands are known to have been placed in public or NGO-ownership in the three years after Hurricane Sandy. In 2015, the length of sandy beach present within public or NGO-owned beachfront lands was 5.31 miles (8.55 km) of sandy beach were present within public or NGO-owned beachfront lands, a slight increase due to the shifting presence or absence of sandy beach seaward of armor structures. The proportion of sandy beach within public or NGO-ownership was unchanged at 53% in 2015.

Beach Armor Modifications

In 2012, prior to Hurricane Sandy, 73% of the sandy shoreline in New Hampshire was modified by armor, or hard shoreline stabilization structures (Rice 2015b). No new armor was constructed in the three years after Hurricane Sandy, from 2012 through 2015. One section of private revetment was repaired in Rye, with new armor stone added to the seaward side of the revetment, extending it farther across the narrow beach.

In 2015, 6.91 miles (11.12 km) of sandy beach habitat in New Hampshire was modified by armor and another 0.83 miles (1.34 km) of armored shoreline had no beach present in early 2016 (Table C-3). The total length of sandy shoreline modified by armor in New Hampshire as of early 2016 was 7.74 miles (12.46 km), or 72%. There were 2 jetties, 13 groins, and 47

Table 10. Approximate number of each type of armoring visible on the oceanfront beach in each community in New Hampshire visible on Google Earth imagery between April 1992 and April 2016. Note that multiple seawalls, bulkheads or revetments are counted as one structure if they are continuous with no separations; for example, if five individual properties each have an individual seawall protecting their property and the seawalls are attached to each other with no gaps, the armoring is counted as one seawall structure and its overall length is counted in Table C-3 in Appendix C.

Community	Number of Groins	Number of Jetties	Number of Seawalls, Bulkheads and/or Revetments	Number of Breakwaters
New Castle	0	0	4	0
Rye	2	0	20	2
North Hampton	0	0	5	0
Hampton	11	1	7	0
Seabrook	0	1	11	0
TOTAL	**13**	**2**	**47**	**2**

contiguous sections of seawalls, bulkheads and/or revetments present along the New Hampshire oceanfront in late 2015 / early 2016 (Table 10). Although 2 breakwaters are present at Rye Harbor, they lacked sandy beaches on the shoulders of the harbor entrance in early 2016.

Proposed and Anticipated Habitat Modifications
The USACE has proposed to repair the north jetty at Hampton River Inlet in 2016. The repairs were originally proposed in 2014 but the bids received were too high and the work delayed (Pease Development Authority 2015).

Sediment Placement Modifications

Sediment placement has modified sandy beach habitat in only three known locations on New Hampshire's oceanfront coast: Wallis Sands SP, Hampton Beach SP, and Seabrook (Rice 2015b). Both Hampton Beach SP and Seabrook beaches have been modified by the placement of sediment dredged from the adjacent Hampton River inlet and its associated channels. Prior to Hurricane Sandy, at least 1.37 miles (2.20 km), or 14%, of the state's sandy beach habitat was known to be modified by sediment placement. The precise length and location of the dredged material placement at Seabrook was not available (Rice 2015b).

In the three years after Hurricane Sandy, sediment (167,947 cy) dredged from the Hampton River inlet and its associated channels was placed on an unknown length of sandy beach in Hampton Beach SP (north of the inlet) and Seabrook (south of the inlet) between November 2012 and March 2013 in a project that was scheduled prior to the hurricane (Pease Development Authority 2015).

As of 2015, the length of sandy beach habitat in oceanfront New Hampshire modified by sediment placement remains the same at more than 1.37 miles (2.20 km), with the length of sandy beach habitat modified in Seabrook unknown (Table C-4). At least 14% of New Hampshire's oceanfront sandy beach habitat has been modified by sediment placement.

Beach Scraping Modifications

The threat from beach scraping on the Atlantic Ocean shoreline of New Hampshire is minimal, limited to 0.20 miles (0.32 km) of sandy beach, or 2%, from late 2012 to 2015 (Table C-5). Only 1 section of beach scraping was identified in imagery for the three years after Hurricane Sandy, modifying a total of 957 ft (292 m) of sandy beach at Sawyers Beach in Rye. The general absence of beach scraping is due to the predominantly rocky shoreline for most of the New Hampshire oceanfront – dunes are uncommon and wide, sandy beaches are most common in Hampton and Seabrook at the south end of the state's coastline.

Sand Fencing Modifications

The threat from sand fencing on the New Hampshire oceanfront shoreline is minimal, limited to 0.20 miles (0.32 km) of sandy beach, or 2%, from late 2012 to 2015 (Table C-6). Only 7 sections of sand fencing were identified in imagery for the three years after Hurricane Sandy, modifying a total of 1,047 ft (319 m) of sandy beach habitat. The 7 sections of sand fencing all were located in Seabrook, modifying 14% of the community's sandy beach habitat. The general absence of sand fencing is due to the predominantly rocky shoreline for most of the New Hampshire oceanfront – dunes are uncommon and wide, sandy beaches are most common in Hampton and Seabrook at the south end of the state's coastline.

Summary

New Hampshire's oceanfront beaches are most threatened by habitat modification from development (84%) and armor (72%). The length of sandy beach habitat present in oceanfront New Hampshire in late 2015 / early 2016 is the least in the entire U.S. Atlantic Coast breeding range of the piping plover at ~10 miles (~16 km), yet the state's sandy beach habitat is the most modified by development and armor. Sandy beach habitat along New Hampshire's oceanfront is minimally threatened by beach scraping (2%), sand fencing (2%), and sediment placement (14%). Habitat modifications are not uniformly distributed along New Hampshire's sandy beaches, with the wider, more continuous sandy beaches in Hampton and Seabrook at the southern end of the state the only areas modified by sand fencing, beach scraping and recent sediment placement.

Massachusetts

Beachfront Development

In 2015 there were 458.40 miles (737.72 km) of sandy beach present along the Massachusetts coastline, not including inner harbors and bays (Table D-1). Sandy beach habitat was absent seaward of armor structures along an additional 47.86 miles (77.02 km) of shoreline where evidence suggested sandy beach habitat would be present in the absence of the armor (Table D-3). Altogether a total of 506.26 miles (814.75 km) of sandy shoreline was identified along the Massachusetts coast, excluding inner harbors and bays, in 2015.

Prior to Hurricane Sandy, there were 460.56 miles (741.20 km) of sandy beach and 47.59 miles (76.59 km) of armored shoreline with no sandy beach along the shoreline of Massachusetts, for a total of 508.15 miles (817.79 km) of sandy shoreline[4]. The small decrease to 506.26 miles

[4] Rice (2105b) utilized data provided by the Massachusetts Coastal Erosion Commission (MA CEC) and the Massachusetts Office of Coastal Zone Management to calculate the length of sandy beach within each Massachusetts coastal community and the proportion of the sandy beach that was developed (MA CEC 2015a, 2015b). These data were limited because the presence of a beach was based upon outdated data from 1990-1991, included inner harbors and bays, and may have not distinguished between beaches that were predominantly sandy

(814.75 km) of sandy shoreline is due to changes in the distribution of predominantly rocky beaches[5] in areas that were previously predominantly sandy, plus changes in sandy beach habitat at unstabilized inlets and barrier spits.

Sandy beach habitat in Massachusetts may occur directly adjacent to rocky beach habitat, and the distribution of predominantly sandy versus predominantly rocky beaches may shift over time. On Noman's Land Island NWR most of the island's shoreline is composed of predominantly rocky beach and only about one-quarter of the island's shoreline was sandy beach in 2015, a reduction from the length of sandy beach present in 2012. Sections of beach in Westport, Chilmark (Martha's Vineyard), and on Nashawena Island in Gosnold also converted from predominantly sandy in 2012 to predominantly rocky in 2015. Lengthy sections of rocky beach were directly adjacent to sandy beach habitat in 2015 in Gosnold, Chilmark, Plymouth, Bourne, and Dartmouth. Altogether there were at least 26.57 miles (42.67 km) of rocky beach directly adjacent to sandy beaches on the Massachusetts shoreline (excluding the Elizabeth Islands) in 2015; additional rocky beaches were present along sections of shoreline that were not adjacent to predominantly sandy beach habitat.

Barrier spits and inlet shorelines are highly dynamic, shifting in length and location over time. Between 2012 and 2015, sandy beach habitat increased by 11.28 miles (18.15 km) in some locations but decreased by 13.45 miles (21.65 km) in other locations. Near the boundary between Cape Cod NS and Monomoy NWR in Chatham, for example, Chatham Inlet reopened in 2013, redistributing the sandy beach habitat on the Nauset spit and South Beach. Chatham Inlet periodically opens and closes, and was most recently open from the 1950s to the early 1990s (Rice 2016). Then in 2014, a second inlet opened on the north side of Chatham Inlet. As of 2015, five islets were fully emergent within the dual-inlet complex and the shorelines both to the north and south had shifted position. Between 2012 and 2015, the length of sandy beach habitat present in and near the new Chatham Inlet dual-inlet complex increased by more than 4,400 ft (1,341 m). Changes in sandy beach habitat occurred at other inlets as well. A new islet emerged at Mill Creek inlet in Chatham. Four new islets formed near Tuckernuck and Muskeget Islands near Nantucket. The closure of the inlets to Richmond Pond in Westport, Katama Bay in Edgartown (Martha's Vineyard) and James Pond in West Tisbury (Martha's Vineyard) created small amounts of sandy beach habitat.

The length of sandy beach habitat present in 2015 at a number of inlet complexes and barrier spits decreased in a number of other locations. Wingaersheek Beach in Gloucester, on the north side of Annisquam River Inlet, shortened by almost 500 ft (152 m). Four islets that were present

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versus those that were composed primarily of cobble or boulders. Rice (2015b) identified an estimated 729.94 miles (1,124.72 km) of beach habitat along the Massachusetts coast in 2012. The figure cited here, 505.73 miles (813.89 km) of sandy shoreline, was determined using Google Earth imagery from 2012 to identify predominantly sandy beach habitat, excluding inner harbor and bay shorelines; this total length of sandy shoreline updates the total included in Rice (2015b) that utilized the limited data from MA CEC (2015a, 2015b).

[5] Rocky beaches are defined as beaches composed predominantly of gravel, cobble and/or boulders. Rocky beaches may have minor amounts of sandy substrate. Solid rock outcrops are not considered rocky beaches. Beaches in the study area may convert from predominantly sandy to predominantly rocky or vice versa seasonally or yearly; for the purposes of this inventory, the substrate was categorized using the highest resolution imagery available within Google Earth for 2015 or early 2016. Only rocky beach segments of shoreline directly adjacent to sandy beach habitat are included, not including the Elizabeth Islands which have predominantly rocky beach shorelines.

in the New Inlet complex in Scituate prior to Hurricane Sandy in 2012 were submerged in 2015. The barrier spit on the west side of Bucks Creek Inlet in Chatham shortened by approximately 600 ft (183 m) between 2012 and 2015. In Dennis, the barrier spit on the west side of Swan Pond Inlet shortened by approximately 670 ft (204 m), possibly by the inlet cutting a new channel through the spit. The spit on the west end of Esther Island, on Nantucket, shortened by ~415 ft (126 m) during the three years after Hurricane Sandy. On nearby Tuckernuck Island, the spit on the northwest tip of the island receded by ~4,400 ft (1,341 m) from 2012 to 2015.

Where sandy beaches were present in 2015, the beachfront was 35% developed and 65% undeveloped. When sections of shoreline where sandy beaches were absent due to hard shoreline stabilization structures are included, the beachfront that was developed increases to 41% and the beachfront that was undeveloped decreases to 59%. In 2012, the proportion of sandy shoreline (where sandy beach habitat was both present and absent) that was developed was 39%. Three years later in 2015, the length of sandy shoreline modified by development, including segments of shoreline lacking sandy beach habitat due to armor, was 41%, a small increase due to a net increase in the length of sandy beach habitat modified by development during that time period.

The length of sandy beach habitat modified by development in Massachusetts increased from 2012 to 2015 due to the construction of new buildings but also the application of the methodology used in Rice (2015b) to identify beachfront development in other states. In Rice (2015b), the length of sandy beach habitat modified by development along the Massachusetts coast was based on the data and analysis of MA CEC (2015a, 2015b). For this 2015 assessment, the methodology was revised to be consistent with that used in Rice (2015b) along the other states from Maine to New York. That is, the distance from the beach in which development was evaluated was limited to the area from the vegetation line to a shore parallel road or 500 ft (152.4 m), whichever was closer to the beach (see the Methods section for more information)[6]. This refinement resulted in slight changes to the proportions of beachfront classified as developed or undeveloped in Cohasset, Dennis, Truro, Dartmouth, Oak Bluffs, Tisbury and Nantucket.

The construction of new buildings also changed the length of sandy beach habitat modified by development in Massachusetts in the three years after Hurricane Sandy. At East Beach in Westport, approximately 2,800 ft (853 m) of sandy beach was modified by development during the three years after Hurricane Sandy. The beachfront along East Beach Road was previously developed, but a number of private properties were damaged by Hurricane Irene in 2011 and the beachfront remained mostly undeveloped when Hurricane Sandy made landfall in October 2012. As of 2015, many of the properties were redeveloped and the beachfront converted back to developed. In Mashpee, the construction of new buildings modified more than 350 ft (107 m) of sandy beach habitat with development. New development also modified short sections of sandy beach habitat in Bourne, Mattapoisett, Edgartown and Nantucket.

The distribution of sandy beach habitat modified by beachfront development also shifted with the removal and relocation of buildings along the Nantucket shoreline between 2012 and 2015, locally decreasing the length of sandy beach habitat modified by development. On Red Barn

[6] The methodology used by MA CEC (2015a, 2015b) measured development within approximately 150 to 200 meters (492 to 656 feet) of the beach.

Road near Sheep Pond on the south side of Nantucket, one home was removed in 2012-13, decreasing the length of sandy beach modified by development along ~265 ft (81 m) of shoreline. At nearby Sheep Pond Road, 2 homes were removed and 2 other homes were relocated landward, decreasing the local length of sandy beach habitat modified by development by ~550 ft (168 m). One home in Madaket near Smith Point was removed in 2014-15. One the north shore of Nantucket, near Eel Point, 1 building was removed and 3 other buildings were relocated landward between 2012 and 2015; none of the relocated buildings were set back greater than 500 ft (183 m) from the beach, however, and the sandy beach habitat remained modified by development. Altogether, the length of sandy beach habitat modified by development increased by 12.47 miles (20.07 km) in some areas and decreased by 4.31 miles (6.94 km) in other areas, for a net increase of 8.16 miles (13.13 km) during the three years after Hurricane Sandy.

In 2012, 217.49 miles (350.02 km) of the Massachusetts sandy beachfront was in public or NGO ownership (Rice 2015b). A new information source (i.e., OLIVER 2016) recently identified a number of new sandy beachfront tracts in public or NGO ownership. In 2015, 241.50 miles (388.65 km) of sandy beach were present within public or NGO-owned beachfront lands, an increase primarily due to newly identified beachfront tracts in public or NGO ownership but also partly due to the shifting of unstabilized inlets and their adjacent barrier spits (Table D-2). The new information source expanded the inventory of public and NGO-owned lands, or lands on which there are conservations easements, on the offshore islands in particular. Approximately 28 miles (45 km) of sandy beach habitat on Nantucket was in public or NGO ownership or easement in 2015, and more than 25 miles (40 km) on Martha's Vineyard. All of Muskeget Island near Nantucket is in public or NGO ownership (2.60 miles or 4.18 km), and nearly 3 miles (5 km) of the sandy beach habitat on nearby Tuckernuck Island is owned by or has easements from public or NGO entities. There is a conservation easement on Nashawena Island, which is mostly rocky beach but had 1.77 miles (2.85 km) of sandy beach present in 2015. The proportion of sandy beach in Massachusetts within public or NGO-ownership was 53% in 2015.

Beach Armor Modifications

In 2015, the sandy beaches on the shoreline of Massachusetts were modified with 109.38 miles (176.03 km) of armor (Table D-3). In 2012, prior to Hurricane Sandy, 106.08 miles (170.72 km) of sandy beach habitat were known to be armored. An increase of 3.30 miles (5.31 km) of armored sandy beaches between 2012 and 2015 is due to both the construction of new armor (0.26 miles or 0.42 km) and the identification of new armor that was exposed and newly identified during the three years after Hurricane Sandy (3.04 miles or 4.89 km). Another 47.86 miles (77.02 km) of shoreline were armored but did not have sandy beaches present in May 2015; this is approximately the same as the 47.59 miles (79.59 km) of sandy shoreline with no beach present in 2012. Altogether 157.24 miles (253.05 km), or 31%, of sandy shoreline (with and without beaches present in May 2015) was modified by armor on the Massachusetts coast, excluding inner harbors and bays, in 2015.

The extent of sandy beach habitat modified by armor in 2012 has been revised from the estimates presented in Rice (2015b), which relied upon data from MA DCR (2009), Fontenault et al. (2013) and MA CEC (2015a, 2015b). The total length of sandy shoreline armored in

Massachusetts described in Rice (2015b) using the MA CEC (2015a, 2015b) datasets was 180.24 miles (290.07 km). Using Google Earth imagery, as described in the *Beachfront Development* section above, the location and length of sandy beach habitat modified by armor in Massachusetts in 2012 was measured using the same methodology that was applied to all the other states. In 2012, the updated total length of sandy shoreline modified by armor in 2012 was 153.67 miles (247.31 km), or 30%.

In the 2012 baseline habitat inventory (Rice 2015b), the number of hard shoreline stabilization structures located on sandy beaches in Massachusetts was unknown. Using data from Fontenault et al. (2013) and MA DCR (2009), Rice (2015b) identified up to 5,378 seawalls / bulkheads / revetments, 2,030 groins, 73 jetties and 21 breakwaters present along the entire Massachusetts shoreline prior to Hurricane Sandy. With this updated analysis, the number of these structures that were present *on the sandy beaches included in the new baseline inventory* was calculated. A total of 1,164 contiguous sections of seawalls/bulkheads/revetments, 1,611 groins, 89 jetties and 21 breakwaters were identified.

The number of seawalls, bulkheads and revetments declined significantly from the estimates provided in Rice (2015b) due to the use of the methodology described in Dallas et al. (2013) where contiguous sections of walls were counted as one structure, and because there are a high number of seawalls, revetments and bulkheads built on the rocky sections of shoreline in Massachusetts as well as along inner harbors and bays that were excluded from this analysis. In addition, there are several locations where multiple rows of seawalls, revetments or bulkheads were found; these rows of walls were counted as individual structures in Fontenault et al. (2013) and MA DCR (2009) but were merged in this analysis to calculate the total length of sandy beach armored by the walls in that location (and notations were made for each instance). The number of jetties increased from 73 (in Rice 2015b) to 89 because there are some jetties that are located at inlets that were not open prior to Hurricane Sandy or that were landlocked, detached from land, or on small channels that were not identified as inlets in Rice (2015a).

In the three years after Hurricane Sandy, a number of hard shoreline stabilization structures (armor) were repaired or reconstructed on the Massachusetts coast. Nine (9) new revetments, bulkheads or seawalls and 1 new groin were constructed between 2012 and 2015. Seven (7) revetments or bulkheads were extended during the same time period. During the three years after Hurricane Sandy a number of armor structures were exposed that were buried prior to the hurricane and not previously identified in Rice (2015b).

Hurricane Sandy damages to the dual jetties at the Merrimack River inlet to Newburyport Harbor were repaired in between 2012 and 2015 by the USACE; no modifications to the size or location of the jetties were made (USACE New England District website). The beach on the north side of the jetty expanded during the three years after Hurricane Sandy, lengthening the amount of sandy beach habitat modified by the jetty (which is oriented at an oblique angle to the shoreline). The state repaired 3 groins and the seawall at Winthrop Beach in 2013-14 (MA DCR 2015). Jetties were repaired at Green Harbor inlet in 2014 and the east jetty was scheduled for further repairs in late 2016 for damages resulting from a January 2015 storm (Kashinsky 2014, Sparks 2016). The jetties at Nantucket Harbor were scheduled for repairs in 2015 but delayed until 2016 (USACE

2014y, 2016m). The USACE also repaired jetties at Menemsha Creek, Rockport Harbor, and Cohasset Harbor (USACE 2016m, USACE North Atlantic Division website).

A number of new armor structures were constructed between 2012 and 2015. On Plum Island in Newburyport, a new geotube revetment was constructed across 4 properties. In adjacent Newbury, one new revetment was constructed along 23 contiguous properties and another revetment was constructed along 4 other contiguous properties. These 3 new revetments extended along over 2,360 ft (719 m) of shoreline but only increased the length of sandy beach habitat modified by beach armor by ~230 ft (70 m) due to a pre-existing groin field that had already modified that area of shoreline. In Winthrop, one new groin was constructed by MA DCR at the north end of the existing groin field in 2014 (MA DCR 2015). In the Sagamore area of Bourne, near Sandwich, 2 new revetments were constructed between 2012 and 2014 along Sagamore Road; although the revetments extended along ~ 270 ft (82 m) of shoreline, both were constructed with pre-existing groin fields and did not increase the length of sandy beach habitat modified by armor. In nearby Sandwich, a nearly 400 ft (122 m) revetment was constructed in 2014-15 along Bay Beach Lane, but again was constructed within a pre-existing groin field. At Nonquitt Marsh in Dartmouth, two revetments were constructed to armor the channel of a new inlet. Finally, one new 210 ft (64 m) long bulkhead/seawall was constructed along Edgartown Oak Bluffs Road in Oak Bluffs on Martha's Vineyard, but was constructed within a pre-existing groin field and did not increase the length of sandy beach habitat modified by armor.

Several existing contiguous sections of seawalls, bulkheads and/or revetments were extended during the three years after Hurricane Sandy. In Plymouth, one revetment near Locust Street and Nameloc Road was extended both north and south between 2012 and 2014, increasing the length of sandy beach habitat modified by armor by 150 ft (46 m). On Seacliff Drive in Plymouth a revetment was extended south by 190 ft (58 m) in 2014-15. Two revetments in the Sagamore area of Bourne were extended between 2012 and 2014, one along over 810 ft (247 m) of shoreline along Hawes Road and the other along 420 ft (128 m) along Phillips Road; both structures were within pre-existing groin fields and did not increase the overall length of shoreline modified by armor. In Eastham, 2 revetments were extended in 2013-14. One revetment along Eastham Avenue was extended north across one property, modifying ~ 90 ft (27 m) of sandy beach habitat. The second revetment that was extended was along Shurtleff Road, where ~610 ft (186 m) of sandy beach habitat was newly modified by armor across multiple properties. Lastly, in Wellfleet a revetment was extended east across 1 adjacent property on King Philip Road, modifying an additional ~85 ft (26 m) of sandy beach habitat. Altogether 1,360 ft (415 m) of sandy beach habitat was modified by new armor construction between 2012 and 2015 along the Massachusetts coast. More than 3 miles (4.8 km) of additional sandy beach habitat were identified as modified by armor through the exposure and identification of armor structures that were previously not visible.

The length of sandy beach habitat that was lost seaward of armor in 2015 remained about the same as in 2012, nearly 48 miles (77 km), but the location of the lost sandy beach habitat shifted during the three years after Hurricane Sandy. Sandy beach habitat was present in 2015 where it was absent in 2012 along more than 4.7 miles (7.6 km) of shoreline. The highest reductions in sandy beach habitat absent due to beachfront armor were in Plymouth, Winthrop and Marshfield. At the same time, sandy beach habitat in 2015 was absent along more than 4.4 miles (7.1 km) of shoreline where it was present in 2012. The length of sandy beach habitat absent due to armor increased the most in New Bedford, Scituate, Duxbury and Kingston. Although there was a net increase of 0.27 miles (0.43 km) in the length of sandy shoreline where sandy beach habitat was absent seaward of armor in 2015, where sandy beach habitat was present or absent seaward of the armor shifted along ~ 9.2 miles (14.8 km) of sandy shoreline.

In 2015, there were a total of 1,615 groins, 90 jetties, 21 breakwaters, and 1,168 contiguous sections of seawalls, bulkheads and/or revetments along the sandy shoreline of Massachusetts, excluding inner harbors and bays (Table 11). The number of groins increased by 4 between 2012 and 2015, one of which was newly constructed in Winthrop and the other three of which were newly exposed and identified. The number of jetties increased by one, when the sandy beach adjacent to a jetty in Marion extended to be longer than 500 ft (152 m), allowing its inclusion in this 2015 habitat assessment. The number of breakwaters remained the same in 2015 as in 2012. The number of contiguous sections of seawalls, bulkheads and/or revetments had a net increase of 4 from 2012 to 2015; although 6 new revetments and seawalls/bulkheads were constructed between 2012 and 2015, the net increase was only 4 due to the conversion of some sandy beach habitat to rocky shoreline, which reduced the number of contiguous sections of seawalls / bulkheads / revetments in Gloucester and Chilmark, and the exposure of newly identified sections of seawalls / bulkheads / revetments in various other locations.

Altogether 157.24 miles (253.05 km), or 31%, of sandy shoreline (with and without beaches present in May 2015) was modified by armor on the Massachusetts coast, excluding inner harbors and bays, in 2015. Only 1 of the 57 communities along the Massachusetts coast, excluding inner harbors and bays, had not been modified by beachfront armor in 2015 (Table D-3). Although the beaches in Ipswich, Orleans and Aquinnah had zero percent of their beaches modified by armor (as listed in Table D-3), all three of those communities had solitary groins or jetties present that were not measured but influence the adjacent shorelines. Only the sandy beach habitat in Rowley, which is entirely within the Parker River NWR, had no armor at all.

All the other 53 communities' sandy beaches had been modified by varying levels of armor, ranging from 3 to 100%. Twenty-seven (27) of the 57 coastal communities in Massachusetts had at least 50% of their sandy shoreline modified by armor, with 10 of those exceeding 75%. The sandy shorelines in 2 communities – Lynn and New Bedford – were 100% modified by armor in 2015.

Proposed and Anticipated Habitat Modifications

The USACE and MA DCR have proposed the Nantasket Beach Coastal Storm Damage Reduction (CSDR) Project in Hull. The proposed CSDR project would construct a 2,100 ft (640 m) stone revetment seaward of the existing seawall at Nantasket Beach (USACE 2014aa). The proposed project, if constructed, would not modify any new sandy beach habitat with armor because of the existing seawall. The sandy beach habitat present in 2015 seaward of the existing seawall was very narrow, however, and may not be much wider than the footprint of the proposed revetment.

Table 11. Approximate number of each type of armoring visible on the oceanfront beach in each community in Massachusetts visible on Google Earth imagery between March 1995 and May 2015 or identified by MA DCR (2009) and Fontenault et al. (2013). Note that multiple seawalls, bulkheads or revetments are counted as one structure if they are continuous with no separations; for example, if five individual properties each have an individual seawall protecting their property and the seawalls are attached to each other with no gaps, the armoring is counted as one seawall structure and its overall length is counted in Table D-3 in Appendix D.

Community	Number of Groins	Number of Jetties	Number of Seawalls, Bulkheads and/or Revetments	Number of Breakwaters
Salisbury	0	1	3	0
Newburyport	1	1	1	0
Newbury	4	0	2	0
Rowley	0	0	0	0
Ipswich	2	0	0	0
Gloucester	0	0	3	0
Rockport	0	0	8	0
Manchester	0	0	24	0
Beverly	5	0	42	0
Salem	1	0	5	0
Marblehead	0	0	34	0
Swampscott	2	0	13	0
Lynn	0	0	1	0
Nahant	0	0	15	0
Revere	1	0	5	1
Winthrop	7	0	15	5
Boston	9	0	21	1
Quincy	41	0	26	0
Weymouth	7	0	10	0
Hingham	2	0	1	0
Hull	5	0	53	0
Cohasset	0	0	6	0
Scituate	3	0	45	4
Marshfield	4	2	28	0
Duxbury	37	0	17	0
Kingston	10	0	15	0
Plymouth	54	1	54	0
Sandwich	35	6	14	0
Barnstable	82	6	28	1
Yarmouth	104	4	31	0
Dennis	64	3	27	1
Brewster	30	0	11	0
Orleans	0	1	0	0

Community	Number of Groins	Number of Jetties	Number of Seawalls, Bulkheads and/or Revetments	Number of Breakwaters
Eastham	8	1	16	0
Wellfleet	13	0	14	1
Truro	26	2	17	0
Provincetown	33	0	22	0
Chatham	22	3	8	0
Harwich	59	8	18	0
Mashpee	9	1	3	0
Falmouth	148	25	98	3
Bourne	102	2	50	0
Wareham	49	0	66	1
Marion	46	2	16	0
Mattapoisett	131	0	59	0
Fairhaven	168	0	52	0
New Bedford	30	0	12	0
Dartmouth	70	0	48	1
Westport	5	0	10	0
Gosnold	11	2	10	0
Oak Bluffs	42	10	16	0
Edgartown	33	1	11	0
West Tisbury	8	0	7	0
Chilmark	5	1	3	0
Aquinnah	0	1	0	0
Tisbury	51	4	27	2
Nantucket	36	2	27	0
TOTAL	**1,615**	**90**	**1,168**	**21**

The NPS at Cape Cod NS has proposed to relocate the parking lot at Herring Cove Beach in Provincetown. A new parking lot would be constructed 125 ft (38 m) inland, allowing for the removal of the existing parking lot and revetment (NPS 2013, Schupp et al. 2015). In 2015 and 2016 sections of the parking lot and revetment were damaged by erosion. Once constructed, 0.69 miles (1.11 km) of sandy beach habitat would be restored through the removal of the revetment and parking lot asphalt; the project is anticipated to be constructed in 2018 (Mark Adams, NPS, pers. communication, 1/25/2017).

Sediment Placement Modifications

The majority of the sediment placement projects that modify sandy beach habitat in Massachusetts are the placement of dredged material from navigation channels. In the three years following Hurricane Sandy, several inlets and channels were dredged by the USACE, Barnstable County, and several Towns, with placement of material on nearby beaches. As of 2015, at least 20.91 miles (33.65 km) of sandy shoreline has been modified by sediment placement (Table D-4). A number of sediment placement project lengths and precise locations remain unknown, however, just as in 2012 (Rice 2015b).

The USACE dredged Cohasset Harbor/Inlet in 2014-15. The ~60,000 cubic yards (cy; 45,873 cubic meters [m^3]) of sediment dredged from Cohasset Harbor and inlet was placed on the intertidal zone of Sandy Beach, a pocket beach to the north; previous dredging had deposited the material in an offshore disposal site (USACE 2014w).

In Chilmark and Aquinnah on Martha's Vineyard, maintenance dredging of the federal navigation channel at Menemsha Creek was proposed in 2014 but construction was delayed until December 2015 (USACE 2014x). The project was not completed before seasonal restrictions halted work in February 2016. The dredged material was placed along ~1,500 ft (457 m) of Lobsterville Beach to the southwest of the inlet, which was not known to have been modified previously by sediment placement. The project was anticipated to be continued in October 2016, with continued placement of the dredged material at Lobsterville Beach (Elvin 2016a-d).

Barnstable County owns and operates its own dredge, which has been used to dredge at least 21 inlets in the county. In FY2013, Barnstable County dredged 10 inlet systems and placed 72,331 cy (55,301 m^3) of dredged material on adjacent beaches (Barnstable County 2013). Sediment was placed along an unknown length of sandy beach habitat near Pamet River (Truro), Mill Creek (Chatham), Doanes Creek/Allen Harbor (Harwich), Herring River (Harwich), Sesuit Harbor (Dennis), Bass River (Dennis and Yarmouth), Parkers River (Yarmouth), Cotuit Bay (Barnstable), Popponesset Bay (Mashpee), and Eel River (Falmouth).

In FY2014, Barnstable County dredged 11 inlet systems and placed 106,774 cy (81,635 m^3) of dredged material on adjacent beaches (Barnstable County 2014). Sediment was placed along an unknown length of sandy beach habitat near Pamet River (Truro), Mill Creek (Chatham and Yarmouth), Sesuit Harbor (Dennis), Saquatucket Harbor (Harwich), Allen Harbor (Harwich), Centerville River (Barnstable), Popponesset Bay (Mashpee), Falmouth Great Pond Inlet, Falmouth Green Pond Inlet, Lake Tashmoo (Tisbury), and Vineyard Haven Harbor (Tisbury).

In FY2015, Barnstable County dredged 10 inlet systems and placed 102,418 cy (78,304 m^3) of dredged material on adjacent beaches (Barnstable County 2015). Sediment was placed along an unknown length of sandy beach habitat near Pamet River (Truro), Mill Creek (Chatham), Saquatucket Harbor (Harwich), Swan Pond River (Dennis), Sesuit Harbor (Dennis), Bass River (Dennis and Yarmouth), Parkers River (Yarmouth), Popponesset Bay (Mashpee), Eel River (Falmouth), and Green Pond (Falmouth).

Barnstable County and the Town of Marshfield placed an unknown volume of material dredged from the South River on Rexhame Beach in 2013 and 2015 (Funderburk 2016). Sediment had previously been placed on Rexhame Beach in 2007 but was not identified in Rice (2015b). Precise project location and length data were not available for any of the sediment placement episodes, however.

In 2013 the Town of Chatham renewed its USACE regulatory permit for dredging of 6 waterways and 17 disposal sites and added one new waterway for dredging – Morris Island Cut – under one Comprehensive Dredging and Disposal Project (USACE 2013ii). Of the 17 disposal locations, 14 are beach nourishment sites and the other 3 are nearshore disposal sites; 5 of the 14 beach fill sites are along beaches included in this assessment, all of which have previously been modified for sediment placement. At Mill Creek in Chatham, new data identified 425 ft (130 m) of beach east of the inlet as the dredged material placement site (USACE 2013ii). The new USACE permit authorizes the continued placement of sediment along these beaches for 10 years.

In 2013 the Town of Falmouth also renewed its USACE regulatory permit for one Comprehensive Dredging and Disposal Project, expanding the project to include the dredging of 2 channels (at Green Pond and Waquoit Bay) with placement at 3 beach locations: Acapeket Association Beach, Pyne Trustees Beach, and South Cape Beach (in Mashpee). The Town anticipated dredging a total of 2,300 cy (1,758 m^3) of sediment over a 10-year period, placing the sediment along sandy beach habitat that has previously been modified by sediment placement (USACE 2013hh).

The Town of Mashpee's Comprehensive Dredging and Nourishment Project proposed a 10-year renewal of the periodic placement of dredged material along the Popponesset spit, South Cape Beach and one interior bay shoreline site in December 2015 (USACE 2015y). Both areas have previously been modified by sediment placement, although precise project lengths and locations were not known (Rice 2015b); with the new information, 4,600 ft (1,402 m) of sandy beach habitat in Mashpee is known to be modified by sediment placement.

In 2015, the Town of Oak Bluffs, on Martha's Vineyard, artificially opened North Inlet to Sengekontacket Pond, which had closed naturally. The ~6,800 cy (5,199 m^3) of dredged material was placed along the beach at Pay Beach, which had previously been modified by sediment placement (USACE 2013gg, Dukes County 2015b, Hull 2015).

The Town of Edgartown unified their dredging and beach nourishment activities under one comprehensive permit from the USACE in 2014 (USACE 2014v, Woods Hole Group 2012). While all of the sediment placement sites were previously modified, the comprehensive permit provided new information on the precise locations and lengths for 11 dredged material placement sites on Martha's Vineyard. The new information increased the known length of sandy beach habitat modified by sediment placement by 15,058 ft (4,590 m).

In addition to the placement of dredged material on sandy beaches in Massachusetts, a number of other sediment placement projects were constructed during the three years after Hurricane Sandy. In Winthrop, the MA DCR constructed a sediment placement project in two phases at Winthrop Beach, along with the construction of a new terminal groin at the north end of the project area. Sediment that had accumulated landward of the Five Sisters breakwaters was dredged and placed along the southern portion of Winthrop Beach in early 2013. Sediment from an upland source(s) was then placed on the northern portion of Winthrop Beach in 2014 (MA DCR 2015). Altogether approximately 500,000 cy (382, 277 m^3) of material was placed along 3,680 ft (1,122 m) of sandy beach, all of which had been modified by sediment placement in the 1950s.

In Sandwich, Google Earth imagery indicates that a number of private property owners along Salt Marsh Road placed sediment from upland sources along the base of the embankment on the beach in 2015. The total length of sandy beach habitat that appears to have been modified by these private sediment placement projects is ~ 2,556 ft (779 m). Similarly, Google Earth imagery suggests that a number of private property owners in Brewster placed sediment from upland sources along the base of the embankment on the beach in 2015, modifying a total of ~ 3,268 ft (996 m) of sandy beach habitat that was not previously known to have been modified by sediment placement. The extent of other private sediment placement projects on the sandy beach habitat of Massachusetts is unknown.

During the three years after Hurricane Sandy, more than 3 miles (4.8 km) of sandy beach habitat were modified by sediment placement, with 15 additional projects lacking sufficient data to determine their length (Table D-4). Approximately 1.71 miles (2.75 km) of the sandy beach habitat modified by sediment placement between 2012 and 2015 were located on sections of beach not previously known to have been modified by sediment placement. Altogether, as of 2015, more than 20.90 miles (33.63 km) of sandy beach habitat is known to have been modified by sediment placement. Sandy beach habitat has been modified by sediment placement in at least 36 of the 57 coastal communities in Massachusetts.

Proposed and Anticipated Habitat Modifications

In 2015 the Town of Sandwich and/or USACE proposed to place up to 388,000 cy (296,647 m^3) of sediment along 5,000 ft (1,524 m) of beach, using sediment from either upland or dredged sources (USACE 2015v, 2015w). The project placed ~130,000 cy (99,392 m^3) of sediment along an unknown portion of the proposed project area in January 2016 (Brennan 2016).

Three Bays Preservation and Mass Audubon proposed in 2015 to place ~133,600 cy (102,145 m^3) of sediment dredged from the inlet to Cotuit Bay and the western tip of Sampson's Island along 2,400 ft (732 m) of beach at the east end of Dead Neck Island in Barnstable (USACE 2015x); the project area previously received sediment in 1985 and 1999-2000.

In 2016 the USACE anticipated dredging the Federal Navigation Project in Chatham Stage Harbor, with placement of 40,000 to 60,000 cy (30,582 to 45,873 m^3) of sediment in one or both nearshore disposal sites off adjacent Harding Beach (one previously-used site and one new site); no sediment was anticipated to be placed directly on the beach (USACE 2016m).

Beach Scraping Modifications

The threat from beach scraping on the sandy beach shoreline of Massachusetts is minimal, limited to 0.41 miles (0.66 km) of sandy beach, or 0.1%, from late 2012 to 2015 (Table D-5). Only 4 sections of beach scraping were identified in imagery for the three years after Hurricane Sandy, modifying a total of 2,155 ft (657 m) of sandy beach. The 4 sections of beach scraping were located at the Plum Island area in Newbury and at the Harthaven Harbor area in Oak Bluffs on Martha's Vineyard.

The general absence of beach scraping[7] likely is due to the prevalent bluffs and embankments that line much of the Massachusetts sandy shoreline. Bluffs or embankments are located at the back of a beach on non-barrier island or spit beaches and generally occupy the same area of the beach profile that dunes would on a barrier island or spit (Tanski 2012). If the beach at the base of the bluff or embankment is wide enough, dunes *could* form at the base of the bluff or embankment (but the beaches are typically not wide enough). Beach scraping as identified in this assessment is intended to create artificial dunes or levees. Where bluffs or embankments are present, beach scraping is not practical except in rare cases where it could be used to in an attempt to protect the toe of the bluff or embankment from erosion.

Sand Fencing Modifications

The threat from sand fencing on the sandy beach shoreline of Massachusetts is minimal, limited to 18.50 miles (29.77 km) of sandy beach from late 2012 to 2015 (Table D-6). There were a total of 397 contiguous sections of sand fencing identified in imagery during the three years after Hurricane Sandy, modifying a total of 97,665 ft (29,768 m) of sandy beach in 33 of the 57 coastal communities. The sandy beach habitat in Salisbury has been the most modified by sand fencing at 91%. In Duxbury, 52% of the sandy beach habitat was modified by sand fencing between 2012 and 2015. Sand fencing modified 27% of the sandy beach habitat in Newburyport and Gloucester and 20% in Newbury. No sand fencing was identified in 24 of the 57 coastal communities. Altogether only 4% of the sandy beach habitat in Massachusetts was modified by sand fencing between 2012 and 2015, indicating that sand fencing is a localized threat in certain communities but a minimal threat statewide.

The general absence of sand fencing likely is due to the prevalent bluffs and embankments that line much of the Massachusetts sandy shoreline. Bluffs or embankments are located at the back of a beach on non-barrier island or spit beaches and generally occupy the same area of the beach profile that dunes would on a barrier island or spit (Tanski 2012). Sand fencing is generally intended to create dunes by creating an obstacle to trap windblown sand. The bluffs and embankments on the Massachusetts coast are much higher in elevation than sand fencing and can function as larger (natural) obstacles to windblown sand. Where bluffs or embankments are present, sand fencing is not practical except in rare cases where it could be used to in an attempt to protect the toe of the bluff or embankment from erosion.

Summary

The sandy beach habitat on the Massachusetts sandy shoreline is threatened by beachfront development and armoring, with only minimal levels of habitat modified by sediment placement (> 4%), beach scraping (< 1%) or sand fencing (4%). Forty-one percent (41%) of the sandy shoreline of Massachusetts has been developed and 31% has been armored with hard shoreline

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[7] Grading of the bluff or embankment at the back of the beach as part of bluff stabilization projects also occurs on the Massachusetts shoreline, typically in conjunction with armor repairs / replacement or sediment placement projects. These projects were excluded from this assessment because they are related to sediment placement, including backfilling landward of armor structures, and do not scrape the beach itself.

stabilization structures. In the three years after Hurricane Sandy, both the levels of development and armor increased. New armor was constructed during the three years after Hurricane Sandy. Several armor structures were repaired or reconstructed after Hurricane Sandy, indicating that the armor is a long-term, if not permanent, modification of the sandy beach habitat. While some buildings were removed or relocated away from eroding bluffs or embankments, other buildings were newly constructed.

As sea level continues to rise the bluffs and embankments that line the much of the Massachusetts shoreline will continue to erode, threatening the development situated on top of the bluffs; where armor is not present, the eroded sediment will increase the sediment supply to the sandy beaches and is likely to sustain the local habitat indefinitely. Where bluffs and embankments do not line the coast, communities are more vulnerable as sea level continues to rise and storms may become more frequent and/or intense. Kleinfelder (2013, p. 50) evaluated the risk of the communities of Scituate, Marshfield and Duxbury to sea level rise and found that all three communities could have "partial or complete loss of some ocean front beaches at high tides" without beach nourishment projects to maintain and elevate them; similarly, existing armor structures will be increasingly vulnerable to damages and overtopping unless structures are raised and sediment placement projects are constructed seaward of the armor. Potential adaptation strategies described in Kleinfelder (2013) include rebuilding existing seawalls at least 2 ft (0.6 m) higher, raising roads and associated utilities, investigating the construction of offshore breakwaters and beach nourishment projects, prohibiting future construction on the beachfront, and evaluating the creation of home buy-back plans and rolling easements to relocate development away from the beach over time. While some of these potential adaptation strategies would maintain or increase current habitat modifications to sandy beach habitat, others could decrease habitat modifications if development is relocated or removed.

Rhode Island

Beachfront Development

In 2015 there were 48.76 miles (78.47 km) of sandy shoreline on the oceanfront shoreline of Rhode Island, with 46.48 miles (74.80 km) of sandy beaches and 1.89 miles (3.04 km) of armored shoreline where no sandy beach was present (Table E-1). Where sandy beaches were present, the beachfront was 31% developed and 69% undeveloped. When sections of shoreline where sandy beaches were absent due to hard shoreline stabilization structures are included, the beachfront that was developed increases to 34% and the beachfront that was undeveloped decreases to 66%.

Prior to Hurricane Sandy, there were 49.56 miles (79.76 km) of sandy beach and 1.42 miles (2.29 km) of armored shoreline with no sandy beach along the southern shoreline of Rhode Island, for a total of 50.99 miles (82.06 km) of sandy shoreline (Rice 2015b). The small decrease to 48.37 miles (77.84 km) of sandy shoreline is due to changes in the distribution of predominantly rocky beaches in areas that were previously predominantly sandy and changes in the length of armored, sandy shoreline with and without beach present. On Block Island, in

2015/2016[8] there were 3.20 miles (5.15 km) of shoreline that were categorized as predominantly sandy in 2012 that were predominantly rocky in 2015 due to erosion of boulders and cobble from the bluffs that line much of the island's coastline. This conversion of predominantly sandy beach to rocky beach was offset slightly by an increase in sandy beach habitat in Little Compton and Westerly; in Westerly, for example, the spits at Napatree Point and Sandy Point Island both accreted, or grew by 0.30 miles (0.48 km). Altogether there were 9.01 miles (14.50 km) of rocky beach[9] on the southern exposed shoreline of Rhode Island in 2015/2016.

The proportion of sandy shoreline that was modified by development prior to Hurricane Sandy was 31% (Rice 2015b). In 2015 this proportion increased slightly to 34% (when the sections of sandy shoreline where sandy beaches were absent seaward of armor are included). The increase is due to the conversion of sandy beach to rocky beach on Block Island and also to a revision to the methodology for identifying developed versus undeveloped beachfront. That is, the distance from the beach in which development was evaluated was limited to the area from the vegetation line to a shore parallel road or 500 ft (152.4 m), whichever was closer to the beach (see the Methods section for more information). This refinement resulted in changes to the proportions of beachfront classified as developed or undeveloped in Middletown and Narragansett.

One section of beach in South Kingstown, at Roy Carpenter's Beach, was intentionally converted from developed sandy beach to undeveloped sandy beach between 2012 and 2015. After Hurricane Sandy, several cottages in the first row of the seasonal community were damaged. During the three years after Hurricane Sandy, a new street was constructed on the north, or inland, side of the seasonal development and 26 cottages from the first and second beachfront rows were relocated to the new street, away from the beach (Town of South Kingstown 2015, Google Earth 2016). The relocation of the first and second rows on the east side of Roy Carpenter's Beach converted 500 ft (152 m) of sandy beach habitat from developed to undeveloped; the proportion of sandy beach habitat modified by beachfront development in South Kingstown decreased by 2% as a result of the cottage relocations. The Town of South Kingstown relocated the pavilion (~150 ft or ~46 m) and wastewater treatment system (~450 ft or ~137 m) at the Town Beach landward in 2014-15 (Town of South Kingstown 2015, Google Earth 2016). Also in South Kingstown, near the eastern boundary of Trustom Pond NWR, three buildings were removed on two parcels, along with a geotube revetment, after Hurricane Sandy; the two properties remained undeveloped but in private ownership in 2015/2016.

The length of beachfront in public and/or NGO ownership changed slightly in the three years following Hurricane Sandy (Table E-2). In 2012, 27.27 miles (43.89 km), or 55%, of the Rhode Island beachfront was in public or NGO ownership (Rice 2015b). In the three years following Hurricane Sandy, the length of sandy beach habitat present on beachfront tracts in public or NGO-ownership declined slightly even though one additional beachfront area was purchased by a public entity. In 2013 the Town of South Kingstown purchased two beachfront parcels along

[8] Aerial imagery is available for May 2015 in some areas of Rhode Island's coast and for April or August 2016 in other areas. Where 2015 imagery was not available, imagery from 2016 was used to assess the sandy beach habitat.
[9] Rocky beaches are defined as beaches composed predominantly of gravel, cobble and/or boulders. Rocky beaches may have minor amounts of sandy substrate. Solid rock outcrops are not considered rocky beaches. Beaches in the study area may convert from predominantly sandy to predominantly rocky or vice versa seasonally or yearly; for the purposes of this inventory, the substrate was categorized using the highest resolution imagery available within Google Earth for 2015 or early 2016.

Matunuck Beach Road with ~550 ft (~168 m) of shoreline that is entirely armored with a revetment. Only the eastern end of the public property has had sandy beach present seaward of the armor since at least 1995, with ~80 ft (~24 m) of sandy beach present in 2014.

In 2015, 26.13 miles (42.05 km) of sandy beach were present within public or NGO-owned beachfront lands, a slight decrease due to the conversion of some beaches that were predominantly sandy to predominantly rocky, particularly on Block Island. Sandy beach habitat in public or NGO-ownership increased slightly at unstabilized inlets and their adjacent barrier spits, particularly at Napatree Point in Westerly, but not enough to completely offset the conversion of several Block Island beaches to predominantly rocky. The proportion of sandy beach within public or NGO-ownership was nearly unchanged at 56% in 2015.

Beach Armor Modifications

The construction of new armor structures is generally prohibited by the Rhode Island Coastal Resources Management Program (Section 300.7) along the beachfront included in this assessment and the armor identified in Rice (2015b). State rules allow for the repair and reconstruction of armor that is determined to be less than 50% damaged; the repair/reconstruction is limited to previously approved dimensions and conditions and cannot significantly expand the footprint of the structure. Change described in this 2015 update involve structures constructed before the general ban on oceanfront beach armor.

In 2015, 6.51 miles (10.48 km) of sandy beach habitat along Rhode Island's southern shoreline, or 13%, were modified by armor in 2015 (Table E-3), an increase from the length of sandy beach habitat modified by armor in 2012. In 2012, 5.63 miles (9.06 km), or 11%, of sandy beach habitat in southern Rhode Island had been modified by armor, or hard shoreline stabilization structures (Rice 2015b).

During the three years after Hurricane Sandy, a number of armor structures were repaired and reconstructed, some new armor structures were constructed, several pre-existing armor structures were removed, and some pre-existing armor was exposed after the hurricane and newly identified. The jetty on the east side of Point Judith inlet was repaired by the USACE in 2014; Hurricane Sandy had removed and displaced a number of the jetty's stones (Dugan 2014). At least 10 private seawalls / bulkheads / revetments were repaired or reconstructed during the three years after Hurricane Sandy.

A number of new armor structures[10] were constructed between 2012 and 2015, and several pre-existing structures were removed. In the spring of 2015 the USACE constructed a 200 ft (61 m) revetment extending east from the Point Judith breakwater and the state of RI extended the revetment another 300 ft (91 m) onto state property at Camp Cronin, modifying a total of nearly 400 ft (123 m) of sandy beach habitat (USACE 2014o). A second revetment was constructed at the base of the bluff/embankment to the memorial site at Camp Cronin just to the east, modifying

[10] Some, perhaps all, of these apparently new structures may have been reconstructions of armor that was within previously-permitted structure footprints, although the armor may have been in very poor condition and not readily identifiable prior to Hurricane Sandy.

an additional 124 ft (38 m) of sandy beach. A revetment was also constructed, or extended, at Sachuest Point NWR to protect Sachuest Point Road in 2013, modifying ~190 ft (~58 m) of sandy beach habitat in 2015/2016 and extending for another ~600 ft (~183 m) of shoreline where no sandy beach was present. The revetment protecting Corn Neck Road in New Shoreham on Block Island, at New Shoreham Town Beach, was also extended during 2013-14, modifying an additional ~260 ft (~79 m) of sandy beach habitat.

In 7 locations, revetments were removed or shortened between 2012 and 2015. Two sandbag revetments at South Kingstown Town Beach were removed and the pavilion relocated landward, decreasing the length of sandy beach habitat modified by armor by over 200 ft (61 m). At the east end of Cards Pond in South Kingstown, half of a geotube revetment was removed along with three buildings in 2013-14, reducing the length of sandy beach habitat modified by armor by another 200 ft (61 m). A revetment at Wuskenau Beach in Westerly was removed along with a building in 2013-14. A revetment constructed of boulders piled on the beach at the end of Highland Road in Charlestown was removed in 2013-14 as well. Two revetments in Westerly were reconfigured with smaller footprints after Hurricane Sandy. Altogether the length of sandy beach habitat modified by armor was reduced by 0.12 miles (0.19 km) through the removal of 4 revetments and shortened lengths of 3 other revetments in the three years after Hurricane Sandy.

An additional 0.64 miles (1.03 km) of pre-existing armor was newly identified after a number of structures, or contiguous sections of structures, were exposed in the three years after Hurricane Sandy. At 6 locations sandy beach habitat expanded seaward of pre-existing armor structures, allowing for the inclusion of those structures in the inventory of habitat modifications. Altogether 6.51 miles (10.48 km) of sandy beach habitat along Rhode Island's southern shoreline, or 13%, were modified by armor in 2015 (Table E-3).

Altogether during the three years after Hurricane Sandy, 5 new seawalls / bulkheads / revetments were constructed, 7 walls were extended or reconfigured with longer footprints, 4 walls were removed, and 3 walls were shortened. Two (2) new groins were constructed, 1 reconstructed with a new footprint, and 1 pre-existing groin newly identified. At Camp Cronin and the Point Judith Lighthouse, two pre-existing breakwaters were included in this habitat assessment update due to the extension of sandy beach habitat landward of both structures in the three years after Hurricane Sandy. An offshore breakwater between the Point Judith Lighthouse and Camp Cronin was newly identified as modifying 236 ft (72 m) of habitat; previously the beach was rocky and the breakwater mostly submerged. In 2015 the beach was predominantly sandy, counted in the inventory, and the breakwater emergent. The federal Point Judith breakwater was connected with the new revetment constructed on its east side after Hurricane Sandy, allowing the total number of breakwaters to increase from 1 to 3 between 2012 and 2015. Altogether in 2015/2016, there were a total of 16 groins, 11 jetties, 71 contiguous sections of seawalls / bulkheads / revetments, and 3 breakwaters along the sandy shoreline of southern Rhode Island (Table 12).

Table 12. Approximate number of each type of armoring visible on the oceanfront beach in each community in Rhode Island visible on Google Earth imagery between March 1995 and April 2016. Note that multiple seawalls, bulkheads or revetments are counted as one structure if they are continuous with no separations; for example, if five individual properties each have an individual seawall protecting their property and the seawalls are attached to each other with no gaps, the armoring is counted as one seawall structure and its overall length is counted in Table E-3 in Appendix E.

Community	Number of Groins	Number of Jetties	Number of Seawalls, Bulkheads and/or Revetments	Number of Breakwaters
Little Compton	0	0	11	0
Portsmouth	0	0	1	0
Middletown	0	0	6	0
Newport	0	0	4	0
Jamesport	0	0	1	0
Narragansett	13	2	13	2
South Kingstown	0	0	9	0
Charlestown	0	4	9	0
Westerly	2	2	13	0
New Shoreham (Block Island)	1	3	4	1
TOTAL	**16**	**11**	**71**	**3**

Proposed and Anticipated Habitat Modifications

The Town of South Kingstown has proposed to construct a seawall along the seaward side of Matunuck Beach Road, with construction scheduled for late 2016. The new steel sheet pile seawall will be approximately 200 ft (61 m) long and is located landward of an existing rock revetment, some of which is in poor condition (Alfred 2016). Reconstruction of the relic revetment has also been proposed by an adjacent private property owner and/or the Town, but if constructed the repaired revetment would maintain its historical footprint (Alfred 2016, Kuffner 2016). Neither project would increase the length of sandy beach modified by armor due to the presence of the relic revetment; sandy beach habitat has been absent along the majority of the revetment since at least 1995 (based on Google Earth imagery), with only ~80 ft (24 m) of sandy beach present at the eastern end of the wall in 2014 and none in August 2016.

Sediment Placement Modifications

In the three years following Hurricane Sandy, at least 2.70 miles (4.35 km) of the Rhode Island's sandy beaches were modified with sediment placement, with 1.83 miles (2.95 km) of those beaches having previously been modified with sediment placement and 0.87 miles (1.40 km) of those beaches newly modified after Hurricane Sandy (Table E-4). Sediment was placed on 18 areas on Rhode Island's southern sandy beaches between 2012 and 2015, but volume data is only available for 3 and totaled 152,400 cubic yards (cy; 116,518 cubic meters [m^3]). Prior to

Hurricane Sandy, more than 6.15 miles (9.66 km)[11] of sandy beach on the south shore of Rhode Island had been modified by sediment placement (Rice 2015b). Altogether, as of the end of 2015, at least 7.02 miles (11.30 km), or 15%, of sandy beaches on the Atlantic Ocean shoreline of Rhode Island had been modified with sediment placement at least once.

The USACE initially placed fill at Misquamicut State Beach in 1959-60 and utilized Hurricane Sandy funds to restore the project to its 1960 authorized design profile. Sediment from an upland source was trucked to the beach in early 2014, with an anticipated 90,000 cy (68,810 m^3) to be placed on the state beach (USACE 2013w). The USACE dredged the Pawcatuck River, Little Narragansett Bay and Watch Hill Cove Federal Navigation Project as well as the western tip of Sandy Point Island in the winter of 2014-15 and placed 61,900 cy (47,326 m^3) of sediment on Sandy Point Island at the RI-CT boundary[12]; dredged material has previously been placed on the island but precise placement locations for those placement episodes were not available (USACE 2014p). Sediment was also placed at a number of private properties to restore dunes and/or beaches following Hurricane Sandy.

Beach Scraping Modifications

Beach scraping is a minor threat to sandy beach habitat in southern Rhode Island. Between 2012 and 2015, at least 3.10 miles (4.99 km) of sandy beach habitat in southern Rhode Island was modified by beach scraping to create or restore artificial dunes (Table E-5). While only 7% of the sandy beach habitat was modified by beach scraping, the habitat modified in this way was not uniformly distributed throughout Rhode Island. The sandy beaches in Middletown and Newport were the most modified by beach scraping, affecting 32% and 25% respectively. Thirteen percent (13%) of the sandy beach habitat in Westerly was known to have been modified by beach scraping in the three years after Hurricane Sandy, and 10% of Narragansett's sandy beach habitat. None of the sandy beach habitat in Portsmouth, Jamestown, South Kingstown or Charlestown were known to have been modified by beach scraping. Beach scraping was documented at 18 separate locations during the three years following Hurricane Sandy, the longest of which were at Second Beach in Middletown, Narragansett Town Beach, and along two sections of beach in Westerly; between 1,875 and 3,300 ft (572 and 1,006 m) of contiguous sandy beach habitat was scraped in each of these 4 locations.

Sand Fencing Modifications

The use of sand or snow fencing to trap windblown sand and create dunes along Rhode Island's southern sandy beaches modified 18%, or 8.49 miles (13.66 km), of the sandy beach habitat present between 2012 and 2015 (Table E-6). The proportion of sandy beach habitat modified by sand fencing ranged from 0% to 50% within each beachfront community. The least modified beachfronts were in Portsmouth (0%), Newport (3%), New Shoreham (4%) and Little Compton

[11] A new information source increased the length of known sandy beach habitat known to be modified by sediment placement prior to Hurricane Sandy by 0.15 miles (0.24 km) from the 6.00 miles (9.66 km) listed in Rice (2015b).
[12] The western tip of Sandy Point Island is located in Connecticut. The majority of the island is located in Rhode Island.

(6%). While half of Jamestown's sandy beach habitat was modified by sand fencing between 2012 and 2015, there was only one sandy pocket beach in the community at Mackerel Cove Town Beach that is limited to 0.23 miles (0.37 km) in length. The longest length of sandy beach modified by sand fencing was in Westerly, where 2.88 miles (4.63 km), or 30%, of the community's beaches had sand fencing present at some point during the three years after Hurricane Sandy. The sandy beach habitat in South Kingstown (34%), Charlestown (23%), Narragansett (22%) and Middletown (22%) were also significantly modified by sand fencing between 2012 and 2015. Altogether there were 239 contiguous sections of sand fencing along the sandy beaches of southern Rhode Island in the three years after Hurricane Sandy.

Summary

Sandy beach habitat in southern Rhode Island is threatened most by development (34%) and less so by sand fencing (18%), sediment placement (15%+), armor (13%) and beach scraping (7%). Between 2012 and 2015, some sandy beach habitat was converted from developed to undeveloped with the relocation of numerous structures in South Kingstown, indicating that habitat modifications due to development of Rhode Island's sandy beach habitat may sometimes be reversible.

While ~1 mile (~1.6 km) of sandy beach habitat was modified by newly constructed and newly identified armor between 2012 and 2015, another 0.12 miles (0.20 km) of sandy beach habitat was restored with the removal of armor, indicating that beachfront armor may not always pose a permanent threat to sandy beach habitat in Rhode Island either. The net increase of 0.87 miles (1.40 km) of sandy beach habitat modified by armor represents a 2% increase from 11 to 13% of the state's southern sandy shoreline, however, and the length of sandy shoreline where sandy beach habitat was lost in 2015/2016 was 0.47 miles (0.76 km) higher than in 2012. Therefore armor continues to be a threat to sandy beach habitat, but the removal of several armor structures suggests an opportunity for additional reduction in the magnitude of the threat.

A total of 93 permits from the RI CRMC were issued during the three years after Hurricane Sandy for habitat modifications to sandy beach habitat. Seventy-one (71) of the 93 permits were for dune restoration projects, which typically involved beach scraping or sediment placement to reconstruct artificial dunes after the storm. These reconstructed dunes were often stabilized with sand fencing and/or vegetation plantings. Although these projects generally are conducted by private property owners and are small in scale, the largest project areas are at public beaches. Cumulatively more than 15% of the sandy beach habitat in southern Rhode Island has been modified by sediment placement, 18% by sand fencing and 7% by beach scraping. Where artificial dunes are reconstructed following a storm, low elevation, sparsely vegetated or bare overwash habitat is converted to vegetated artificial dune habitat. As sea level rises, these habitat modifications may pose an increasing threat to sandy beach habitat for beach-nesting birds in Rhode Island.

Connecticut

Beachfront Development

In late 2015/early 2016[13] there were 106.41 miles (171.25 km) of sandy shoreline on the oceanfront shoreline of Connecticut, with 88.29 miles (142.09 km) of sandy beaches and 18.12 miles (29.16 km) of armored shoreline where no sandy beach was present (Table F-1). Where sandy beaches were present, the beachfront was 46% developed and 54% undeveloped. When sections of shoreline where sandy beaches were absent due to hard shoreline stabilization structures are included, the beachfront that was developed increases to 55% and the beachfront that was undeveloped decreases to 45%.

Prior to Hurricane Sandy, there were 82.16 miles (132.22 km) of sandy beach and 18.03 miles (59.60 km) of armored shoreline with no sandy beach along the southern shoreline of Rhode Island, for a total of 100.19 miles (161.24 km) of sandy shoreline (Rice 2015b). The increase to 106.41 miles (171.25 km) of sandy shoreline is due to changes in the length of armored, sandy shoreline with and without beach present, an increase in the number of pocket beaches exceeding 500 ft (152 m) in length in 2015/2016, and slight changes to the lengths of beach habitat that were predominantly sandy versus predominantly rocky. Of the 24 communities along the Connecticut coast, the length of sandy beach habitat increased by a total of 6.68 miles (10.75 km) in 18 communities and decreased by a total of 1.21 miles (1.95 km) in the other 6 communities during the three years after Hurricane Sandy. The largest gains in sandy beach habitat between 2012 and 2015/2016 were in Greenwich (1.04 miles or 1.67 km), Madison (0.83 miles or 1.34 km), Westbrook (0.62 miles or 1.00 km) and Bridgeport (0.62 miles or 1.00 km). In Greenwich, the sandy beach habitat present on three islands (Shell, Great Captain and Little Captain) increased in length and/or converted from predominantly rocky to predominantly sandy in certain areas. Altogether there were 9.50 miles (15.29 km) of rocky beach[14] adjacent to sandy beaches on the shoreline of Connecticut in 2015/2016.

The proportion of sandy shoreline that was modified by development prior to Hurricane Sandy was 54% (Rice 2015b). In 2015 this proportion increased slightly to 55% (when the sections of sandy shoreline where sandy beaches were absent seaward of armor are included). The increase is due to the conversion of rocky beach to sandy beach in some developed beachfront areas and the inclusion of new pocket beaches that were at least 500 ft (152 m) in length in 2015/2016.

The estimated length of beachfront in public and/or NGO ownership increased by 1% in the three years following Hurricane Sandy (Table F-2). In 2012, 35.10 miles (56.49 km), or 43%, of the Connecticut beachfront was in public or NGO ownership (Rice 2015b). In 2015/2016, 39.66

[13] Aerial imagery is available for September 2015 for Connecticut's coast from Westbrook west to Greenwich and for April 2016 for Old Saybrook east to the RI state boundary. Where 2015 imagery was not available, imagery from 2016 was used to assess the sandy beach habitat.

[14] Rocky beaches are defined as beaches composed predominantly of gravel, cobble and/or boulders. Rocky beaches may have minor amounts of sandy substrate. Solid rock outcrops are not considered rocky beaches. Beaches in the study area may convert from predominantly sandy to predominantly rocky or vice versa seasonally or yearly; for the purposes of this inventory, the substrate was categorized using the highest resolution imagery available within Google Earth for 2015 or early 2016.

miles (63.83 km), or 44%, of the sandy beach habitat in Connecticut was in public or NGO ownership. This increase is due to the identification of new public/NGO owned beachfront parcels through new information sources, the inclusion of several tracts that extended their sandy beach habitat to exceed 500 ft (152 m), and the purchase of one new public beachfront property. Within the public/NGO beachfront lands identified in Rice (2015b), the lengths of sandy beach habitat present in 2015/2016 increased in some areas (e.g., Bluff Point Coastal Reserve in Groton, Hammonasset State Park in Madison/Clinton, Seaside Park in Bridgeport) and decreased in others (e.g., Sandy Point Bird Sanctuary in West Haven, Griswold Point in Old Lyme).

New information sources identified the public or NGO ownership of beaches near Lynde Point in Old Saybrook, Railroad Beach (Cini Memorial Park) and Hole-in-the-Wall Beach in East Lyme, the Seaside Avenue Open Space in Westbrook, Jacob's Beach in Guilford, Seabluff and Prospect Beaches in West Haven, Gulf Beach in Milford, Southport Beach and Sasco Creek Beach in Fairfield, Bayley Beach in the Rowayton section of Norwalk, Cove Island Park in Stamford, and Byram Park in Greenwich (Table F-2). The length of sandy beach present on three islands in Greenwich increased to more than 500 ft (152 m) and/or converted from predominantly rocky to predominantly sandy: Shell Island, Great Captain Island, and Little Captain Island (aka Island Beach). New information sources also identified the private ownership of Lordship Point in Stratford, removing its inclusion in the inventory of public and NGO-owned beachfront lands.

The state acquired the abandoned Seaside Sanatorium in Waterford in 2014 and released a master plan to convert the property into Seaside State Park in 2016; the entire ~1,500 ft (~457 m) shoreline of the property is armored with a mix of short pocket beaches and armored shoreline with no sandy beach present in early 2016. The state park master plan proposes to develop the property as a destination park that includes maintenance of the seawall and 7 groins, with the conversion of the longest groin into a fishing pier and "living breakwater" with reef balls. Three (3) tidal pools are proposed to be created between pairs of groins and 3 pockets of sandy beach are proposed to be enlarged, presumably through sediment placement; dune swales and wet meadows are also proposed to be created or restored on the site landward of the seawall and new boardwalk. The historical buildings on the site are proposed to be adaptively reused in public/private partnership, indicating that the new public beachfront property will remain developed and armored (CT DEEP 2016a).

In East Lyme, in 2013 Amtrak and the Town completed improvements to Railroad Beach (part of Cini Memorial Park) on the west shoulder of the inlet at the Niantic River. As part of a railroad bridge replacement at the adjacent Niantic River inlet, the public beach was modified by armor and sediment placement. Prior to Hurricane Sandy a terminal groin was under construction but not completed and the shoreline lacked a wide, continuous beach. In 2013 a half-mile continuous beach was restored and widened via sediment placement, creating an additional ~345 ft (~105 m) of sandy beach habitat. Rice (2015b) did not identify Railroad Beach as publicly-owned beachfront and the rebuilt beach increases the length of sandy beach habitat known to be in public or NGO ownership in Connecticut. Altogether the length of sandy beach habitat known to be in public or NGO ownership in Connecticut increased by 4.56 miles (7.34 km) in 2015/2016 from 2012.

Beach Armor Modifications

A total of 57.50 miles (92.53 km) of sandy shoreline was modified by armor in Connecticut in 2015/2016, with 39.38 miles (63.38 km) of sandy beach habitat modified by armor and 18.12 miles (29.16 km) of sandy shoreline where sandy beaches were absent seaward of the armor (Table F-3). Newly constructed armor increased the length of sandy beach modified by armor by 0.57 miles (0.92 km). Armor exposed during the three years after Hurricane Sandy and newly identified[15] increased the length of sandy beach habitat known to be modified by armor by 1.89 miles (3.04 km). In 2015/2016 the proportion of sandy shoreline modified by armor in Connecticut remained the same at 54%, but the length of sandy beach habitat modified by armor increased by 2.47 miles (3.98 km), the length of sandy shoreline with no beach present due to armor increased by a net 0.09 miles (0.14 km)[16], and the length of total sandy shoreline modified by armor increased by 2.56 miles (4.12 km).

During the three years after Hurricane Sandy, a number of armor structures were repaired and reconstructed, a small number of pre-existing armor structures were destroyed and not rebuilt or removed, new armor structures were constructed, and numerous pre-existing armor structures were exposed after the hurricane and newly identified. The USACE repaired the breakwater at New Haven Harbor in 2014-15, repairing damages to the armor structure resulting from Hurricane Sandy (USACE 2016i). The breakwaters on both sides of the inlet at Bridgeport Harbor inlet were repaired in 2015, following damages from Hurricane Sandy (USACE 2016i). The dual training walls (groins) at Nettleton Creek in Silver Sands SP were removed in 2013 (Laura Saucier, CT DEEP, pers. communication, 4/1/15). A third remnant groin in Milford was destroyed by the hurricane and not rebuilt. Five contiguous sections of seawalls, bulkheads and/or revetments were shortened during the three years after Hurricane Sandy, generally when damaged structures were not reconstructed after the storm.

At least 3 groins and 25 sections of bulkheads, seawalls or revetments were constructed between November 2012 and late 2015 or early 2016. Amtrak completed the construction of the concrete wall and terminal groin along the re-aligned railroad approach to the new bridge across the Niantic River in East Lyme (Weggel et al. 2011, Google Earth 2016). A total of 16 sections of bulkheads, seawalls or revetments were extended or reconstructed with new footprints in the three years after Hurricane Sandy.

The length of total sandy shoreline modified by armor increased in 17 coastal communities and declined in the remaining 7 coastal communities. The proportion of sandy shoreline modified by armor declined in 13 communities, remained the same in only 1 community, and increased in 10 communities. In 5 of the 10 communities where the proportion of sandy shoreline modified by armor increased during the three years after Hurricane Sandy, the increase was by more than 10% - New London, Waterford, Guilford, New Haven and Darien. These significant increases

[15] High resolution Google Earth imagery is available for most of the state of Connecticut's coastline for 2013, 2014, 2015 and 2016. This time series of 4 high resolution sets of imagery allowed for the identification of numerous additional armor structures that were exposed by Hurricane Sandy or during the three years that followed.
[16] The length of sandy shoreline lacking beaches seaward of armor in 2015/2016 declined by a total of 3.36 miles (5.41km) in 12 communities and increased by a total of 3.45 miles (5.55 km) in the other 12 communities, for a net change of 0.09 miles (0.14 km).

were due to the inclusion of new pocket beaches (with armor) that were at least 500 ft (152 m) long in New London and Guilford, and an increase in the length of armored sandy shoreline[17] with no beach present in Waterford, New Haven and Darien.

Altogether, as of 2015/2016 there were 944 groins, 24 jetties, 22 breakwaters, and 424 contiguous sections of seawalls, bulkheads and/or revetments along the sandy shoreline of Connecticut (Table 13). Numerous other armor structures are present on the rocky beaches and shorelines of Connecticut but those structures were not included in this assessment. Due primarily to the exposure of armor structures that were not visible in 2012 prior to Hurricane Sandy, the number of groins known to be present on the sandy shoreline of Connecticut increased by 89, the number of breakwaters by 4, and the number of contiguous sections of seawalls, bulkheads and/or revetments by 61 as compared to the number of armor structures identified in Rice (2015b).

Proposed and Anticipated Habitat Modifications
In 2016 the City of Milford released a draft Coastal Resilience Plan that includes the potential to construct jetties and/or offshore breakwaters to retain sediment as part of a project to restore Laurel and Walnut Beaches at Wildemere. The proposed armor projects, if constructed, are anticipated for 2020-21 (City of Milford 2016). The City of Milford also proposed to reconstruct the breakwater at Gulf Beach between 2016 and 2018 and to evaluate a flood wall protection system at Bayview and Point Beaches between 2025 and 2030 as part of the draft resilience plan (City of Milford 2016).

Sediment Placement Modifications

Prior to Hurricane Sandy, more than 15.58 miles (25.07 km) of sandy beach on the Connecticut coastline had been modified by sediment placement, with several sediment placement projects known to have taken place but lacking precise location information (revised from Rice 2015b). In the three years following Hurricane Sandy, at least 1.83 miles (2.95 km) of the Connecticut's sandy beaches were modified with sediment placement, with 1.14 miles (1.83 km) of those beaches having previously been modified with sediment placement and 0.69 miles (1.11 km) of those beaches newly modified after Hurricane Sandy (Table F-4). At least 220,600 cubic yards (cy) of sediment were placed on Connecticut's southern sandy beaches between 2012 and 2015, with volume data only available for 3 out of 7 placement areas. Altogether, as of the end of 2015, at least 16.27 miles (26.18 km), or 15%, of sandy beaches on the Long Island Sound shoreline of Connecticut had been modified with sediment placement at least once.

The USACE initially placed fill at Prospect Beach in West Haven in 1957 and then on a 4,500 ft (1,371 m) section of the beach in 1995; the USACE utilized Hurricane Sandy funds to restore the project to its 1995 authorized design profile. Sediment from an upland source was trucked to the

[17] High resolution Google Earth imagery is available for most of the state of Connecticut's coastline for 2013, 2014, 2015 and 2016. This time series of 4 high resolution sets of imagery allowed for the identification of additional sections of armored shoreline that would have sandy beach habitat (versus rocky beaches) in the absence of the armor.

Table 13. Approximate number of each type of armoring visible on the oceanfront beach in each community in Connecticut visible on Google Earth imagery between April 1991 and September 2015 or April 2016. Note that multiple seawalls, bulkheads or revetments are counted as one structure if they are continuous with no separations; for example, if five individual properties each have an individual seawall protecting their property and the seawalls are attached to each other with no gaps, the armoring is counted as one seawall structure and its overall length is counted in Table F-3 in Appendix F.

Community	Number of Groins	Number of Jetties	Number of Seawalls, Bulkheads and/or Revetments	Number of Breakwaters
Stonington	10	1	4	0
Groton	7	2	14	0
New London	19	1	7	0
Waterford	15	1	4	0
East Lyme	47	0	24	2
Old Lyme	23	0	15	0
Old Saybrook	77	4	28	0
Westbrook	68	1	25	2
Clinton	111	0	13	0
Madison	43	1	27	0
Guilford	17	0	8	0
Branford	5	0	12	0
East Haven	28	0	22	1
New Haven	4	0	15	4
West Haven	22	0	10	1
Milford	57	2	38	3
Stratford	23	0	8	1
Bridgeport	9	0	6	2
Fairfield	41	1	30	1
Westport	154	5	37	0
Norwalk	44	0	23	2
Darien	22	0	12	0
Stamford	90	4	22	3
Greenwich	8	1	20	0
TOTAL	**944**	**24**	**424**	**22**

beach in 2014, with an anticipated 90,700 cy (69,345 m^3) to be placed on the beach (USACE New England District website). At Woodmont Beach in Milford the USACE placed an unknown volume of sediment from an upland source along ~1,500 ft (~457 m) of beach in 2014 that had previously received fill in 1994 and 1959 (USACE New England District website). The USACE dredged the navigation channels at Clinton Harbor in 2013 and placed 49,500 cy (37,845 m^3) of sediment on an unknown length of beach at Hammonasset State Park, which has periodically received sediment placement since 1955 (USACE 2015o).

In East Lyme, Amtrak and the Town completed a project in 2013 that started in 2011 to modify Railroad Beach, adjacent to the inlet at the Niantic River. The beach was modified by both sediment placement and armor (as described above in the Armor section). The sediment placement project at Railroad Beach modified nearly 2,600 ft (792 m) of sandy beach habitat with ~80,000 cy (61,164 m^3) of sediment from an upland source, creating ~345 ft (~105 m) of sandy beach that was absent in 2012 seaward of existing armor (Weggel et al. 2011, Google Earth 2016). Google Earth imagery identified two private sediment placement projects in Old Lyme, one adjacent to the inlet at Three Mile River and the other along Hartung Place, both in 2013. A third private sediment placement project at the Tokeneke Club in Darien is visible in both late 2015 and early 2016 Google Earth imagery as part of a beach club reconstruction or remodeling project.

A new information source identified one additional previous sediment placement area at Grove Beach Point, on the west side of the inlet to the Menunketesuck and Patchogue Rivers in Westbrook; in 2005, ~6,000 cy (4,587 m^3) of upland sediment were placed along an unknown length of beach at Grove Beach Point (Woods Hole Group 2009).

Sediment placement appears to be a minor but widespread threat to Connecticut's sandy beach habitat, with at least 15% of the state's sandy shoreline known to have been modified in this manner. Only 4 of Connecticut's 24 coastal communities are known to have not been modified at least once by sediment placement: Stonington, Westbrook, New Haven and Greenwich (Table F-4). In the remaining 20 coastal communities, the length of sandy shoreline known to have been modified by sediment placement ranges up to 44%. The most modified communities are Fairfield (44%), Milford (43%), Bridgeport (> 36%), West Haven (> 34%), Madison (27%), East Haven (21%), and Westport (20%). Within these 7 coastal communities, sediment placement appears to be a moderate and localized threat to sandy beach habitat.

Proposed and Anticipated Habitat Modifications

The USACE New England District is developing beach erosion and hurricane and storm damage reduction projects at Broadway and Bayview Beaches in Milford, Cosey Beach in East Haven and Fairfield Beach in Fairfield (USACE 2016i); the potential projects are likely to include sediment placement but no specific project areas have been proposed as of 2016. The USACE currently places material dredged from the inlet at Milford Harbor in a nearshore disposal site off Bayview Beach (Rice 2016).

In 2016 the City of Milford released a draft Coastal Resilience Plan that includes the artificial restoration of dunes at Walnut Beach and the sediment placement at Wildemere Beach. The dune restoration project at Walnut Beach is anticipated for 2016-18 and would modify 1,750 ft (533 m) of sandy beach habitat that has not previously been modified by sediment placement. The proposed Wildemere sediment placement project is anticipated for 2020-21 and would modify an anticipated ~2,135 ft (~651 m) of sandy beach habitat that has not previously been modified by sediment placement (City of Milford 2016). Together the two proposed projects in Milford, if constructed, would increase the length of sandy shoreline known to be modified by sediment placement in Connecticut by 0.73 miles (1.17 km).

Also in 2016 the USACE proposed to place sediment dredged from the Housatonic River Federal Navigation Project along ~ 1 mile (1.6 km) of beach at Hammonasset Beach SP in Madison; no sandy beach habitat would be newly modified by the placement of the dredged material. The USACE anticipated construction of the dredging and sediment placement project in the winter of 2016-17.

The Giant Neck Improvement Club also proposed a sediment placement project for the winter of 2016-17 (CT DEEP 2016b). Sediment from an upland source would be placed along ~1,115 ft (340 m) of beach along Giant Neck Road in Niantic; if constructed, the project would newly modify that section of sandy beach habitat. Altogether 2.36 miles (3.80 km) of sandy beach habitat in Connecticut have been proposed for sediment placement (Table 5).

Beach Scraping Modifications

Beach scraping is a minor threat to sandy beach habitat in Connecticut. Between 2012 and 2015, at least 2.97 miles (4.78 km) of sandy beach habitat in Connecticut was modified by beach scraping to create or restore artificial dunes (Table F-5). While only 3% of the sandy beach habitat was modified by beach scraping, the habitat modified in this way was not uniformly distributed throughout Connecticut. The sandy beaches in Darien (10%), Greenwich (10%) and Milford (9%) were the most modified by beach scraping. None of the sandy beach habitat in Stonington, New London, Waterford, East Lyme, Clinton, Branford, New Haven, Bridgeport, Fairfield or Stamford were known to have been modified by beach scraping. Beach scraping was documented at 29 separate locations during the three years following Hurricane Sandy, the longest of which were at Compo Beach in Westport, Westbrook Town Beach, Short Beach in Stratgord and along two sections of beach in Greenwich Point Park in Greenwich; between 1,000 and 2,700 ft (305 and 826 m) of contiguous sandy beach habitat was scraped in each of these 5 locations. Beach scraping is relatively uncommon in Connecticut due to the limited length and width of most beaches, with extensive armor present in developed beachfront habitats.

Sand Fencing Modifications

The use of sand or snow fencing to trap windblown sand and create dunes along Connecticut's sandy beaches modified nearly 4%, or 3.23 miles (5.20 km), of the sandy beach habitat present between 2012 and 2015 (Table F-6). The proportion of sandy beach habitat modified by sand fencing ranged from 0% to 28% within each beachfront community. No sand fencing was present in 5 of the 24 beachfront communities of Connecticut: Old Saybrook, Guilford, Norwalk, Darien and Stamford. The beachfront communities with the highest proportion of sandy beach habitat modified by sand fencing during the three years after Hurricane Sandy were New London (28%), Fairfield (19%), and Waterford (17%). The longest length of sandy beach modified by sand fencing was in Fairfield, where 0.86 miles (1.38 km) of the community's beaches had sand fencing present at some point during the three years after Hurricane Sandy.

Altogether there were 196 contiguous sections of sand fencing along the sandy beaches of Connecticut in the three years after Hurricane Sandy. Although sand fencing was present in all but 5 of Connecticut's 24 coastal communities, 73 out of the 196 contiguous sections of sand fencing (37%) were located perpendicular to the beach to delineate property boundaries rather than trap windblown sand and create dunes; in those locations the habitat modification appears to be incidental to the primary purpose of marking property boundaries on the beach. Sand fencing is relatively uncommon in Connecticut due to the limited length and width of most beaches, with extensive armor present in developed beachfront habitats.

Summary

Sandy beach habitat in Connecticut is threatened most by development (55%) and armor (54%) and less so by sediment placement (15%+), sand fencing (4%), and beach scraping (3%). Between 2012 and 2015, no beachfront was converted from developed to undeveloped, indicating that habitat modifications due to development may be a permanent threat to Connecticut's sandy beach habitat. Sediment placement is a localized threat within some communities, but sand fencing and beach scraping are minor threats, primarily due to the lack of wide, sandy beaches on which either modification would be appropriate to artificially create and maintain dunes.

Both the length of sandy shoreline modified by armor and the length of sandy shoreline where sandy beach habitat was lost, or absent, due to armor increased during the three years after Hurricane Sandy. Many armor structures were repaired and/or reconstructed in the three years following Hurricane Sandy, and new armor structures were constructed. While a few armor structures were not reconstructed after Hurricane Sandy, only the two training walls (groins) at Nettleton Creek in Silver Sands SP were intentionally removed. More than half (50%) of the sandy shoreline has been modified by armor within 14 of 24 coastal communities in Connecticut; in 5 communities, more than two-thirds (66%) of the sandy shoreline has been modified by armor. Beachfront armor continues to be a threat to sandy beach habitat in Connecticut three years after Hurricane Sandy, with no reduction in the proportion of sandy shoreline modified by armor and ~18 miles (~29 km) of sandy beach habitat remaining lost seaward of armor structures (17% of the state's total sandy shoreline). The vast majority of armor structures are decades old, and given that many structures were repaired and reconstructed after Hurricane Sandy, a major storm, beachfront armor appears to be a permanent and significant threat to sandy beach habitat in Connecticut.

New York – Long Island Sound Shoreline

Beachfront Development

In 2015 there were 128.51 miles (206.82 km) of sandy shoreline on the North Shore of Long Island, with 124.19 miles (199.86 km) of sandy beaches and 4.32 miles (6.95 km) of armored shoreline where no sandy beach was present (Table G-1). Another 13.83 miles (22.26 km) of shoreline were composed of rocky beach. Where sandy beaches were present, the beachfront was 61% developed and 39% undeveloped. When sections of shoreline where sandy beaches were absent due to hard shoreline stabilization structures are included, the beachfront that was developed increases to 62% and the beachfront that was undeveloped decreases to 38%.

Prior to Hurricane Sandy, there were 120.75 miles (194.33 km) of sandy beach and 6.07 miles (9.77 km) of armored shoreline with no sandy beach along the Long Island Sound shoreline of New York, for a total of 126.82 miles (204.10 km) of shoreline (Rice 2015b). The slight increase to 128.51 miles (206.82 km) of sandy shoreline is due to changes in the distribution of predominantly sandy beaches at the base of bluffs, the shifting positions of inlets and their adjacent barrier spits, and the decrease in the length of armored, sandy shoreline with no beach present. The sandy beaches on the North Shore were generally wider in 2015 than in 2012.

In 2012 before Hurricane Sandy, the sandy beachfront along the North Shore was 61% developed and 39% undeveloped. Three years after Hurricane Sandy, the proportion of sandy beachfront modified by development was unchanged. Only one or two vacant lots were newly developed between 2012 and 2015 and no developed areas were converted to undeveloped beachfront.

The length of beachfront in public and/or NGO ownership did not significantly change in the three years following Hurricane Sandy (Table G-2). In 2012, 34.79 miles (59.99 km), or 29%, of the North Shore beachfront was in public or NGO ownership (Rice 2015b). No new sandy beachfront lands are known to have been placed in public or NGO-ownership in the three years after Hurricane Sandy. In 2015, 35.55 miles (57.21 km) of sandy beach were present within public or NGO-owned beachfront lands, a slight increase due to the shifting of unstabilized inlets and their adjacent barrier spits. The proportion of sandy beach within public or NGO-ownership was unchanged at 29% in 2015.

Beach Armor Modifications

In the three years after Hurricane Sandy, 107 hard shoreline stabilization structures (armor) were repaired or reconstructed on the North Shore of Long Island. Six (6) revetments or bulkheads were extended during the same time period. Hurricane Sandy also exposed a number of armor structures that were buried prior to the hurricane and not previously identified in Rice (2015b).

In 2015, the beaches on the Long Island Sound shoreline of New York were modified with 38.96 miles (62.70 km) of armor (Table G-3). In 2012, prior to Hurricane Sandy, 34.66 miles (55.78 km) of sandy beaches were known to be armored. An increase[18] of 1.82 miles (2.30 km) of armored sandy beaches between 2012 and 2015 is due to both the construction of new armor (0.82 miles or 1.32 km) and the identification of new armor that was exposed by Hurricane Sandy (1.00 miles or 1.61 km). Another 4.32 miles (6.95 km) of shoreline were armored but did not have sandy beaches present in May 2015; this is a decline from the 6.07 miles (9.77 km) of sandy shoreline with no beach present in 2012. Altogether 43.29 miles (69.67 km), or 34%, of sandy shoreline (with and without beaches present in May 2015) was modified by armor on the North Shore in 2015.

[18] Note that the apparent increase from 34.66 to 38.96 miles is 4.30 miles (6.92 km), but the actual increase is only 1.82 miles (2.93 km) because of a decline in the length of sandy shoreline with no beach present seaward of armor and because new sections of shoreline on Fisher Island were classified as sandy that were armored with no beach in 2015.

The beachfront armor on the North Shore includes groins, jetties, seawalls, revetments, bulkheads and breakwaters (Table 14). In 2015 there were 594 groins, 21 jetties, 280 contiguous sections of seawalls / revetments / bulkheads, and 4 breakwaters on the Long Island Sound shoreline of New York. While the number of jetties and breakwaters did not change between 2012 and 2015, both the number of groins and number of seawalls / revetments / bulkheads increased through new construction, the presence of sandy beaches seaward of armor where beaches were absent in 2012, and the new identification of armor exposed by Hurricane Sandy. The number of groins increased from 511 in 2012 to 554 in 2015, although none of the new groins were newly constructed. The number of contiguous seawalls / revetments / bulkheads increased from 255 in 2012 to 274 in 2015; 15 new revetments and bulkheads were constructed in the three years after Hurricane Sandy. An additional 6 contiguous seawalls / revetments / bulkheads and 44 groins were located on the 4.32 miles (6.95 km) of armored shoreline where sandy beaches were absent in May 2015, for a total of 594 groins, 21 jetties, 4 breakwaters, and 280 contiguous sections of seawalls, bulkheads and/or revetments along the sandy shoreline of the North Shore of Long Island (Table 14).

Only 1 of the 40 communities along the North Shore of Long Island have not been modified by beachfront armor (Table G-3). Although the beaches in East Marion, Mt. Sinai, the unincorporated portion of the Town of Brookhaven at McAllister County Park (Port Jefferson Harbor), and the tiny section of Locust Valley on Long Island Sound have zero percent of their beaches modified by armor (as listed in Table G-3), the first three of those communities have solitary groins or jetties present that were not measured but influence the adjacent shorelines. Only the section of Locust Valley on Long Island Sound, which is only one 178 ft (54m) lot wide, has no armor at all. All the other 36 communities' sandy beaches have been modified by varying levels of armor, ranging from 2 to 81%.

Proposed and Anticipated Habitat Modifications
The USACE proposed in late 2015 to rehabilitate 2 groins and construct 1 new groin on Asharoken beaches near Bevin Road, along with ~2.4 miles (3.9 km) of beach fill (USACE 2015h). In 2016 the USACE proposed to construct 6,790 linear ft (2,070 m) of seawalls, some buried, in Bayville; a number of private bulkheads and seawalls exist in the project area and the new seawalls would be constructed 10 ft (3 m) seaward of the private armor structures (USACE 2016b). Of the 6,790 linear ft (2,070 m) of seawalls proposed to be constructed, 3,434 ft (1,047 m) of sandy beach would be newly modified with armor (i.e., no armor exists in those areas as of 2015).

Three (3) private property owners in Nissequogue proposed to construct revetments or bulkheads at the toe of the bluff along Bluff Road and adjacent Long Beach Road. State permits to construct the revetments / bulkheads were under review at the NYS DEC in the fall of 2016 (NYS DEC Permit ID 1-4734-00711/00014, 1-4734-01029/00012 and 1-4734-01913/00006). If constructed, the three new armor structures in Nissequogue would modify 601 ft (183 m) of sandy beach that was not modified by armor in May 2015. Altogether, if constructed, the proposed private and federal armor projects would increase the length of sandy beach modified by armor on Long Island's North Shore by 0.76 miles (1.22 km) to a total of 39.72 miles (63.92 km) of sandy beach (32%), or 44.05 miles (70.89 km) of sandy shoreline with and without beaches present in May 2015 (34%).

Table 14. Approximate number of each type of armoring visible on the Long Island Sound sandy shoreline in each community of New York visible on Google Earth imagery between April 1994 and May 2015. Note that multiple seawalls, bulkheads or revetments are counted as one structure if they are continuous with no separations; for example, if five individual properties each have an individual seawall protecting their property and the seawalls are attached to each other with no gaps, the armoring is counted as one seawall structure and its overall length is counted in Table G-3 in Appendix G.

Community	Number of Groins	Number of Jetties	Number of Seawalls, Bulkheads and/or Revetments	Number of Breakwaters
Fishers Island	1	0	19	0
Plum Island	12	2	1	0
Orient	12	0	5	0
East Marion	1	0	0	0
Greenport	3	0	1	0
Southold	41	1	17	0
Peconic	4	0	6	0
Mattituck	0	2	5	0
Jamesport	17	0	9	0
Riverhead	3	0	2	0
Baiting Hollow	8	0	8	0
Wading River	6	0	13	0
East Shoreham	0	3	4	0
Shoreham	0	0	6	0
Rocky Point	1	0	13	0
Sound Beach	4	0	6	0
Miller Place	0	0	4	0
Mt. Sinai	0	1	0	0
Port Jefferson	0	1	2	0
Belle Terre	3	0	2	0
Town of Brookhaven (unincorporated area)	0	1	0	0
Old Field	3	3	4	0
Stony Brook	5	0	0	0
Nissequogue	5	0	6	0
Fort Salonga	25	3	15	0
Asharoken	17	0	5	0
Eatons Neck	26	0	2	0
Huntington Bay	32	0	8	0
Lloyd Harbor	92	1	25	2
Cold Spring Harbor	3	0	1	0

Community	Number of Groins	Number of Jetties	Number of Seawalls, Bulkheads and/or Revetments	Number of Breakwaters
Laurel Hollow	36	0	8	0
Cove Neck	11	0	7	0
Centre Island	19	0	6	0
Bayville	20	0	15	0
Locust Valley	0	0	0	0
Lattingtown	8	3	8	0
Glen Cove	57	0	15	2
Sea Cliff	25	0	4	0
Port Washington	6	0	3	0
Sands Point	88	0	25	0
TOTAL	**594**	**21**	**280**	**4**

Sediment Placement Modifications

In 2012 prior to Hurricane Sandy the length of sandy beach modified by sediment placement projects on the Long Island Sound shoreline of New York was 3.52 miles (5.66 km)[19]. A number of historical sediment placement projects have modified the North Shore but data were not available on their precise location and/or length (Rice 2015b). In the three years after Hurricane Sandy, 3.04 miles (4.89 km) of sandy beaches were newly modified by sediment placement projects (Table G-4). Sediment placement projects occurred at 48 locations between 2012 and 2015, all but 7 of them on private properties. Nearly all of the private sediment placement activities were associated with the repair or reconstruction of armor structures, often placing the sediment as backfill. One exception is in Asharoken, where artificial dunes were reconstructed along 1.00 mile (1.61 km) of beach from sediment trucked from an upland source to the beach after Hurricane Sandy (USACE 2015h).

Federal, county and local projects placed sediment dredged from nearby inlets on Bailie’s Beach in 2014, east of Wading River Inlet in 2014, at Stony Brook Harbor in 2013, and at Short Beach and Sunken Meadows SP in 2014. The U.S. Coast Guard placed sediment dredged from Eaton’s Neck Harbor Inlet on adjacent beaches annually from 2011-2015 (USACE 2015o). Altogether at least 6.56 miles (10.56 km), or 5%, of sandy beach on the Long Island Sound shoreline of New York have been modified by sediment placement projects as of 2015.

[19] Rice (2015b) cited the length of sandy beach modified in 2012 as 0.57 miles (0.92 km). New information sources available after Hurricane Sandy provided data on previous sediment placement project locations, correcting the length of sandy beach known to have been modified by sediment placement prior to Hurricane Sandy to 3.52 miles (5.66 km).

The sandy beaches of only 2 communities (out of 40) have been significantly modified by sediment placement. In Asharoken, 53% of the sandy beach has been modified by sediment placement as of 2015, and in Port Washington 43% (Table G-4). Belle Terre is the only other community with more than 10% of its sandy beaches modified by sediment placement; all the other communities were 7% or less. Twenty (20), or half, of the North Shore's communities have no beaches known to have been modified by sediment placement projects as of 2015.

Proposed and Anticipated Habitat Modifications

The USACE has proposed the Hashamomuck Cove Coastal Storm Risk Management Project, which would place 160,000 cubic yards (cy) of upland sand hauled in by truck on 8,500 ft (2,591 m) of beach in Southold. The initial design for the project does not proposed to construct any dunes, install any sand fencing, or plant any vegetation (USACE 2016c). In 2015, 360 ft (110 m) of the project area did not have any sandy beach present, either due to the presence of armoring or a high proportion of rocks on the beach; the proposed project, if constructed, thus could create 360 ft (110 m) of new beach. Only 155 ft (47 m) of the 8,500 ft (2,591 m) proposed project area is known to have previously been modified sediment placement, when a single private property owner placed sediment as backfill during repairs to a revetment/bulkhead in 2013 (NYS DEC Permit ID 1-4738-04227/00003). In 2016 the USACE proposed initial construction of the 50-year federal beach fill project in 2019, with periodic renourishment of 7,250 cy (5,543 m^3) of sediment placed on the beach every 5 years (USACE 2016c).

A second large sediment placement project has been proposed in Asharoken. The USACE proposed in 2015 to construct a ~2.4 mile (3.9 km) beach fill project in Asharoken, all but 1,318 ft (402 m) of which has previously been modified by sediment placement for artificial dune construction or sediment bypassing of the Northport Basin jetties. Initial construction of the project would place 600,000 cy (458,733 m^3) of sediment dredged from an offshore source along the beach extending north and west from the west jetty at Northport Basin. A groin field of 3 groins (2 rehabilitated and 1 new) would anchor the northwest end of the project area, as described in the Armor section above. Periodic renourishment of 80,000 cy (61,164 m^3) of sediment every 5 years, with 75,000 cy (57,342 m^3; 15,000 cy/year or 11,468 m^3/year) from sediment bypassing at Northport Basin[20] and 5,000 cy (3,823 m^3) from an upland source (USACE 2015h).

In addition to the two proposed federal projects, individual property owners have also proposed sediment placement projects on the North Shore. In 2015 three private property owners in Nissequogue proposed to place sediment as backfill behind new armor structures. State permits to construct the revetments / bulkheads and place the sediment were under review at the NYS DEC in the fall of 2016 (NYS DEC Permit ID 1-4734-00711/00014, 1-4734-01029/00012 and 1-4734-01913/00006). If constructed, the three new sediment placement projects in Nissequogue would modify 601 ft (183 m) of sandy beach that had not been modified by sediment placement as of 2015.

[20] According to USACE (2015h), the Long Island Power Authority, the owners of the Northport Power Station, is required by permit to bypass 15,000 cy (11,468 m^3) per year to beaches west of the Northport Basin jetties, or 45,000 cy (34,405 m^3) every 3 years. Of this sediment volume, 10,000 cy/year (7,646 m^3/year) are dredged from Northport Basin and the remaining 5,000 cy (3,823 m^3) are trucked in from an upland source.

If all 5 proposed sediment placement projects are constructed, the length of sandy beach modified by sediment placement projects would increase to at least 8.50 miles (13.68 km), or 7%, of the Long Island Sound shoreline of New York.

Beach Scraping Modifications

The threat from beach scraping on the Long Island Sound shoreline of New York is minimal, limited to 1.07 miles (1.72 km) of sandy beach, or 0.9%, from late 2012 to 2015 (Table G-5). Only 3 sections of beach scraping were identified in imagery and NYS DEC permits for the three years after Hurricane Sandy, modifying a total of 5,657 ft (1,724 m) of sandy beach. The 3 sections of beach scraping were located at the Fishers Island Club on Fishers Island, Sunken Meadows SP in Fort Salonga, and on Shorewood Drive in Bayville.

The general absence of beach scraping is due to the prevalent bluffs that line the North Shore of Long Island – dunes are uncommon. Bluffs or embankments are located at the back of a beach on non-barrier island or spit beaches and generally occupy the same area of the beach profile that dunes would on a barrier island or spit (Tanski 2012). If the beach at the base of the bluff or embankment is wide enough, dunes *could* form at the base of the bluff or embankment (but the beaches are typically not wide enough). Beach scraping as identified in this assessment is intended to create artificial dunes or levees. Where bluffs or embankments are present, beach scraping is not practical except in rare cases where it could be used to in an attempt to protect the toe of the bluff or embankment from erosion.

Sand Fencing Modifications

The threat from sand fencing on the Long Island Sound shoreline of New York is minimal, limited to 0.65 miles (1.05 km) of sandy beach, or 0.5%, from late 2012 to 2015 (Table G-6). Only 13 sections of sand fencing were identified in imagery for the three years after Hurricane Sandy, modifying a total of 3,436 ft (1,047 m) of sandy beach. The 13 sections of sand fencing were located in 4 communities: Wading River, Miller Place, Mt. Sinai and Asharoken.

The general absence of sand fencing is due to the prevalent bluffs that line the North Shore of Long Island – dunes are uncommon. Bluffs or embankments are located at the back of a beach on non-barrier island or spit beaches and generally occupy the same area of the beach profile that dunes would on a barrier island or spit (Tanski 2012). Sand fencing is generally intended to create dunes by creating an obstacle to trap windblown sand. The bluffs and embankments on the North Shore are much higher in elevation than sand fencing and can function as larger (natural) obstacles to windblown sand. Where bluffs or embankments are present, sand fencing is not practical except in rare cases where it could be used to in an attempt to protect the toe of the bluff or embankment from erosion.

Summary

Beaches on the North Shore were generally wider three years after Hurricane Sandy than they were before the storm, and sandy beach was present seaward of more armor structures in 2015 than in 2012 – a natural restoration of 1.25 miles (2.01 km) of sandy beach. Both phenomenon were most likely due to an overall increased sediment supply from bluff erosion caused by storms, including Hurricane Sandy.

The sandy beach habitat on the Long Island Sound shoreline of New York is threatened by beachfront development and armoring, with only minimal levels of habitat modified by sediment placement, beach scraping or sand fencing. Nearly two-thirds (62%) of the sandy shoreline of the North Shore has been developed and 34% has been armored with hard shoreline stabilization structures. In the three years after Hurricane Sandy, the level of development did not change and the level of armor increased. Only one armor structure was removed, but it was rebuilt in a slightly landward position. Over 100 armor structures were repaired or reconstructed after Hurricane Sandy, indicating that the armor is a long-term, if not permanent, modification of the sandy beach habitat. USACE (2015h) found that the private bulkheads along the southeastern section of Asharoken's beaches have offset the beach 50 ft (15 m) from its natural position. That is, the presence of the bulkhead armor has prevented the natural migration of the beach by 50 ft (15 m) as of 2015. USACE (2015h) also found that the jetties at Northport Basin to the west of Asharoken's beaches have influenced, through increased downdrift erosion, the shoreline for 6,000 ft (1,829 m) to the west. Both private and federal armor have been proposed along the North Shore, showing that armor remains a significant threat to the sandy beach habitat on the Long Island Sound shoreline of New York.

As sea level continues to rise the bluffs that line the majority of the shoreline will continue to erode, threatening the development situated on top of the bluffs; where armor is not present, the eroded sediment will increase the sediment supply to the sandy beaches and is likely to sustain the local habitat indefinitely. Where armor is present at the base of bluffs, the sediment supply to downdrift sandy beach habitat is likely to be reduced because the armor impounds a portion of the sediment supply and does not allow the beach to migrate landward (Tanski 2012). Over 4 miles (6.4 km) of sandy beach habitat on the North Shore was lost in 2015 as a result of armoring, and if existing armor is maintained (and raised), more sandy beach habitat may be lost as sea level continues to rise. As a result, sandy beach habitat in and downdrift of highly armored areas may not be as sustainable as sandy beach habitat near bluffs that have not been modified by armor.

New York – Peconic Estuary Shoreline

Beachfront Development

In 2015 there were 154.92 miles (249.32 km) of sandy shoreline on the Peconic Estuary shoreline of Long Island, with 144.87 miles (233.15 km) of sandy beaches and 10.02 miles (16.13 km) of armored shoreline where no sandy beach was present (Table H-1). Another 0.04 miles (0.06 km) of shoreline were composed of rocky beach. Where sandy beaches were present, the beachfront was 36% developed and 64% undeveloped. When sections of shoreline where sandy beaches were absent due to hard shoreline stabilization structures are included, the beachfront that was developed increases to 40% and the beachfront that was undeveloped decreases to 60%.

Prior to Hurricane Sandy, there were 134.98 miles (217.23 km) of sandy beach and 17.24 miles (27.75 km) of armored shoreline with no sandy beach along the Long Island Sound shoreline of New York, for a total of 152.22 miles (204.10 km) of shoreline (Rice 2015b). The increase of 9.89 miles (15.92 km) of sandy beach habitat and 2.70 miles (4.35 km) of sandy shoreline is due primarily to the growth of several barrier spits and the decrease in the length of armored, sandy shoreline with no beach present. Barrier spits lengthened between 2012 and 2015 at Jessups Neck in Noyack (~415 ft or 126 m), Simmons Point in Aquebogue (~700 ft or 213 m), Nassau Point in Cutchogue (~2,950 ft or 899 m), the spits extending both north and south from Robins Island (~2,600 and ~400 ft, or 792 and 122 m, respectively) and Paradise Point in Southold (~320 ft or 98 m); the total increase in new sandy beach habitat along these spits was 1.40 miles (2.25 km). The length of sandy shoreline where no sandy beach was present seaward of armor decreased 42% from 17.24 miles (27.75 km) to 10.02 miles (16.13 km) between 2012 and 2015; sandy beach habitat was present in 2015 in numerous locations where none was present in 2012, although the 2015 sandy beach habitat was very narrow seaward of the armor. The shifting positions of inlets and their adjacent barrier spits also changed the length and location of sandy beach habitat in the Peconic Estuary between 2012 and 2015.

In 2012 before Hurricane Sandy, the sandy shoreline (both where sandy beach was present and where absent seaward of armor) along the Peconic Estuary exposed shoreline was 41% developed and 59% undeveloped (Rice 2015b). Three years after Hurricane Sandy, the proportion of sandy shoreline modified by development decreased slightly to 40% with the growth of numerous undeveloped spits. No developed areas were converted to undeveloped beachfront between 2012 and 2015. Some homes on developed beachfront were torn down and rebuilt in the three years after Hurricane Sandy, indicating that the modification to sandy beach habitat due to development is long-term.

The length of beachfront in public and/or NGO ownership increased slightly in the three years following Hurricane Sandy (Table H-2). In 2012, 60.99 miles (98.15 km), or 45%, of the Peconic Estuary beachfront was in public or NGO ownership (Rice 2015b). One new sandy beachfront land is known to have been placed in public or NGO-ownership in the three years after Hurricane Sandy – Widow's Hole Preserve in Greenport. In December 2012, ExxonMobil donated a former petroleum fuels distribution terminal site to the Peconic Land Trust; the terminal had been removed and the site remediated in 2003. Habitat restoration of the site was ongoing in 2016 with the Peconic Land Trust, ExxonMobil, and other partners. The Widow's Hole Preserve included 0.14 miles (0.23 km) of sandy beach in 2015.

In addition, one tract of beach in public ownership was newly identified in Northwest Harbor through a new information source. Altogether in 2015, 62.53 miles (100.63 km) of sandy beach were present within public or NGO-owned beachfront lands, a slight increase due to shifting spits at inlets and the growth, or accretion, of the spits at Elizabeth Morton NWR (Jessups Neck) and Robins Island. The proportion of sandy beach within public or NGO-ownership declined slightly to 43% in 2015 due to the overall ~10 mile (~16 km) increase in length of sandy beach habitat in the Peconic Estuary.

Beach Armor Modifications

During the three years after Hurricane Sandy, 2.18 miles (3.51 km) of sandy beach habitat on the Peconic Estuary were modified by the construction of new armor structures. Nineteen (19) new armor structures were constructed between November 2012 and December 2015. Thirteen (13) of the 19 new armor structures were extensions of existing revetments, bulkheads or seawalls. An additional 0.60 miles (0.97 km) of armor were exposed after Hurricane Sandy that was not identified by Rice (2015b) in imagery from 2012 and earlier. In 2015, 10.02 miles (16.13 km) of sandy shoreline were armored but lacked sandy beach seaward of the armor structures. Altogether 47.07 miles (75.75 km), or 30%, of the sandy shoreline on the Peconic Estuary of New York were modified by armor in 2015 (Table H-3). In 2012, 27.05 miles (43.53 km) of sandy shoreline was modified by armor, and another 17.24 miles (27.75 km) of shoreline was armored but sandy beaches were absent due to the armor; altogether 44.29 miles (71.28 km), or 29%, of sandy shoreline on the Peconic Estuary was modified by armor prior to Hurricane Sandy.

A large number of armor structures were repaired and/or reconstructed during the three years after Hurricane Sandy, indicating that the threat of armor structures to modifying sandy beach habitat is permanent. The USACE repaired the breakwaters at Sag Harbor in the three years after Hurricane Sandy (USACE 2013t). The jetty and bulkheads at the inlet at the Devon Yacht Club in Amagansett were replaced in 2014-15 (NYS DEC Permit Application 1-4724-00030/00060). At least 256 private property owners repaired and/or reconstructed individual armor structures between November 2012 and December 2015 on the Peconic Estuary. Only one bulkhead was removed and not rebuilt after Hurricane Sandy, restoring 70 ft (21 m) of sandy beach habitat in Laurel.

The beachfront armor on the Peconic Estuary beachfront includes groins, jetties, seawalls, revetments, bulkheads and breakwaters (Table 15). In 2015 there were 1,036 groins, 50 jetties, 310 contiguous sections of seawalls / revetments / bulkheads, and 14 breakwaters on the exposed Peconic Estuary Sound sandy shoreline of New York. While the number of jetties (50) and breakwaters (14) did not change between 2012 and 2015, both the number of groins and number of seawalls / revetments / bulkheads increased through new construction and the new identification of armor exposed by Hurricane Sandy. The number of groins increased from 1,020 in 2012 to 1,036 in 2015, with 7 newly constructed groins and 9 groins exposed after Hurricane Sandy[21]. The number of contiguous seawalls / revetments / bulkheads increased from 305 in 2012 to 310 in 2015; 4 new revetments and bulkheads were constructed in the three years after Hurricane Sandy[22] and 1 bulkhead was exposed after the storm (having previously been buried).

[21] The 9 groins that were exposed after Hurricane Sandy were submerged prior to the storm and not identified in Rice (2015b). Prior to Hurricane Sandy these groins were submerged seaward of bulkheads or revetments where no sandy beach was present in 2012. In 2015, sandy beach habitat was present seaward of the armor and the groins became emergent and identifiable.
[22] Rice (2015b) identified a total of 306 seawalls / bulkheads / revetments and 1,021 groins present along the sandy shoreline of the exposed Peconic Estuary, including areas where sandy beach habitat was absent seaward of the

Table 15. Approximate number of each type of armoring visible on the sandy shoreline in each community on the Peconic Estuary shoreline of New York visible on Google Earth imagery between April 1994 and May 2015. Note that multiple seawalls, bulkheads or revetments are counted as one structure if they are continuous with no separations; for example, if five individual properties each have an individual seawall protecting their property and the seawalls are attached to each other with no gaps, the armoring is counted as one seawall structure and its overall length is counted in **Table H-3** **in Appendix H.**

Community	Number of Groins	Number of Jetties	Number of Seawalls, Bulkheads and/or Revetments	Number of Breakwaters
Montauk	5	2	8	0
Napeague	10	0	8	0
Amagansett	12	2	2	0
Springs	57	2	14	0
Northwest Harbor	0	3	3	0
Sag Harbor	0	0	4	4
North Haven	73	4	22	0
Noyack	43	0	9	0
North Sea	15	0	17	0
Tuckahoe	0	0	6	0
Hampton Bays	18	2	8	0
Flanders	1	0	1	0
Riverhead	0	0	0	0
Aquebogue	14	2	14	0
Jamesport	76	4	13	0
Laurel	74	0	4	0
Mattituck	92	0	13	1
Cutchogue	35	6	16	0
New Suffolk	56	1	9	3
Robins Island	2	0	4	0
Peconic	2	0	4	0
Southold	106	7	23	0
Greenport West	37	5	18	0
Greenport	14	1	10	2
East Marion	43	4	12	0
Shelter Island	179	2	52	4
Orient	63	1	16	0
Gardiners Island	9	2	0	0
TOTAL	**1,036**	**50**	**310**	**14**

armor. The total number of seawalls / bulkheads / revetments (3015) and groins (1,020) present in 2012 has been revised here to correct mathematical errors.

In addition, 13 contiguous sections of seawalls / revetments / bulkheads were extended through new construction and 15 seawalls / revetments / bulkheads were extended through exposure of previously buried sections.

Proposed and Anticipated Habitat Modifications
A 500 ft (152 m) brush-filled jetty[23] was proposed to be constructed on Budds Pond inlet in 2015, but no permits had been issued approving the work by the end of 2015 (NYS DEC Permit Application 1-4738-04140/00007). In 2016, the USACE proposed to construct 4 new groins in Montauk as part of the Lake Montauk Harbor Coastal Storm Risk Management Project. The 4 groins would initially be constructed with geotubes, but if the geotube groins perform satisfactorily after 10 years the geotube groins will be replaced with permanent, hard structures (USACE 2016g). If constructed, the 4 groins would increase the length of sandy beach modified by armor in Montauk by 270 ft (82 m).

Sediment Placement Modifications

During the three years after Hurricane Sandy, at least 4.54 miles (7.31 km) of sandy beaches on the Peconic Estuary shoreline of New York were modified by sediment placement. At least 65 private property owners placed sediment on the beach or at the toe of a bluff or embankment between November 2012 and December 2015, many of them as backfill behind repaired armor structures. At least 84,785 cubic yards (cy) of sediment were placed on the sandy beaches of the Peconic Estuary in the three years after Hurricane Sandy.

In addition, new information sources provided data previously missing regarding the precise locations and lengths of sandy beach modified by several inlet dredging projects conducted by Suffolk County. In 2012, the length of sandy beach known to be modified by sediment placement was at least 1.44 miles (2.32 km), or > 1%, with numerous known sediment placement projects (44 of 47) lacking sufficient placement location and length data (Rice 2015b). Altogether, as of 2015 at least 7.76 miles (12.49 km) of sandy shoreline, or 5%, in the Peconic Estuary are known to have been modified by sediment placement (Table H-4).

Proposed and Anticipated Habitat Modifications
In 2016, Suffolk County received a new permit from the USACE to conduct 10 years of maintenance dredging of the Shinnecock Canal, with the placement of the dredged material at Meschutt Beach County Park east of the Canal. The USACE permit also authorized the one-time dredging of a nearshore area immediately northeast of the west jetty on the Shinnecock Canal, with placement of 23,500 cy (17,967 m^3) along 1,500 ft (457 m) of sandy beach at Meschutt Beach County Park in May-June 2016. Suffolk County anticipates dredging the Canal and placing the dredged material on the beach every 2 years (USACE 2016h).

In 2016 the USACE proposed to construct a storm risk management project west of the inlet to Lake Montauk Harbor in Montauk. The proposed project would place 100,000 cy (76,455 m^3) of

[23] Some jetties in the northeastern U.S. are box-shaped, constructed out of steel sheet pile in the shape of a box rather than a narrower rock wall or dike extending perpendicular to shore. These box-jetties are typically filled with sediment, but this project proposes to use brush.

sediment dredged from the inlet channel and mined from adjacent areas on the beach west of the inlet every 10 years, adjacent to the four proposed geotube groins described in the previous section. Every 2 years, 20,000 cy (15,291 m^3) of sediment would be backpassed from the western end of the project area (within the new groin field) to the eastern end of the project area (near the jetty at the inlet) (USACE 2016g). In 2015, approximately 2,675 ft (815 m) of sandy shoreline within the proposed Lake Montauk Harbor Coastal Storm Risk Management Project area did not have beaches present seaward of existing armor. If constructed, the project would restore sandy beaches along those areas. Up to 5,550 ft (1,692 m) of sandy beach[24] would be newly modified by sediment placement in Montauk if the proposed project is constructed.

Also in 2016, the Property Owners Association of Noyac Harbor, Inc., proposed to perform 10 years of maintenance dredging of Noyac Creek and place the dredged sediment along 1,300 ft (396 m) of beach at Clam Island. Suffolk County dredged the inlet in 1969 and placed 134,900 cy (103,138 m^3) of sediment on adjacent beaches, but precise project location(s) were not available and whether the proposed 1,300 ft (396 m) placement area has previously been modified by sediment placement remains unknown.

If all three anticipated and proposed sediment placement projects are constructed, the length of sandy beach habitat on the Peconic Estuary known to have been modified by sediment placement will increase to 9.34 miles (15.03 km), or 6%.

Beach Scraping Modifications

The threat from beach scraping on the Peconic Estuary shoreline of New York is virtually nonexistent, limited to 0.02 miles (0.03 km) of sandy beach, or 0.01%, from late 2012 to 2015 (Table H-5). Only 1 section of beach scraping was identified in imagery and NYS DEC permits for the three years after Hurricane Sandy, modifying a total of 126 ft (38 m) of sandy beach in Cutchogue.

The general absence of beach scraping[25] is due to the generally narrow beaches and prevalent bluffs or embankments that line the Peconic Estuary of Long Island – dunes are uncommon. Bluffs or embankments are located at the back of a beach on non-barrier island or spit beaches and generally occupy the same area of the beach profile that dunes would on a barrier island or spit (Tanski 2012). If the beach at the base of the bluff or embankment is wide enough, dunes *could* form at the base of the bluff or embankment (but the beaches are typically not wide enough). Beach scraping as identified in this assessment is intended to create artificial dunes or levees. Where bluffs or embankments are present, beach scraping is not practical except in rare cases where it could be used to in an attempt to protect the toe of the bluff or embankment from erosion.

[24] An unknown length of sandy beach west of the inlet to Lake Montauk Harbor has previously been modified by placement of sediment dredged from the inlet (Rice 2015b).
[25] Grading of the bluff or embankment at the back of the beach as part of bluff stabilization projects also occurs on the Peconic Estuary shoreline, typically in conjunction with armor repairs / replacement or sediment placement projects. These projects were excluded from this assessment because they are related to sediment placement, including backfilling landward of armor structures, and do not scrape the beach itself.

Sand Fencing Modifications

The threat from sand fencing on the Peconic Estuary shoreline of New York is minimal, limited to 0.79 miles (1.27 km) of sandy beach, or 0.55%, from late 2012 to 2015 (Table H-6). Only 38 sections of sand fencing were identified in imagery for the three years after Hurricane Sandy, modifying a total of 4,169 ft (1,271 m) of sandy beach. The 38 sections of sand fencing were located in 12 of the 28 communities along the Peconic Estuary beachfront. The proportion of sandy beach habitat modified by sand fencing within those 12 communities ranged from 0.1 to 4.8%.

The general absence of sand fencing is due to the generally narrow beaches and prevalent bluffs or embankments that line the Peconic Estuary shoreline of Long Island – dunes are uncommon. Bluffs or embankments are located at the back of a beach on non-barrier island or spit beaches and generally occupy the same area of the beach profile that dunes would on a barrier island or spit (Tanski 2012). Sand fencing is generally intended to create dunes by creating an obstacle to trap windblown sand. The bluffs and embankments on the Peconic Estuary shoreline are much higher in elevation than sand fencing and can function as larger (natural) obstacles to windblown sand. Where bluffs or embankments are present, sand fencing is not practical except in rare cases where it could be used to in an attempt to protect the toe of the bluff or embankment from erosion.

Summary

Sandy beach habitat on the exposed shoreline of the Peconic Estuary in New York is most threatened by development and armor. Forty percent (40%) of the sandy shoreline on the exposed Peconic Estuary shoreline was modified by beachfront development in 2015. The sandy beach habitat in 19 of the 28 communities (68%) along the Peconic Estuary beachfront was more than 50% developed in 2015. Laurel (95%), Tuckahoe (91%), Mattituck (86%), East Marion (83%), New Suffolk (78%) and Sag Harbor (77%) all had more than three-quarters of their sandy shorelines (with and without beaches present) developed in 2015. In contrast, the least developed sandy shorelines in 2015 were in Riverhead (0%), Gardiners Island (0%), Robins Island (3%), and Orient (11%). Much of the development has modified the sandy shoreline for decades, and given that no significant developed areas were removed in the three years after a major storm (Hurricane Sandy), development appears to be a long-term and perhaps permanent source of habitat modification for the sandy beach ecosystem of the Peconic Estuary.

Beachfront armor is a significant and long-term threat to sandy beach habitat in the Peconic Estuary as well. In 2012, 17.24 miles (27.75 km) of sandy beach habitat was absent seaward of armor. In 2015, the length of armored shoreline without sandy beach declined to 10.02 miles (16.13 km), nearly always in the same locations as in 2012. Only 5 (of 28) communities had not lost any sandy beach habitat due to armor in 2015: Flanders, Riverhead, Robins Island, Peconic and Gardiners Island (Table H-3). Over half of the sandy beach habitat was modified by armor in 5 communities in 2015: Laurel (92%), Mattituck (91%), East Marion (75%), Jamesport (54%) and New Suffolk (52%). Between 30 and 50% of the sandy beach habitat was modified by armor in 2015 in another 12 communities. Altogether at least 30% of the sandy beach habitat was modified by armor in 61% of the communities (17 of 28) on the Peconic Estuary in 2015.

The repair and replacement of over 256 armor structures in the three years after Hurricane Sandy, and the removal of only 1 structure, indicates that the habitat modifications due to armor are long-term and likely permanent on the Peconic Estuary beachfront.

Sediment placement minimally threatens the sandy beach habitat on the Peconic Estuary shoreline, most notably adjacent to inlets that are dredged. In those locations, the sandy beach habitat may be heavily modified with the placement of dredged material annually or every few years, more frequently than is typically documented to be necessary for the invertebrate prey base to fully recover. Beach scraping and sand fencing are currently minimal threats to sandy beach habitat in the Peconic Estuary.

New York – Atlantic Ocean Shoreline

Beachfront Development

In 2015 there were 125.69 miles (202.28 km) of sandy shoreline on the South Shore of Long Island, with 122.57 miles (197.26 km) of sandy beaches and 3.12 miles (5.02 km) of armored shoreline where no sandy beach was present (Table I-1). Another 0.65 miles (1.04 km) of shoreline in Montauk were predominantly rocky. Where sandy beaches were present, the beachfront was 43% developed and 57% undeveloped. When sections of shoreline where sandy beaches were absent due to hard shoreline stabilization structures are included, the beachfront that was developed increases to 45% and the beachfront that was undeveloped decreases to 55%. Of the 3.12 miles (5.02 km) of armored shoreline were sandy beaches were absent in 2015, 0.13 miles (0.21 km) were scheduled to receive sediment placement in 2016 as part of a federal erosion control project that initiated construction in 2015; as a result, the length of shoreline armored with no beach is anticipated to decrease to 2.99 miles (4.81 km) in the very near future.

Prior to Hurricane Sandy, there were 124.88 miles (200.97 km) of sandy beach and 1.38 miles (2.22 km) of armored shoreline with no sandy beach along the Atlantic Ocean shoreline of New York, for a total of 126.26 miles (203.20 km) of shoreline (Rice 2015a). The slight decrease to 125.69 miles (202.28 km) of shoreline is due to changes in the distribution of predominantly sandy beaches at the base of bluffs in Montauk and the shifting positions of inlets at coastal ponds. In the three years since Hurricane Sandy, the new inlet/breach at Fire Island National Seashore has accreted spits and shoals along its shoulders, resulting in no net loss of sandy beach available to wildlife resources as of 2015; the overall length of sandy beaches on Fire Island actually increased slightly from 2012 to 2015, by approximately 264 feet (90.5 m). The increase from 1.38 miles (2.22 km) to 3.12 miles (5.02 km) of armored shoreline without beaches is primarily due to an increase in Oak Beach, where 1.43 miles (2.30 km) of armored shoreline were lacking beaches in 2015.

Three years after Hurricane Sandy, 45% of the beachfront along the South Shore was developed and 55% undeveloped. Prior estimates from 2012 (before Hurricane Sandy), the beachfront were 47% developed and 53% undeveloped. However, this shift is primarily due to a revision to the methodology for identifying developed versus undeveloped beachfront. The methodology was revised to be consistent with that used in Rice (2015b) along the shoreline from Maine to the Long Island Sound and Peconic Estuary shorelines of New York. That is, the distance from the beach in which development was evaluated was limited to the area from the vegetation line to a shore parallel road or 500 ft (152.4 m), whichever was closer to the beach (see the Methods section for more information). This refinement resulted in slight changes to the proportions of beachfront classified as developed or undeveloped in Lido Beach, where beachfront development is present but set back over 500 ft (152.4 m) from the beach.

The beaches of New York have multiple layers of governance and management. Most of Long Island falls within Suffolk and Nassau Counties. Within the counties, there are a number of Towns such as Southampton, East Hampton, Brookhaven and Islip. These towns have multiple incorporated villages or hamlets (e.g., Montauk, Sagaponack, Westhampton Beach, and Long Beach) as well as unincorporated areas. The Dongan Patent of 1686 granted the Towns ownership of the waters and beaches (amongst other natural resources) within their boundaries, which the Towns manage via Boards of Trustees. These Boards of Trustees are separate from the Town Councils or Boards.

The sandy beaches of Long Island are therefore publicly owned by the various Towns, although their use is often restricted to residents of the Town. The property immediately adjacent to the beach, however, is most often privately owned. For example, the Town of Hempstead owns the sandy beach along eastern Long Beach Island and manages several sections as public parks. Immediately adjacent to the public beaches that are not within larger parks, however, are a number of private properties including beach clubs, beach camps, and private residences. The Town of Southampton owns the oceanfront beach within its boundaries, but private property again lines the shoreline behind the beach.

The length of beachfront in public and/or non-governmental organization (NGO) ownership did not change significantly in the three years following Hurricane Sandy (Table I-2). In 2012, 60.73 miles (97.74 km), or 48%, of the South Shore beachfront was estimated in public or NGO ownership (Rice 2015c). Although no new sandy beachfront lands are known to have been placed in public or NGO-ownership in the three years after Hurricane Sandy, three public beachfront lands owned by the Town of Southampton were newly identified through a new information source (Tiana Beach Oceanside, Sand Bar Beach, and Triton Beach). In 2015, 61.60 miles (99.13 km) of sandy beach were present within public or NGO-owned beachfront lands, a slight increase due to the identification of new public beachfront lands in the Town of Southampton. The proportion of sandy beach within public or NGO-ownership therefore increased slightly to 50% in 2015. The public and NGO owned lands listed in Table I-2 do not include Town-owned beaches unless the adjacent properties are also public or NGO lands. It is unknown whether the Towns' ownership and management of the beaches (through the Dongan Patent) will move along with the beaches as they migrate with rising sea level, or if the adjacent private property will affect that ownership and/or management of the sandy beaches.

Beach Armor Modifications

Prior to Hurricane Sandy, 25.33 miles (40.76 km) of the Atlantic Ocean shoreline of New York were known to be modified by hard shoreline stabilization structures, or armoring. Seventy (70) new revetments and bulkheads were constructed in the three years following Hurricane Sandy, totaling 11.41 miles (18.36 km) in length. Some of these revetments and bulkheads were constructed in areas that were previously armored with groin fields, and others such as those on the Rockaway peninsula were constructed in two rows (on both sides of the boardwalk under reconstruction). Removing overlapping hard shoreline stabilization structures, a total of 7.06 new miles (11.36 km) of sandy beaches on the South Shore were armored with bulkheads and revetments from late 2012 to 2015. Most of this increase was due to the construction of sand-filled geotextile revetments, referred to as "sand cubes," "geocubes," or the brand-name "TrapBags."

Another 3.24 miles (5.21 km) of sandy beach armored with hard shoreline stabilization structures were identified following Hurricane Sandy; these structures were exposed by Hurricane Sandy or hurricane rebuilding efforts. Altogether the length of sandy beach armored (both newly constructed and newly identified) in the three years following Hurricane Sandy was 10.30 miles (10.58 km), an increase of 41% from the length of shoreline armored prior to the storm. As of the end of 2015, 35.63 miles (57.34 km), or 28%, of Atlantic Ocean shoreline of New York was armored (Table I-3). Of the 35.63 miles (57.34 km) of armored beaches identified three years after Hurricane Sandy, 3.12 miles (5.02 km) had no sandy beach present at the time the 2015 aerial imagery was taken.

Ten (10) of the 30 communities listed in Table I-3 on the South Shore were more than 50% armored in 2015. Prior to Hurricane Sandy, 8 of the 30 communities were not known to have been modified by any hard shoreline stabilization structures. Three years after Hurricane Sandy, the sandy beaches of only 3 of the 30 communities have not been modified by beach armoring: Napeague, Captree State Park (SP) in Islip[26], and Oyster Bay (Tobay Beach)[27]. Hard shoreline stabilization structures were either newly constructed or newly identified in Amagansett, Wainscott, the Village of Sagaponack, Bridgehampton, and Water Mill in the three years after Hurricane Sandy, modifying the sandy beaches in those communities.

Hurricane Sandy destroyed one geotube revetment in Ocean Beach on Fire Island. Between November 2012 and December 2015, 3 groins were intentionally removed on the South Shore – one in East Hampton Village (where the stone was re-used to build a revetment) and two in Rockaway Park. In Sea Gate, one breakwater was converted to a T-groin and 3 new T-groins were constructed. The jetty at Jones Inlet was repaired by the USACE in 2014 (USACE 2013u). The east jetty at East Rockaway Inlet was also repaired in 2014 by the USACE (USACE 2013v). Altogether the South Shore of Long Island had 114 seawalls / bulkheads / revetments, at least 295 groins, 8 jetties and 1 breakwater as of the end of 2015 (Table 16). Dallas et al. (2013) identified an additional 63 groins that may exist on the Rockaway peninsula, but they are not visible in Google Earth imagery.

[26] A section of Fire Island is also located within the Town of Islip but that section contains armoring.
[27] While the beaches in Hampton Bays and East Quogue have zero length of sandy beaches listed as modified by armoring (Table I-3), there is one jetty within the municipal boundaries.

Table 16. Approximate number of each type of armoring visible on the oceanfront beach in each community on the Atlantic Ocean shoreline of New York visible on Google Earth imagery between April 1994 and May 2015 or identified by Dallas et al (2013). Note that multiple seawalls, bulkheads or revetments are counted as one structure if they are continuous with no separations; for example, if five individual properties each have an individual seawall protecting their property and the seawalls are attached to each other with no gaps, the armoring is counted as one seawall structure and its overall length is counted in Table I-3 in Appendix I.

Community	Number of Groins	Number of Jetties	Number of Seawalls, Bulkheads and/or Revetments	Number of Breakwaters
Montauk	2	0	4	0
Napeague	0	0	0	0
Amagansett	0	0	1	0
East Hampton Village	8	0	8	0
Wainscott	0	0	1	0
Village of Sagaponack	0	0	4	0
Bridgehampton	0	0	1	0
Water Mill	0	0	2	0
Village of Southampton	3	1	10	0
Hampton Bays & East Quogue	0	1	0	0
Quogue	0	0	7	0
Westhampton Beach	11	0	0	0
Town of Southampton (unincorporated areas)	4	1	0	0
West Hampton Dunes	1	0	0	0
Fire Island	2	2	19	0
Islip (Captree SP)	0	0	0	0
Babylon (Oak Beach & Gilgo Beach) [1]	43	0	23	0
Oyster Bay (Tobay Beach)	0	0	0	0
Hempstead (Jones Beach SP, Point Lookout, Lido Beach & Silver Point County Park) [2]	11	2	2	0
Long Beach	25	0	3	0
East Atlantic Beach	8	0	1	0
Atlantic Beach	9	0	2	0
Far Rockaway [3]	12	0	2	0
Arverne [3]	16	0	4	0
Rockaway Park [3]	65	0	6	0
Breezy Point [3]	40	1	5	0
Manhattan Beach	3	0	3	0
Brighton Beach	8	0	1	0
Coney Island – West Brighton	16	0	1	0

Community	Number of Groins	Number of Jetties	Number of Seawalls, Bulkheads and/or Revetments	Number of Breakwaters
Sea Gate	8	0	4	1
TOTAL	**Up to 358†**	**8**	**114**	**1**

1 – Babylon also has the "sore thumb dike" at Fire Island Inlet which is a shore-perpendicular structure similar to a groin but is composed of sand with two armored rock tips at the end. It is not categorized here due to its unique nature. The section of shoreline east of the dike contributes all 43 groins and 23 seawalls, bulkheads or revetments to the Babylon total.

2 – The total number of groins listed here for Hempstead includes the 4 new groins under construction in 2015-16 by the USACE.

3 – An additional 63 groins may exist but are not visible on the Rockaway peninsula within available imagery sources (Dallas et al. 2013).

† - The total number of groins includes the groins reported by Dallas et al. (2013) for the Rockaway peninsula that were not located in available imagery sources.

Proposed and Anticipated Habitat Modifications

Four additional projects involving hard shoreline stabilization structures have been proposed along the South Shore. The USACE has proposed to improve the revetment at Montauk Point, with final project plans anticipated in 2016; project construction has been funded with Disaster Relief Appropriations Act of 2013 appropriations. Previous project plans did not propose to expand the revetment into previously unarmored sections of sandy beach. Two private property owners have proposed a revetment and bulkhead on their properties in Montauk, but neither had received NYS DEC permits as of the end of 2015. Finally, the USACE initiated construction in early 2016 on the East Rockaway Inlet (Long Beach Island) Hurricane and Storm Damage Reduction Project in Long Beach, Lido Beach and Point Lookout in early 2016. This project includes construction of 4 new groins that will increase the length of Hempstead shoreline armored by 0.51 miles (0.82 km).

Sediment Placement Modifications

Prior to Hurricane Sandy, ~65 miles (~105 km)[28] of sandy beach on the South Shore of Long Island had been modified by sediment placement, and another 5.00 miles (8.05 km) had been proposed (not including any new sediment placement actions considered under the federal Fire Island to Montauk Point [FIMP] project). In the three years following Hurricane Sandy, 44.98 miles (72.39 km) of the South Shore's sandy beaches were modified with sediment placement, with 32.31 miles (52.00 km) of those beaches having previously been modified with sediment placement and 12.67 miles (20.39 km) of those beaches newly modified after Hurricane Sandy, an increase of 20% (Table I-4). Altogether, as of the end of 2015, 77.27 miles (124.35 km), or 62%, of sandy beaches on the Atlantic Ocean shoreline of New York had been modified with sediment placement at least once.

[28] This total has been corrected from the 65.30 miles listed in Table 10 of Rice (2015a) to adjust overlapping project boundaries from additional data sources.

In one location sediment was being placed where no sandy beach was present due to armoring. In Sea Gate, a federal erosion control project was in the process of (as of 2016) constructing a series of T-groins and placing sediment along 2,000 feet (610 meters [m]) of shoreline, creating 667 feet (203 m) of sandy beach where the shoreline was lacking sandy beach prior to the start of the project.

Proposed and Anticipated Habitat Modifications
As of the end of 2015, an additional 15.88 miles (25.56 km) of sandy beaches were proposed or scheduled to be modified with sediment placement; 10.22 miles (16.45 km) of the proposed project areas have previously been modified by sediment placement, and 5.66 miles (9.11 km) have not. The 11 proposed project areas include the developed communities on Fire Island, which are proposed to receive fill as part of the federal Fire Island to Moriches Inlets (FIMI) Project, and the federal Jones Inlet to East Rockaway Inlet (Long Beach) Hurricane and Storm Damage Reduction Project (which is also constructed 4 new groins as described in the Armor section above). Both of these projects have been funded and began construction in 2016.

At least 125 separate project areas or sections received or were proposed to receive beach and/or dune fill in the three years after Hurricane Sandy along the Atlantic Ocean coast of New York. Of the 43 projects where sediment volume data were available, 17,292,352 cubic yards (cy) of sediment were placed or in the process of being placed at the end of 2015. An additional 7,962,285 cubic yards (cy) were anticipated to be placed as part of the FIMI and Long Beach projects beginning in 2016, and another 1,100,100 cy (841,087 m^3) has been proposed for placement in a community-wide project in Quogue and a private property project in Montauk. Three years after Hurricane Sandy, 68% of the South Shore's sandy beaches (82.93 miles or 1332.46 km) have been or are proposed to be modified by sediment placement projects, an increase of 15% from the proportion of sandy beaches modified by sediment placement prior to Hurricane Sandy.

Beach Scraping Modifications

In the three years following Hurricane Sandy, at least 22.48 miles (36.18 km), or 18%, of sandy beach on the South Shore of Long Island were modified with beach scraping or grading (Table I-5). The beach can be scraped or graded to create artificial dunes or levees immediately following a storm event, to remove overwash material from developed or paved areas along the beachfront, or to bury newly constructed geotextile revetments, bulkheads or sand retaining walls[29]. Several communities on the Atlantic Ocean shoreline of New York have community-wide, 10-year beach scraping or grading permits from NYS DEC to scrape or grade the beach whenever conditions permit.

[29] Note that beach scraping or grading that scraped/graded fill material as part of a sediment placement project was excluded, unless the fill material was from an upland source and placed to bury or build an artificial dune/levee and involved scraping of the beach in addition to the fill. Technically every sediment placement project involves scraping or grading of the fill material to the design specifications – this metric was intended to capture habitat modifications resulting from scraping of the natural beach profile and sediment, not strictly fill material placed on top of the natural profile.

Beach scraping or grading occurred in all but 8 of the 30 of the communities along the South Shore in the three years since Hurricane Sandy. The sandy beaches in Napeague, Amagansett, Westhampton Beach, Captree SP in the Town of Islip, Tobay Beach in the Town of Oyster Bay, Atlantic Beach, Manhattan Beach, and Sea Gate were not modified by beach scraping or grading in the three years after Hurricane Sandy. Beach scraping or grading modified varying proportions of the sandy beaches in the other 22 communities.

Sand Fencing Modifications

Twelve (12) of the South Shore's 30 communities have had at least 50% of their sandy beaches modified with sand fencing since Hurricane Sandy (Table 5). A total of at least 57.85 miles (93.10 km) of sandy beach have been modified with sand fencing, or 46% of the South Shore's sandy beaches (Table I-6). At least 530 separate sections of sand fencing were identified on the sandy beaches of Long Island's South Shore in the three years following Hurricane Sandy. Only Captree SP in Islip and the Sea Gate area in Brooklyn did not have any sand fencing during the three-year period. An additional 1.60 miles (2.57 km) of sand fencing has been proposed and authorized for installation in Far Rockaway, Arverne, and Rockaway Park (NYS DEC 2013a, NYC Office of Management and Budget 2014) but a lack of imagery for the latter half of 2015 precluded confirmation that any of it had been installed.

The federal Jones Inlet to East Rockaway Inlet (Long Beach Island) Hurricane and Storm Damage Reduction Project initiated construction in early 2016 along the sandy beaches of Hempstead (Lido Beach and Point Lookout) and Long Beach. The sediment placement component of the project (anticipated for 2017) includes the installation of 75,000 linear feet of beach and dunes, which will increase significantly the length of beaches in those two communities modified by sand fencing.

Summary

The sandy beach habitat on South Shore of Long Island has been significantly modified by anthropogenic activities. Nearly half (45%) of the beachfront has been developed (Table 17). Twenty-eight (28) percent of the beachfront is known to be armored with hard shoreline stabilization structures. More than two-thirds (68%) of the beaches have been or are proposed to be modified by sediment placement projects. At least 18% of the beaches were scraped or graded in the three years following Hurricane Sandy. And nearly half (46%) of the sandy beaches were modified by sand fencing between 2012 and 2015.

The beaches in Kings County – Sea Gate, Coney Island, Brighton Beach and Manhattan Beach – are the most developed (92%), armored (100%) and modified by sediment placement (68%). Nassau and Suffolk Counties have the most sand fencing, with 54% and 47% of their beaches modified in this way respectively. The highest proportion of beach scraping (53%) occurred in Queens County, the Rockaways peninsula. The Rockaways are also highly modified by armor

Table 17. The length of sandy shoreline in each county along the Atlantic Ocean coast of New York and the proportion of shoreline modified by beachfront development, armor, sediment placement (fill), beach scraping or grading (from 2012-15), and sand fencing (from 2012-15) as of 2015.

County	Shoreline Length (miles)	Habitat Modification Type				
		Development	Armor	Fill	Beach Scraping	Sand Fencing
Suffolk	93.06	43%	18%	61%	16%	47%
Nassau	17.69	46%	36%	54%	6%	54%
Queens	10.56	38%	79%	67%	53%	39%
Kings	4.38	92%	100%	68%	23%	16%
STATE TOTAL	**125.69**	**45%**	**28%**	**62%**	**18%**	**46%**

(79%) and sediment placement (67%), but are the least modified by beachfront development (38%).

Three areas in particular on the South Shore of Long Island have been heavily modified in the three years since Hurricane Sandy: (1) the beaches from East Hampton Village through the Village of Southampton, (2) Fire Island, and (3) the Rockaway peninsula. Each of these three areas has had significant cumulative impacts to its sandy beaches since Hurricane Sandy.

In the six adjacent communities of East Hampton Village, Wainscott, the Village of Sagaponack, Bridgehampton, Water Mill and the Village of Southampton, which includes 18.62 miles (29.97 km) of sandy beach habitat, a significant number of private and local projects modified the beaches from 2012 to 2015 (Table 18). The largest of these were two locally sponsored sediment placement projects constructed in 2013-2014 that modified 5.63 miles (9.06 km) of sandy beach habitat in the Village of Sagaponack, Bridgehampton and Water Mill. This was the longest contiguous new sediment placement project on the South Shore in the three years after Hurricane Sandy. The only previous time that any of these beaches were known to be modified with sediment placement was in 1962 following the Ash Wednesday Storm.

Numerous private property owners modified the sandy beaches of their individual properties as well following Hurricane Sandy (Table 19). At least 28 individual property owners modified the sandy beaches in this area with hard shoreline stabilization structures in the three years after Hurricane Sandy, with 26 contiguous sections of revetments, bulkheads and/or seawalls identified (either new structures or improvements to pre-existing but previously buried structures). Fifty-seven (57) private property owners are known to have placed sediment on the beach; additional property owners may have placed fill directly underneath their buildings where the hurricane exposed their pilings and foundations. The same number of private property owners (57) scraped or graded the beach, often to fill and/or bury newly constructed sandbag revetments. Sand fencing is also prevalent in these communities, with 99 separate, contiguous

Table 18. The lengths of sandy shoreline and the proportions of sandy beach modified by type of habitat modification in six communities along the Atlantic Ocean shoreline of Suffolk County, New York.

Community	Shoreline Length (miles)	Habitat Modification Type				
		Development	Armor	Sediment Placement	Beach Scraping	Sand Fencing
East Hampton Village	4.33	82%	44%	59%	12%	45%
Wainscott	0.94	46%	4%	69%	3%	94%
Village of Sagaponack	2.56	70%	19%	100%	49%	72%
Bridgehampton	2.29	83%	9%	100%	20%	81%
Water Mill	1.43	46%	15%	100%	36%	83%
Village of Southampton	7.07	80%	16%	55%	18%	69%
TOTAL	**18.62**	**75%**	**19%**	**72%**	**22%**	**68%**

Table 19. The number of private property owners who modified sandy beach habitat on their properties in the three years since Hurricane Sandy in five communities along the Atlantic Ocean shoreline of Suffolk County, New York.

Community	Number of Private Property Owners Who Modified Sandy Beach Habitat with			Number of Sections of Sand Fencing[1]
	Armor	Sediment Placement	Beach Scraping	
East Hampton Village	8	13	13	22
Wainscott	1	2	2	3
Sagaponack	4	11	11	7
Bridgehampton	1	10	10	15
Water Mill	2	9	9	6
Southampton (Village)	12	12	12	46
TOTAL	**28**	**57**	**57**	**99**

1 – A single contiguous section of sand fencing may span across several adjacent private properties.

sections of sand fencing totaling 12.65 miles (20.36 km) identified in the three years after Hurricane Sandy.

The cumulative impacts of these individual projects is significant for this section of sandy beach habitat. In the two years prior to Hurricane Sandy, the NYS DEC received coastal erosion management permits for 7 and 4 projects respectively within the Town of Southampton (covering the communities from the Village of Sagaponack to West Hampton Dunes). In the *two months* following Hurricane Sandy, NYS DEC received 108 permit applications that would allow property owners to modify oceanfront sandy beaches through armoring, sediment placement or beach scraping/grading in the Town of Southampton. In 2013, 41 permit applications were received. In 2014 only 3 permit applications were received, and in 2015 none. Virtually all of these state permits were issued, resulting in a significant cumulative impact to the Town's sandy beach habitat.

In comparison, within the neighboring Town of East Hampton (covering the communities of Montauk to Wainscott), far fewer NYS DEC permit applications were received: 10 in the two months following the hurricane, 20 in 2014, 8 in 2014 and 1 in 2015. The order of magnitude fewer permit applications by property owners in the Town of East Hampton is most likely due to the Town's Local Waterfront Revitalization Plan, which includes a number of protective measures for sandy beach habitat that are approved by the state of New York and the U.S. Office of Ocean and Coastal Resources Management.

On Fire Island, the cumulative impacts of sandy beach habitat modifications in the three years following Hurricane Sandy are also significant. Although 98% of the island has been modified with sediment placement at least once, in the two decades preceding Hurricane Sandy, sediment placement was restricted to Robert Moses SP at the west end, 11 of the developed communities within the Fire Island National Seashore, and Smith Point County Park at the east end; these projects modified 13.42 miles (21.60 km), or 43%, of Fire Island between 1992 and 2012, but in smaller lengths spread out periodically over the 20 years preceding Hurricane Sandy. The federal Fire Island to Moriches Inlets (FIMI) project, however, is in the process of placing sediment along 17.41 miles (28.02 km) of Fire Island beaches, modifying 55% of the barrier island's sandy beach habitat within an anticipated 2-3 year time period. In addition to FIMI, four other sediment placement projects have been constructed at Robert Moses SP since Hurricane Sandy and a breach opened by the storm at Smith Point County Park was closed artificially with fill material immediately after the storm. The National Park Service placed a small volume of sediment dredged from the Watch Hill Marina along approximately 600 ft (183 m) of oceanfront beach in Davis Park in 2014.

In addition to the habitat modifications resulting from sediment placement projects, 11 of the 17 developed communities on Fire Island constructed TrapBag revetments along their entire beachfronts within one year of Hurricane Sandy. These revetments increased the length of sandy beach on Fire Island modified by armoring by 4.86 miles (7.82 km), or *ten times* the length of beach armored on the island before the hurricane. A total of 85 contiguous sections of sand fencing were installed on the island from late 2012 through 2015, modifying 13.65 miles (21.97 km), or 43%, of the island's sandy beaches.

A number of habitat modifications also have generated significant cumulative impacts on the Rockaways peninsula in the three years since Hurricane Sandy. The USACE constructed a beach and dune fill project along 6.1 miles (9.8 km) of beach in Far Rockaway, Arverne and Rockaway Park using 2.8 million cubic yards (mcy) of material dredged from East Rockaway Inlet and an offshore borrow area. Although this sediment placement project was in an existing federal project area, the construction of the virtually continuous dune ridge from Beach 19th to

Beach 149th Streets significantly modified the existing project area as previous renourishment episodes had not in recent years. The New York City (NYC) Department of Parks and Recreation has also undertaken the Rockaway Boardwalk Reconstruction Project[30] from Beach 9th to Beach 149th Streets. In addition to rebuilding the Rockaway Boardwalk itself, the project has installed concrete bulkheads (referred to as "sand retaining walls") underneath the new boardwalk on its landward side. Sand "TrapBag" revetments were installed along the seaward side of the boardwalk and the pre-existing concrete bulkheads from Beach 55th to Beach 19th Streets (NYS DEC 2013a, NYC Office of Management and Budget 2014). Additional sediment is being placed between the concrete bulkheads and the USACE dune, filling in the void underneath and immediately seaward of the new boardwalk from Beach 20th to Beach 126th Streets (NYC Office of Management and Budget 2014). This supplemental sediment placement on the back beach is a new modification of the pre-existing sediment placement project area.

Altogether ten new contiguous sections of bulkheads and revetments were constructed on the Rockaway peninsula from 2012 to 2015, nearly all of which were installed along sandy beaches previously armored with extensive groin fields but not walls. "TrapBags" are filled with sediment excavated, or scraped, from the adjacent beach; thus 4.44 miles (7.15 km) of beach in Far Rockaway, Arverne and Rockaway Park were scraped in 2013. Several smaller areas within this larger scraped area were scraped of overwash material immediately following the storm. Portions of Jacob Riis Park and Breezy Point on the west end of the peninsula were also scraped since Hurricane Sandy, with the latter project using the scraped material to construct a one mile (1.6 km) long artificial dune ridge (NYS DEC 2013b). Extensive sand fencing and vegetation planting of the newly constructed artificial dune/levee have also modified the sandy beaches of the Rockaways, as both are components of the Rockaway Boardwalk Reconstruction Project area, from Beach 9th to Beach 149th Streets (NYS DEC 2013a, NYC Office of Management and Budget 2014).

The sandy beach habitat along the South Shore of Long Island continues to be threatened by development, sediment placement projects, armoring, beach scraping and sand fencing. Only one individual property on which a house was destroyed by Hurricane Sandy has not been rebuilt. In a few other locations, beachfront lots that were vacant prior to the storm have been developed. The length of sandy beach modified by sediment placement increased significantly. Several new miles of hard shoreline stabilization structures have been constructed. A number of communities have 10-year state permits to modify their entire beachfronts with beach scraping as conditions allow. And sand fencing modifies nearly half of the South Shore's sandy beaches. In one community – Quogue – local ordinances actually require private property owners to install and maintain sand fencing on the dunes or beach. The cumulative impacts of these habitat modifications are particularly significant along the entire South Shore shoreline.

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[30] Note that construction of the Rockaways Boardwalk Reconstruction Project began in 2013 with the replacement of damaged sections of pre-existing concrete bulkheads from Beach 126th to Beach 149th Streets and the installation of sand "TrapBag" revetments along the seaward side of the boardwalk and along the existing concrete bulkheads from Beach 126th to Beach 149th Streets. The large project is on-going and is anticipated to be completed in its entirety in 2017 (NYC Office of Management and Budget 2014, NYC Department of Parks and Recreation website).

Beachfront Development

In 2015 there were 127.62 miles (205.38 km) of sandy shoreline on the Atlantic Ocean shoreline of New Jersey, with 125.33 miles (201.70 km) of sandy beaches and 2.29 miles (3.69 km) of armored shoreline where no sandy beach was present (Table J-1). Where sandy beaches were present, the beachfront was 64% developed and 36% undeveloped. When sections of shoreline where sandy beaches were absent due to hard shoreline stabilization structures are included, the beachfront that was developed increases to 65% and the beachfront that was undeveloped decreases to 35%. Of the 2.29 miles (3.69 km) of armored shoreline were sandy beaches were absent in 2015, 1.10 miles (1.77 km) in Long Branch, Deal and Asbury Park were scheduled to receive sediment placement in 2016 as part of a federal erosion control project that initiated construction in 2015; as a result, the length of shoreline armored with no beach is anticipated to decrease to 1.19 miles (1.91 km) in the very near future.

Prior to Hurricane Sandy, there were 125.26 miles (201.59 km) of sandy beach and 1.87 miles (3.01 km) of armored shoreline with no sandy beach along the Atlantic Ocean shoreline of New Jersey, for a total of 127.13 miles (204.60 km) of shoreline (Rice 2015a). The slight increase to 127.62 miles (205.38 km) of shoreline in 2015 is due to the shifting positions of spits at unstabilized inlet shoulders, i.e., Sandy Hook, North Brigantine State Natural Area, Holgate[31], Corson's Inlet State Park (SP), Strathmere State Natural Area and Stone Harbor Point. The increase from 1.87 miles (3.01 km) to 2.29 miles (3.69 km) of armored shoreline without beaches is primarily due to increases in Long Branch, Asbury Park, Seaside Heights, Atlantic City and Avalon (which were offset slightly by decreases in the length of armored shorelines with no beaches in Deal and North Wildwood).

In 2012 before Hurricane Sandy, the beachfront in New Jersey was 67% developed and 33% undeveloped. Three years after Hurricane Sandy, 64% of the beachfront was developed and 36% undeveloped. The length of undeveloped beachfront increased by approximately 4 miles (6 km) from 2012 to 2015. This decrease in development on the beachfront is due to: 1) localized sections of beachfront development that were destroyed in Hurricane Sandy that have not been rebuilt as of 2015, and 2) a revision to the methodology for identifying developed versus undeveloped beachfront. The methodology was revised to be consistent with that used in Rice (2015b) along the shoreline from Maine to the Long Island Sound and Peconic Estuary shorelines of New York. That is, the distance from the beach in which development was evaluated was limited to the area from the vegetation line to a shore parallel road or 500 ft (152.4 m), whichever was closer to the beach (see the Methods section for more information). This refinement resulted in slight changes to the proportions of beachfront classified as developed or undeveloped in Strathmere, Sea Isle City, Avalon, North Wildwood and Wildwood Crest, where beachfront development is present but set back over 500 ft (152.4 m) from the beach.

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[31] The barrier spits at Holgate and Strathmere shortened, or retreated, slightly while the other barrier spits lengthened, or accreted, between 2012 and 2015.

The length of beachfront in public and/or NGO ownership did not change significantly in the three years following Hurricane Sandy, although the length of sandy beach present within individual public properties shifted slightly at unstabilized inlets as mentioned above. In 2012, 34.79 miles (59.99 km), or 29%, of the North Shore beachfront was in public or NGO ownership (Rice 2015b). No new sandy beachfront lands are known to have been placed in public or NGO-ownership in the three years after Hurricane Sandy. In 2015, 32.43 miles (52.19 km) of sandy beach were present within public or NGO-owned beachfront lands, a slight decrease due to the shifting of unstabilized inlets and their adjacent barrier spits (Table J-2). The proportion of sandy beach within public or NGO-ownership was unchanged at 29% in 2015.

In 2013 the USACE dredged the federal navigation channel at Sandy Hook, removing 261,430 cubic yards (cy) of sand and gravel from two shoal areas in the channel which runs just offshore the north tip of Sandy Hook; the material was placed in an offshore disposal site (USACE 2013ff, 2015f). The dredging project removed a portion of intertidal beach at the tip of the Sandy Hook spit, eliminating an unknown amount of intertidal beach habitat; the USACE had previously removed a portion of the intertidal beach that had encroached into the channel in March 2012. In the fall of 2015, the USACE dredged the federal navigation channel again and removed 1.6 acres of intertidal beach habitat. The U.S. Navy also periodically dredges this channel and in the spring of 2016 dredged very close to the Sandy Hook spit. The USFWS and USACE are in consultation regarding future dredging activities that may eliminate sandy beach habitat at Sandy Hook (Wendy Walsh, USFWS, pers. communication, August 11, 2016).

Beach Armor Modifications

Prior to Hurricane Sandy, 75.88 miles (122.12 km) of the Atlantic Ocean shoreline of New Jersey, or 59%, were known to be modified by hard shoreline stabilization structures, or armoring. Nine (9) new or extended revetments and bulkheads were constructed in the three years following Hurricane Sandy, totaling 4.11 miles (6.60 km) in length. Some of these revetments and bulkheads were constructed in areas that were previously armored with groin fields and do not represent new beach habitat modifications. Removing overlapping hard shoreline stabilization structures, a total of 3.65 new miles (5.87 km) of sandy beaches were armored with bulkheads and revetments from late 2012 through 2015. Most of this increase was due to the construction of a 3.5 mile (5.6 km) long steel bulkhead/revetment in Mantoloking and Brick.

Another 1.51 miles (2.43 km) of sandy beach armored with hard shoreline stabilization structures were identified following Hurricane Sandy; these structures were exposed by Hurricane Sandy or hurricane rebuilding efforts, or identified within new information sources; all were located in areas already known to be armored with other structures. As of the end of 2015, 79.53 miles (127.99 km), or 62%, of Atlantic Ocean shoreline of New Jersey was armored, an increase of 3% from 2012 (Table J-3). Of the 79.53 miles (127.99 km) of armored beaches identified three years after Hurricane Sandy, 2.29 miles (3.69 km) had no sandy beach present at the time the 2015 aerial imagery was taken. Once construction of the federal Elberon to Loch Arbour shore protection project is completed in 2016, 1.10 miles (1.77 km) of armored shoreline with no sandy beach present in 2015 will have sandy beach present via sediment placement, reducing the length of shoreline armored with no beach present to 1.19 miles (1.92 km).

Thirty-seven (37) of the 50 communities listed in Table J-3 on New Jersey oceanfront were more than 50% armored in 2015. Prior to Hurricane Sandy, only 3 of the 50 communities were not modified by any known hard shoreline stabilization structures (Rice 2015c). Three years after Hurricane Sandy, the sandy beaches in the same 3 communities still are the only communities unmodified by known beach armoring: Seaside Heights, Galloway Township (Little Beach Island), and Wildwood[32].

The largest increases in beach armoring in the three years after Hurricane Sandy were in Bay Head, Mantoloking and Brick. A pre-existing rock revetment in Bay Head was extended northward by 1,045 ft (319 m) in two sections after Hurricane Sandy. The rock revetment in Bay Head also was extended southward by ~1,524 ft (464.5 m) in 2013, extending over 480 ft (146 m) into Mantoloking. The two revetment extensions armor the entire beachfront of Bay Head with revetments with the exception of two narrow beach access paths at North and Karge Streets and one private property at the north boundary with Point Pleasant Beach. A ~100 ft (30 m) rock revetment was also constructed on a vacant lot at Stephens Place in Mantoloking, although its specific construction date and end points could not be determined due to partial burial by sand within the Google Earth imagery. Then the NJDEP Bureau of Coastal Engineering, along with the Federal Highways Administration and the Boroughs of Brick and Mantoloking, constructed a 3.5 mile (5.6 km) steel bulkhead/seawall from Lyman Street in Mantoloking to the southern boundary of Brick Township in 2014-2015. The steel wall was buried with sand to form an artificial dune and spans all of the areas in Mantoloking where the island was breached by Hurricane Sandy (NJDEP 2014).

Several smaller hard shoreline stabilization projects also were constructed from 2012 to 2015. The USACE is notching 3 groins in Deal as part of the Elberon to Loch Arbour Storm Risk Reduction Project in 2015-16 – one at Philips Avenue, one at the Deal Casino, and one at Marine Place; 10 stormwater outfalls are being extended seaward as well in the project area (Gladden 2015, USACE Philadelphia District website). The state of NJ repaired a bulkhead on Shark River Inlet in Avon-by-the-Sea in 2015-16 (NJDEP Bureau of Coastal Engineering website). The state of NJ and Monmouth County repaired the landward end of the north jetty on Manasquan Inlet in 2013 (NJDEP Bureau of Coastal Engineering website). USACE repairs to the north jetty at Barnegat Inlet began in 2014 but were slowed by the discovery of an apparent historic shipwreck (USACE Philadelphia District website). The USACE repaired ~500 ft (~152 m) of the seawall in the Anglesea area of North Wildwood, near Hereford Inlet, in 2013 (USACE Philadelphia District website).

The bulkhead in Long Branch seaward of Whale Pond appears to have been reconstructed following Hurricane Sandy, with the new bulkhead extending along a portion of the pond's shoreline as well as along the beachfront. A groin or perpendicular bulkhead was exposed in this location by Hurricane Sandy and was not identified in Rice (2015c); the structure was visible in imagery immediately following the storm and in early 2013, but is not visible in later imagery. The structure may have been removed or buried. Neither the reconstruction and inland extension

[32] Although both Point Pleasant Beach and Berkeley Township list 0% of their sandy beach habitat as being modified by armoring in Table 3, both communities have one jetty that is not counted towards that percentage since the jetties are perpendicular structures that modify an unknown length of adjacent beach habitat.

of the bulkhead nor the newly exposed groin/bulkhead increase the length of sandy beach modified by armor in Long Branch because both are located in an existing groin field.

The Borough of Sea Girt initiated extension and repairs to two stormwater outfalls that are armored and act as groins at Baltimore Boulevard and Neptune Place in 2015-2016 (Borough of Sea Girt Council Regular Meeting Minutes, March 9, 2016). In Ocean City, the city installed an experimental 200 ft (61 m) section of geocubes, or TrapBags, at 57th Street in early 2014 (Bergen 2014, NJ Sea Grant Consortium et al. 2015). This section of beach also has a bulkhead, so the new geocube/TrapBag revetment does not increase the length of beach in Ocean City modified by armor.

Finally, Hurricane Sandy exposed a small number of bulkheads and groins that were buried before the storm. Two bulkheads were exposed in Long Branch, 1 bulkhead in Bay Head and 2 groins in Sea Isle City; the three walls appeared to be damaged by the storm and it could not be determined if they were repaired and/or reconstructed, removed or simply buried following the storm. Two groins also were exposed in Atlantic City by Hurricane Sandy, and a new information source identified a number of stormwater outfalls and historical (buried) groins on Absecon Island; the newly exposed groins, location of buried groins, and newly identified stormwater outfalls (some of which may be abandoned) increased the number of groins and armored outfalls in Atlantic County to 42 (Table 4). Two new groins and 4 outfalls on the north end of Ocean City were identified by another new information source, increasing the number of groins in Ocean City to 20 and outfalls to 33. A ~1,600 ft (488 m) long geotube revetment constructed in early 2011 was exposed along East Atlantic Boulevard in northern Ocean City by Hurricane Sandy; the geotubes survived the storm and were reburied within the dune and beach fill placed by the USACE in 2013. This section of beach also has a bulkhead and a groin field, so the newly identified geotube revetment does not increase the length of beach in Ocean City modified by armor.

New information sources have revised the total number of armor structures in oceanfront NJ as well. USACE (1996a) describes 6,300 ft (1,920 m) of geotube revetments[33] as having been installed to reinforce the artificial dune in Atlantic City in 1995; the geotube sections were buried within the dune and it is unknown whether the armor is still present. Google Earth imagery does not show any significant erosion of the reinforced sections of dune since 2002, and the federal beach fill project was constructed in 2004, further increasing the size and volume of the artificial dune seaward of the boardwalk. If the geotube revetments are still present within the dune, the length of beach armored in Atlantic City does not change since it was already at 100%. USACE (1996a) also identified the location of all groins and outfalls present on Absecon Island in 1994, some of which were buried and not located in Rice (2015c). Rice (2014) and (2015c) classified the hard structure on the south side of Absecon Inlet in Atlantic City as a terminal groin, but new information sources (e.g., USACE 1996a) identify the structure as a jetty. These corrections adjust the total number of jetties in oceanfront NJ to 11 and groins to 455 as of 2015 (Table 20).

[33] Two sections of geotube revetments were installed from Massachusetts to Vermont Avenues and from Martin Luther King Boulevard to Chelsea Avenue. Small gaps for beach access may occur between sections of reinforced dunes.

Table 20. Approximate number of each type of armoring visible on the oceanfront beach in each community in New Jersey, visible on aerial imagery between March 1991 and April 2016. Note that multiple seawalls, bulkheads or revetments are counted as one structure if they are continuous with no separations; for example, if five individual properties each have an individual seawall protecting their property and the seawalls are attached to each other with no gaps, the armoring is counted as one seawall structure and its overall length is counted in Table J-3 in Appendix J.

Community	Number of Groins	Number of Jetties	Number of Seawalls, Bulkheads and/or Revetments§	Number of Breakwaters
Middletown Township (Sandy Hook)	11	0	1	0
Sea Bright	17 +	0	7	0
Monmouth Beach	6 +	0	3	0
Long Branch	48 +	0	11	0
Deal	11 +	0	10	0
Allenhurst	3 +	0	5	0
Loch Arbour	1 +	0	1	0
Asbury Park	5 +	0	1	0
Ocean Grove	4 +	0	0	0
Bradley Beach	6 +	0	1	0
Avon-by-the-Sea	3 +	1	1	0
Belmar	6 +	1	2	1
Spring Lake	17 +	0	2	0
Sea Girt	23 +	0	7	0
Manasquan	15 +	1	2	0
Point Pleasant Beach	0	1	0	0
Bay Head	10	0	4	0
Mantoloking	0	0	5	0
Brick (Normandy Beach)	0	0	1	0
Dover Beaches North	0	0	2	0
Lavallette	9	0	15	0
Ortley Beach	0	0	1	0
Seaside Heights	0	0	0	0
Seaside Park	0	0	1	0
Berkeley Township	0	1	0	0
Barnegat Light	0	2	0	0
Loveladies (Long Beach Township)	13	0	0	0

Community	Number of Groins	Number of Jetties	Number of Seawalls, Bulkheads and/or Revetments[§]	Number of Breakwaters
Harvey Cedars	11	0	0	0
North Beach (Long Beach Township)	8	0	0	0
Surf City	7	0	0	0
Ship Bottom	7	0	0	0
Beach Haven	10	0	3	0
Long Beach Township	42	0	6	0
Galloway Township (Little Beach Island)	0	0	0	0
Brigantine	7	1	7	0
Atlantic City	23	1	4	0
Ventnor	1	0	5	0
Margate	6	0	1	0
Longport	5	0	5	0
Ocean City	20	0	18	0
Strathmere	13	0	2	0
Sea Isle City	17	0	12	0
Avalon	1	0	2	1
Stone Harbor	8	0	2	0
North Wildwood	2	0	3	0
Wildwood	0	0	0	0
Wildwood Crest	0	0	3	0
Lower Township[†]	4	1	1	0
Cape May	19	1	1	0
Cape May City	9	0	3	4
TOTAL	**455[‡]**	**11**	**161**	**6**

[§] The number of seawalls, bulkheads and/or revetments includes revetments constructed from geotubes or geocubes/TrapBags.

† At Cape May Point State Park, Battery 223 is a concrete bunker on the beach that may act like armoring along ~0.03 miles (180 ft) of oceanfront beach.

‡ USACE (1989) identified 185 groins from Sea Bright to Manasquan, 158 of which were located in this assessment. The 27 additional groins identified by USACE (1989) are assumed to be present but not visible in Google Earth imagery; their assumed presence is included in the total here.

Proposed and Anticipated Habitat Modifications

In February and March of 2016, the NJDEP Bureau of Coastal Engineering and the Borough of Sea Bright constructed a new sheet steel pile bulkhead near River Street where there is a gap in the pre-existing rock seawall (Spoto 2016). The new bulkhead modifies ~370 ft (113 m) of sandy beach habitat, but is located in an area previously modified by armor and does not increase the length of beach modified by armor in Sea Bright.

A number of beach armor projects have been proposed in New Jersey in the three years since Hurricane Sandy. The NJDEP Bureau of Coastal Engineering, with funding from the Federal Emergency Management Agency, anticipates initiating construction in late 2016 on repairs and reconstruction of the seawall in Sea Bright and Monmouth Beach. Damages from Hurricane Sandy will be repaired along several sections of the wall, with the elevation raised where necessary to a uniform height of +18.0 ft NAVD88, stone toe scour added where necessary, and repairs to the splash pad on the landward side of the seawall made where necessary (NJDEP 2015). Three gaps in the pre-existing seawall will be filled with new seawall sections: 1) at the Sea Bright municipal parking lot at River Street (~424 ft), 2) a small vehicle and beach access at Tradewinds Lane in Sea Bright (~20 ft) that currently has a wooden bulkhead instead of stone seawall, and 3) at the Monmouth Beach municipal bathing pavilion and parking lot (~630 ft). Although these three gaps will be closed, there will be no net change to the length of beach modified by armor in this project area because all three gap sections have pre-existing armor (e.g., bulkheads, revetments, groins). Once completed, a continuous stone seawall will extend from the southern end of Sandy Hook to southern Monmouth Beach, modifying 6.65 contiguous miles (10.70 km) of sandy beach habitat. One-hundred percent (100%) of Sea Bright's and 97% of Monmouth Beach's sandy beach habitat will be modified by the continuous seawall armor.

The USACE proposed constructing two bulkhead/revetments on the Absecon Inlet shoreline of Atlantic City in 1996, neither of which were constructed prior to Hurricane Sandy. One bulkhead/revetment would extend 1,050 ft (320 m) from Atlantic to Oriental Avenues, and the other would extend 550 ft (168 m) from Madison to Melrose Avenues. The bulkhead/revetments were proposed again after Hurricane Sandy but construction has been delayed pending review by the U.S. Government Accountability Office (USACE 1996, USACE Philadelphia District website).

The NJDEP Bureau of Coastal Engineering has three additional armor projects in the Planning, Engineering and Design Phase as of 2016. The first would be to repair the bulkhead on the south side of Manasquan Inlet. The second is for repairs to the jetty on Absecon Inlet in Atlantic City. The third is to reconstruct the jetty, revetment and groin on Great Egg Inlet in Longport (NJDEP Bureau of Coastal Engineering website).

The New Jersey Alternative Long-Term Nourishment Regional Sediment Management Study funded after Hurricane Sandy and scheduled for completion in 2017 (see Sediment Placement section below) includes the possible construction of new groins to reduce fill losses between nourishment episodes, modification of existing groins, and improvements to existing bulkheads (USACE Philadelphia District website, most recently accessed 8/29/2016).

Sediment Placement Modifications

Prior to Hurricane Sandy, 62.04 miles (99.84 km)[34] of sandy beach habitat, or 50%, had been modified in NJ by sediment placement. Since Hurricane Sandy, 18.27 miles (29.40 km) of new sandy beach habitat were modified with sediment placement. As of the end of 2015, a total of 80.31 miles (129.25 km) of sandy beach, or 63%, had been modified by sediment placement[35], an increase of 13% (Table J-4). At least 37.5 million cubic yards (mcy) of sediment were or will have been placed on the oceanfront beaches of NJ as part of projects that began construction between 2012 and 2015.

The only sandy beaches on the New Jersey oceanfront that have *not* been modified by sediment placement activities, or are proposed or anticipated to be modified in 2016 or the near future, are almost exclusively in undeveloped areas or those in public or NGO ownership. Only 1.52 miles (2.45 km) of the 82.86 miles (133.35 km), or 1.8%, of developed oceanfront in NJ has not been or will not soon be modified by sediment placement since Hurricane Sandy[36]. Only 7.00 miles (11 km) of sandy beaches that are *not* in public or NGO ownership have not been or will not soon by modified by sediment placement; these areas are in the communities of Barnegat Light, southern Brigantine, central Avalon, and the Anglesea area of North Wildwood.

Before Hurricane Sandy, the sandy beaches in 18 of the 50 oceanfront communities in NJ were 100% modified by sediment placement projects. Three years after Hurricane Sandy, the number of communities where 100% of the sandy beaches have been modified by sediment placement projects increased to 25.

Several federal beach fill projects that had been proposed but not constructed prior to Hurricane Sandy were constructed in the three years following the hurricane. The federal Elberon to Loch Arbour Storm Risk Reduction Project, proposed but not constructed prior to Hurricane Sandy, initiated construction in April 2015 and is scheduled for completion in 2016. The project is being constructed in two phases: 1) ~3 million cubic yards (mcy; 2.3 million cubic meters [m^3]) of sediment placed on the beach from Lake Takanassee to Philips Avenue in Deal, and 2) ~1.45 mcy (1.11 million m^3) of sediment placed on the beach from Philips Avenue to Deal Lake (Spoto 2013, Gladden 2015, USACE New York District website). The total project length, as measured in Google Earth, is 3.22 miles (5.18 km) of new sandy beach habitat modified by sediment placement.

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[34] This total has been corrected from the 63.10 miles listed in Table 15 of Rice (2015a) to incorporate project information from additional data sources.

[35] This total includes projects that initiated construction in 2015 but not scheduled to complete construction until 2016.

[36] Sediment placement projects that have been proposed and funded but await construction due to legal challenges, Congressional approval, or real estate acquisition issues, as well as projects already constructed in 2016, are counted as areas that will soon be modified. These include the federal Manasquan Inlet to Barnegat Inlet Storm Damage Reduction Project from Point Pleasant Beach to the north end of Island Beach SP, the Margate and Longport section of the federal Absecon Island Shore Protection Project, municipal placement of dredged material along the oceanfront of Stone Harbor in 2016, and the Hereford Inlet to Cape May Inlet Shore Protection Project from North Wildwood to the Diamond Beach section of Lower Township.

The federal Barnegat Inlet to Little Egg Inlet: Long Beach Island Shore Protection Project is divided into 7 sections, 3 of which were constructed prior to Sandy – Harvey Cedars, Surf City, and part of Brant Beach (in Long Beach Township). The 4 remaining sections were proposed but not constructed before Hurricane Sandy, in Loveladies, North Beach, Ship Bottom and Long Beach Township-Beach Haven. The USACE initiated sediment placement on the 4 unconstructed, new sections of fill (more than 8.1 mcy [6.2 million m^3]) in 2015 along 12.07 miles (19.42 km) of Long Beach Island; 6.75 miles (10.86 km) of the project area sandy beach habitat had not previously been modified by sediment placement.

The federal Great Egg Harbor to Tonwsends Inlet Shore Storm Damage Reduction Project was proposed but not constructed prior to Hurricane Sandy; the project includes south Ocean City, Strathmere and Sea Isle City, the latter two having previously received state-sponsored fill projects but not federal. Initial construction of the project on south Ocean City, Strathmere and Sea Isle City placed 4,628,000 cy (3,538,360 m^3) of fill along 9.41 miles (15.14 km) of sandy beach habitat in 2015; 6.29 miles (12.12 km) of the project area had not previously been modified by sediment placement and represent a new modification.

In addition to the 3 new federal beach fill projects that were constructed in the three years after Hurricane Sandy, virtually all of the existing federal beach fill projects in the state received sediment placement in the same time period. A Flood Control and Coastal Emergency (FCCE) project placed 2.2 mcy (1.7 million m^3) of sediment on 5.64 miles (9.08 km) of beach from Sea Bright to Monmouth Beach in 2013 (Spoto 2013, Gladden 2015). Another FCCE project placed 3.3 mcy (2.5 million m^3) of sediment on 2.93 miles (4.72 km) of beach from Seven Presidents Park to Lake Takanassee in Long Branch in 2013-2014 (Spoto 2013, Gladden 2015). The Sandy Hook to Barnegat Inlet Beach Erosion Control Project from Asbury Park to Avon-by-the-Sea received FCCE repairs in 2014, placing 1.2 mcy (0.91 million m^3) of sediment along 3.02 miles (4.86 km) of sandy beach habitat (Spoto 2013, Gladden 2015). The Belmar to Manasquan Inlet section of the same project received 1.5 mcy (1.1 million m^3) of sediment in FCCE repairs in 2013-2014 along 5.93 miles (9.54 km) of beach (Spoto 2013, Gladden 2015).

On Long Beach Island, the federal Barnegat Inlet to Little Egg Inlet: Long Beach Island Shore Protection Project conducted FCCE repairs to the three sections of beach that had previously been modified by sediment placement. Approximately 840,000 cy (642,226 m^3) of sediment were placed on 1.98 miles (3.19 km) of Harvey Cedars in 2013, ~280,000 cy (214,075 m^3) of sediment were placed on 1.41 miles (2.27 km) of Surf City in 2013, and ~880,000 cy (672,808 m^3) of sediment were placed on 1.02 miles (1.64 km) of northern Brant Beach in 2013 (USACE 2014h, 2016a).

In Atlantic County, the USACE was in the process of initiating the second renourishment episode at Brigantine when Hurricane Sandy occurred in October 2012; the dredging contract was amended to add FCCE repairs resulting from Hurricane Sandy, and sediment was placed on 1.80 miles (2.90 km) of beach in January and February 2013. Further FCCE repairs were constructed in June and July 2013, placing a total of 926,836 cy (708,617 m^3) of sediment on the project area's beaches in 2013 (USACE Philadelphia District unpublished data). In Atlantic City and Ventnor City, 1.5 mcy (1.15 million m^3) of sediment were placed on the federal shore protection project on Absecon Island in 2013, along 5.06 miles of beach; the project had received

1.325 mcy (1.013 million m^3) of sediment as part of a periodic nourishment cycle in 2012 immediately prior to Hurricane Sandy and 1.1 mcy (0.84 million m^3) of FCCE repairs in 2011 after a different storm. Thus from 2011 to 2013, Atlantic City and Ventnor City beaches were modified three times by sediment placement with a total of 3.925 mcy (3.001 million m^3) of sediment placed on the sandy beaches of the project area (USACE Philadelphia District website).

In Cape May County, the USACE consolidated a previously scheduled periodic nourishment with FCCE repairs in north Ocean City, placing 1.746 mcy (1.335 million m^3) of sediment along 4.62 miles (7.44 km) of beach in 2013. Then in 2015, the 7th periodic nourishment of the federal project was constructed, placing an additional 968,000 cy (740,089 m^3) of sediment on the project area beaches.

Avalon received fill in both 2013 (302,000 cy or 230,896 m^3) and 2015 (700,000 cy or 535,188 m^3) from the 8th Street jetty to 25th Street, both with material mined from nearby Townsend's Inlet (Borough of Avalon 2014, 2016a). The 2013 project was FCCE repairs to the federal project area, and the 2015 project was a municipal project. In Stone Harbor, 420,000 cy (321,113 m^3) of sediment were placed on 1.43 miles (2.30 km) of beach from 92nd to 114th Streets and 119th Street to the terminal groin near 125th Street as federal FCCE repairs in 2013 (Borough of Avalon 2014, USACE Philadelphia District website).

At Cape May, a federal FCCE project placed 585,000 cy (447,264 m^3) of sediment on 3.61 miles (5.81 km) of beach from the jetty at Cape May Inlet to the terminal groin at 3rd Avenue in 2013-2014 (USACE Philadelphia District website, USACE Philadelphia District unpublished data). The federal shore protection project at Lower Cape May Meadows – Cape May Point received its 2nd renourishment cycle immediately after Hurricane Sandy, placing 345,000 cy (263,771 m^3) of sediment along 2.40 miles (3.86 km) of beach from November 2012 to January 2013.

In addition to the federal sediment placement projects constructed in the three years after Hurricane Sandy, a number of other projects modified New Jersey sandy beach habitat with sediment placement between 2012 and 2015. The local Sea Bright Dune Restoration Project used overwash material removed from developed inland areas to construct artificial dunes along an unknown length of beach in 2013 (Borough of Sea Bright Regular Meeting Minutes, 2/5/2013 and 4/2/2013). Sediment from an upland source was trucked to the Ortley Beach section of Toms River and placed on the beach in late 2013 to construct an interim artificial dune while the community awaits construction of a USACE beach fill project (Maruca 2013); sediment was only placed in areas where real estate easements had been obtained at the time but a precise project length was not available. Google Earth imagery indicates the sediment placement occurred on at least 1,200 ft (366 m) of beach, none of which had previously been known to have received sediment placement. On the Absecon Inlet shoreline of Brigantine, trucks also placed sediment on approximately 415 ft (126 m) of beach immediately following Hurricane Sandy in early November 2012. The sediment was most likely overwash material removed from inland developed areas of Brigantine. Other communities also removed overwash sediment and placed it on their beaches immediately following Hurricane Sandy, particularly at beach access points; all of the other areas receiving overwash sediment placement were within existing sediment placement project areas that received sediment within the three years following the storm.

Maintenance dredging of navigation channels in the Shrewsbury River placed approximately 50,000 cy (38,228 m^3) of sand on Monmouth Beach to create dunes in September 2014 (USACE 2013ee). Maintenance dredging of federal navigation channels in the Shark River placed ~150,000 cy (114,683 m^3) of dredged material in the nearshore as a berm in Avon-by-the-Sea north of the jetty at Shark River Inlet; previous dredging episodes placed the dredged material on the beach in the same area (USACE 2014z).

In 2014 the Borough of Spring Lake received a 10-year maintenance dredging permit from the USACE to periodically dredge Wreck Pond and place up to 37,000 cy (28,289 m^3) of sediment on two sections of oceanfront beach, one located from Sussex to Union Avenues (2,300 ft or 701 m) and another at Brown Avenue (165 ft or 50 m); both sediment placement areas are within the larger federal beach fill project area that includes Spring Lake (the Sandy Hook to Barnegat Inlet Beach Erosion Control Project) and do not modify any new sandy beach habitat (USACE 2014k).

At Stone Harbor Point, NJ Audubon and several partners constructed a restoration project in 2015 where sediment was excavated, or scraped, from the tip of the island at Hereford Inlet and placed on the spit to create three raised platforms intended to enhance bird nesting habitat by reducing the risk of flooding[37]. Two of the raised platforms were located on the oceanside shoreline and one on the bayside shoreline. A total of 0.33 miles (0.53 km) of new sandy beach habitat was modified by this sediment placement project.

In 2013 (and again in 2016) the City of North Wildwood backpassed sediment from near the stormwater outfalls in Wildwood and Wildwood Crest and placed the fill on the beach in North Wildwood between 2nd and 7th Avenues (Todd Pover, Conserve Wildlife Foundation of NJ, pers. communication, 8/1/2016).

Proposed and Anticipated Habitat Modifications

Three federal shore protection projects have been proposed in New Jersey but have not initiated construction. All three projects have funding but await final approvals and/or resolution of real estate acquisition issues.

The federal Manasquan Inlet to Barnegat Inlet Storm Damage Reduction Project was proposed in 2002 prior to Hurricane Sandy from Manasquan Inlet to Island Beach SP, including the communities of Point Pleasant Beach, Bay Head, Mantoloking, Brick, Dover Beaches North, Lavallette, Ortley Beach, Seaside Heights, Seaside Park, and the developed portion of Berkeley Township. The project was proposed again after Hurricane Sandy but has been delayed by real estate easement acquisition issues to allow construction of dunes as part of the project. The proposed project is ~14 miles (~23 km) long, with 11.04 miles (17.77 km) of that length on beach habitat that has not previously been modified with sediment placement. An anticipated 10.728 mcy (8.202 million m^3) of sediment would be placed on the ~14 miles (~23 km) of beach (USACE 2013a, 2014j).

On Absecon Island, the federal Brigantine Inlet to Great Egg Harbor Inlet – Absecon Island shore protection project initiated construction of beach fill in Atlantic City and Ventnor City

[37] Evaluation of the efficacy of this project is in progress.

prior to Hurricane Sandy. Two other sections of the project in Margate City and Longport were proposed but not constructed prior to Hurricane Sandy. Following Hurricane Sandy the project was proposed again by the USACE. An anticipated 2 mcy (1.5 million m^3) of sediment would be place on 3.05 miles (4.91 km) of sandy beach, nearly all of which would be a new modification for this length of habitat (USACE 1996, FedBizOpps.gov website). One length of beach in Longport has been modified by sediment placement before, with dredge disposal placed on an unknown length of beach in 1990 (Rice 2014, PSDS 2016). The USACE Philadelphia District has solicited bids to construct the project, in conjunction with renourishment of Atlantic City and Ventnor City, in the fall of 2016, with a total of over 3 mcy (2.3 million m^3) of sediment anticipated to be placed on the Absecon Island's beaches (FedBizOpps.gov website).

In 2014 the USACE proposed the Hereford Inlet to Cape May Inlet Shore Protection Project in the communities of North Wildwood, Wildwood, Wildwood Crest, and the developed portion of Lower Township east of the Cape May NWR (USACE 2014i, 2015a). The proposed project would backpass sediment, or excavate, an anticipated 1,527,250 cy (1,167,666 m^3) of material from the intertidal zone and seaward edge of the beach along 3.19 miles (5.13 km) from East Glenwood Avenue in Wildwood to Memphis Avenue in Lower Township; the excavation zone would extend from ~400 to 700 ft (~122 to 213 m) wide. The material would by hydraulically pumped to construct a beach berm in North Wildwood and a nearly continuous dune[38] from 2nd Avenue in North Wildwood to the eastern boundary of the Cape May NWR in Lower Township, for a distance of 4.73 miles (7.61 km). Out of the 4.73 mile (7.61 km) project area, 3.31 miles (5.33 km) would be newly modified by sediment placement. Periodic nourishment via backpassing sediment would occur every 4 years in the proposed project.

The proposed Hereford Inlet to Cape May Inlet Shore Protection Project (in Wildwood and North Wildwood) would impact beach habitat in more ways than a typical beach and dune fill project. Of the approximately 4.73 miles (7.61 km) of dune that would be constructed, 1.11 miles (1.79 km) would be where no dunes currently exist as of 2015. The beach is very wide in the western project area, often extending for 800 to 1,000 ft (244 to 305 m) wide. The excavation, or mining, of sediment from this area would narrow the beach, shifting the intertidal zone landward by approximately 350 to 400 ft (107 to 122 m) and converting existing dry beach habitat to intertidal beach requiring colonization by invertebrate prey resources. Although the length of sandy beach habitat would not change with the proposed project, the area of sandy beach available to birds would significantly decrease and the forage base would be at least temporarily removed.

These three proposed federal shore protection projects would modify an additional 17.60 miles (28.32 km) of sandy beach habitat in New Jersey. If constructed, the length of sandy beach habitat modified by sediment placement projects in the state would increase to 97.91 miles (157.57 km). The proportion of sandy beach habitat modified would increase from 63% to 78%. The number of oceanfront communities with 100% of their sandy beach habitat modified by sediment placement would increase from 25 to 37 (out of 50).

[38] No dunes would be built *under* any of the amusement piers, but would be constructed *between* the amusement piers. Where dunes exist at the time of construction, sediment would be placed on their seaward side and graded to form the shape and size of the design template.

In addition to the three proposed federal shore protection projects, several other sediment placement projects were constructed or anticipated to initiate construction in 2016, none of which would modify new sandy beach habitat. In three locations sediment was placed in 2016 where no sandy beach was present due to armoring in 2015. In Long Branch, Deal and Asbury Park the Elberon to Loch Arbour federal erosion control project constructed a sediment placement project in 2015-16 that would place sediment on 1.10 miles (1.77 km) of shoreline where the shoreline was lacking sandy beach due to armoring prior to the start of the project. Once completed, the length of armored shoreline where sandy beaches were absent in NJ will decrease from 2.29 miles (3.69 km) to 1.19 miles (1.91 km).

The USACE constructed repairs to federal beach fill projects in early 2016 resulting from storms in October 2015 (Hurricane Joaquin) and January 2016 (nor'easters). Approximately 1.439 mcy (1.100 million m^3) of sediment mined from Corson's Inlet was placed on the beach in Sea Isle City from 57th Street south to Corson's Inlet SP from January to April 2016. Then in April and May 2016, another ~500,000 cy (382,277 m^3) of sediment mined from Corson's Inlet was placed on the beach in south Ocean City from 34th to 59th Streets (USACE Philadelphia District website, USACE Philadelphia District unpublished data).

North Wildwood backpassed, or excavated, ~150,000 cy (114,683 m^3) of sediment from near the stormwater outfalls in Wildwood to use as beach fill between 2nd and 7th Avenues in early 2016 (Todd Pover, Conserve Wildlife Foundation of NJ, pers. communication, August 1, 2016). Avalon also backpassed ~50,000 cy (38,228 m^3) of sediment from central Avalon beaches (32nd to 38th Streets) to northern Avalon beaches in April and May of 2016 (Borough of Avalon 2016b).

The Borough of Stone Harbor requested a modification to its existing USACE permit for dredging Great Channel and several lagoons and boat basins to allow for placement of suitable sediment on any of the Borough's beaches from 80th to 122nd Streets in December 2015, with work proposed for early 2016; the dredging permit is effective until December 2025 and would authorize up to 185,250 cy (141,634 m^3) of sediment placement on 2.24 miles (3.60 km) of beaches that have already been modified by sediment placement (USACE 2015c).

The USACE proposed in early 2016 to mine the last unmodified tidal inlet in NJ for beach fill on Long Beach Island, which initiated construction in 2015, and for navigational purposes (USACE 2016a). Although the mining of the inlet for beach fill was not approved for the 2015-2016 sediment placement project, the USACE anticipates mining the inlet for future renourishment episodes on Long Beach Island.

In early 2016, as part of a bulkhead and dune restoration project, the NJDEP Bureau of Coastal Engineering and the Borough of Sea Bright constructed a dune with fill material from the north end of a new steel bulkhead near River Street to the Sea Bright Beach Club, a distance of ~420 ft (128 m) of beach (Spoto 2016). The dune construction project does not modify any new beach habitat in Sea Bright, however, because the entire Borough is within a federal beach fill project area.

Sediment placement was anticipated as part of periodic nourishment of existing federal projects in late 2016 at Cape May Inlet to Lower Township and Lower Cape May Meadows – Cape May Point (jointly) (~735,000 cy), Avalon and Stone Harbor (~600,000+ cy), north Ocean City (~700,000 cy), and Atlantic City / Ventnor City (~3+ mcy [2.3+ million m^3] in conjunction with Margate City and Longport initial fill) (USACE Philadelphia District website, FedBizOpps.gov website).

Altogether, at least 35,460,511 cy (27,111,506 m^3) of sediment was placed on New Jersey oceanfront beaches from November 2012 to December 2015. Including sediment placement projects undertaken in 2016 (up to mid-August), the cumulative sediment volume placed on sandy beach habitat increases to at least 37,495,511 cy (28,667,375 m^3). Another 17,475,500 cy (12,360,978 m^3) of sediment have been proposed to be placed on New Jersey oceanfront beaches in the near future, raising the cumulative total of sediment anticipated to be placed since Hurricane Sandy to at least 54,971,011 cy (42,028,353 m^3). In comparison, approximately 38,296,965 cy (29,280,130 m^3) of sediment were placed on New Jersey oceanfront beaches in the 10 years *prior* to Hurricane Sandy. Since the piping plover was listed as a federally-threatened species in 1986, New Jersey's oceanfront sandy beach habitat has been or will soon be modified by the placement of over 118.2 mcy (90.37 million m^3) of sediment, nearly half (46%) of that since Hurricane Sandy.

After Hurricane Sandy, the Philadelphia District of the USACE received funds to proceed with a New Jersey Alternative Long-Term Nourishment Regional Sediment Management Study to develop a comprehensive approach to shore protection on the entire NJ coast, including the prioritization of smaller beach nourishment episodes focusing on the areas with the highest erosion rates, regardless of individually authorized project boundaries, and the development of new sediment borrow areas to avoid future shortages of fill sediment. The study is anticipated to be complete in 2017 (USACE Philadelphia District website, most recently accessed 8/29/2016).

Beach Scraping Modifications

Several communities on the Atlantic Ocean shoreline of New Jersey have community-wide, general beach and dune maintenance permits from NJDEP that allow the communities to scrape or grade the beach whenever conditions permit, amongst other activities. Because the NJDEP general permit allows a variety of activities, and because it is known that some of the communities that have such permits do not scrape the beach but use the permits to authorize other activities[39] instead, the precise extent of sandy beach habitat in NJ modified by beach scraping since Hurricane Sandy could not be determined except by identification of evidence of beach scraping in aerial imagery.

In the three years following Hurricane Sandy, at least 25.31 miles (40.73 km), or 20%, of sandy beach on the New Jersey oceanfront were modified with beach scraping or grading (Table J-5). The beach can be scraped or graded to create artificial dunes or levees immediately following a

[39] Other authorized activities under General Permit 2 include beach raking, debris removal, maintenance of beach access ways, repairs or reconstruction of existing dune walkover structures or gazebos, and the removal of sediment form the ends of streets, boardwalk promenades and residential properties.

storm event, to remove overwash material from developed or paved areas along the beachfront, or to bury newly constructed geotextile or rock revetments, bulkheads or seawalls.

Beach scraping or grading occurred in all but 11 of the 50 of the communities along the New Jersey oceanfront in the three years since Hurricane Sandy (Table J-5). The sandy beaches in Berkeley Township, Barnegat Light, Galloway Township, Atlantic City, Longport, Avalon, Stone Harbor, North Wildwood, Wildwood, Wildwood Crest and Cape May Point were not modified by beach scraping or grading in the three years after Hurricane Sandy (as identified in aerial imagery). Beach scraping or grading modified varying proportions of the sandy beaches in the other 39 communities.

Proposed and Anticipated Habitat Modifications
A total of 7 oceanfront communities and 10 individual property owners (including beach clubs, homeowners' associations, local parks, and individuals) have NJDEP Beach and Dune Maintenance Individual Permits as of June 2016. Another 37 oceanfront communities and 54 individual property owners have NJDEP Beach and Dune Maintenance General Permits as of June 2016. Both of these permits are valid for 5 years, covering the 3-year period since Hurricane Sandy. Only the Sandy Hook Unit of Gateway National Recreation Area, Asbury Park, the Edwin B. Forsythe NWR in Long Beach and Galloway Townships, North Brigantine State Natural Area, Corson's Inlet SP and the Strathmere State Natural Area currently do *not* have valid NJDEP Beach and Dune Maintenance Permits.

These oceanfront communities and property owners represent the ***potential*** magnitude of beach scraping modifications to sandy beach habitat in NJ since they have valid state permits allowing beach scraping, amongst other activities, to manage dunes and beaches. Most of these communities participate in the federal shore protection program that requires the communities to develop beach management plans with the USFWS and NJDEP Endangered and Nongame Species Program. These beach management plans often include provisions or conservation measures that limit when and where activities like beach scraping may occur. Following a large storm such as Hurricane Sandy, however, some of those conservation measures may be suspended temporarily in some beach management plans. Although not all communities with these permits actually conduct beach scraping (Todd Pover, Conserve Wildlife Foundation of NJ, pers. communication, August 1, 2016), the existing state beach and dune maintenance permits ***potentially allow*** up to 112.93 miles (181.74 km), or 88%, of the sandy beach habitat in NJ to be modified by beach scraping.

Sand Fencing Modifications

Mitteager et al. (2006, p. 893) found that prior to Hurricane Sandy, "sand fences are a ubiquitous component of the foredune landscape" in 6 of the 7 New Jersey communities surveyed (Sea Girt, Manasquan, Harvey Cedars, Ship Bottom, Long Beach Township, Beach Haven, and Ocean City). In the 7 community sections that Mitteager et al. (2006) inventoried, sand fencing was present on 39 to 100% of the shoreline. Sand fencing can be both municipally managed or privately managed by individual property owners, with the former using sand fencing to build dunes through the trapping of windblown sand and the latter using sand fencing to delineate property boundaries or prevent sand inundation of the private property (Mitteager et al. 2006).

From 2012 to 2015, this inventory identified over 60 miles (96 km), or 47%, of New Jersey oceanfront beaches that were modified with sand fencing (Table J-6). At least 1,305 separate sections of sand fencing were identified on the sandy beaches of New Jersey's oceanfront in the three years following Hurricane Sandy. Of the 50 communities along the NJ oceanfront, 23 of them had at least 50% of their shoreline modified by sand fencing between 2012 and 2015 (Table J-6). The communities with the highest proportions of their sandy beaches modified with sand fencing include Ship Bottom (100%), Seaside Park (100%), the Loveladies and North Beach sections of Long Beach Township (99% each), Avalon (92%), Lavallette (87%), Surf City (87%), Atlantic City (87%), Strathmere (87%), Bradley Beach (86%), Dover Beaches North (84%) and Wildwood Crest (81%). Only three communities had no sand fencing between 2012 and 2015: Allenhurst, Seaside Heights, and Galloway Township (Little Beach Island).

Proposed and Anticipated Habitat Modifications

The numerous federal beach and dune storm damage reduction and shore protection projects in NJ typically involve extensive sand fencing during initial construction. The initial project design of the Barnegat Inlet to Little Egg Inlet – Long Beach Island Storm Damage Reduction Project, for example, involves installation of 540,000 linear feet (164,592 m) of sand fencing and 347 acres of dune grasses along approximately 17 miles (27 km) of Long Beach Island; the previously approved but unconstructed sections of this project (~12.5 miles or 20.1 km) initiated construction in 2015, with an anticipated completion in the fall of 2016 (USACE 2016). Once completed, the proportions of sandy beach modified by sand fencing in the communities of Loveladies, North Beach, and Beach Haven will increase to 100% and the other sections of Long Beach Township to 66%. Similarly, once the Elberon to Loch Arbour section of the federal Sandy Hook to Barnegat Inlet Beach Erosion Control Project is completed in 2016, the proportions of sandy beach modified by sand fencing in the communities of Deal, Allenhurst, and Loch Arbour would increase to 100% and Long Branch to 47%.

The proposed federal Manasquan Inlet to Barnegat Inlet Storm Damage Reduction Project plans to install 72,077 linear ft (21,969 m) of fencing and 190 acres of dune vegetation along nearly 14 miles (22 km) of beaches in northern Ocean County (USACE 2014j). If constructed as proposed, this project would increase the proportions of sandy beach modified by sand fencing in the communities of Point Pleasant Beach, Bay Head, Mantoloking, Brick, Dover Beaches North, Lavallette, Ortley Beach, Seaside Heights, and Seaside Park to 100% and in Berkeley Township to 46%.

The proposed federal Hereford Inlet to Cape May Inlet Shore Protection Project would construct a nearly continuous dune along 4.73 miles (7.61 km) of sandy beach in the communities of North Wildwood, Wildwood, Wildwood Crest, and the developed portion of Lower Township east of the Cape May NWR. The newly constructed dune would be stabilized with 28,000 linear ft (8,534 m) of sand fencing and 64 acres of dune vegetation plantings (USACE 2014i, 2015a), increasing the proportion of sandy beach modified by sand fencing in Wildwood and Wildwood Crest (including the Diamond Beach section of Lower Township) to 100% and North Wildwood to 63%.

Altogether, if all of the anticipated and proposed projects are constructed as designed in regards to the installation of sand fencing, the total length of sandy beach habitat modified by sand fencing in NJ would increase by 11.67 miles (18.78 km), from 60.26 to 71.93 miles (96.98 to 115.76 km). The proportion of sandy beach habitat modified by sand fencing would increase from 47% to 56%.

Summary

The sandy beach habitat on the Atlantic Ocean coast of New Jersey has been significantly modified by anthropogenic activities. Nearly two-thirds (65%) of the beachfront has been developed (Table 21). Sixty-two (62) percent of the beachfront is known to be armored with hard shoreline stabilization structures. More than three-quarters (78%) of the beaches have been or are proposed to be modified by sediment placement projects. At least 20% of the beaches were scraped or graded in the three years following Hurricane Sandy. And nearly half (47%) of the sandy beaches were modified by sand fencing between 2012 and 2015.

The beaches in Monmouth County – Sandy Hook to Manasquan – are the most developed (69%), armored (83%) and modified by sediment placement (82%). Both Ocean and Cape May Counties have the most sand fencing, with 59% and 58% of their beaches modified in this way respectively. The highest proportion of beach scraping (35%) occurred in Ocean County. The beaches of Cape May County are also highly modified by armor (67%) and sediment placement (72%), but are the least modified by beach scraping (3%).

Three areas in particular in New Jersey have been heavily modified in the three years since Hurricane Sandy: (1) the beaches from Sea Bright through Manasquan, (2) Long Beach Island, and (3) the beaches from Ocean City through Sea Isle City. Each of these three areas has had significant cumulative impacts to its sandy beaches since Hurricane Sandy.

Table 21. The length of sandy shoreline in each county along the Atlantic Ocean coast of New Jersey and the proportion of shoreline modified by beachfront development, armor, sediment placement (fill), beach scraping or grading (from 2012-15), and sand fencing (from 2012-15) as of 2015.

County	Shoreline Length (miles)	Habitat Modification Type				
		Development	Armor	Fill	Beach Scraping	Sand Fencing
Monmouth	26.90	69%	83%	82%	30%	28%
Ocean	44.93	66%	52%	47%	35%	59%
Atlantic	19.10	53%	47%	46%	3%	25%
Cape May	36.71	67%	67%	72%	3%	58%
STATE TOTAL	**127.62**	**65%**	**62%**	**63%**	**20%**	**47%**

With the construction of the 3.22 mile (5.18 km) Elberon to Loch Arbour and ~6 mile (~9.7 km) Belmar to Manasquan shore protection projects since Hurricane Sandy, a total of 20.76 contiguous miles (33.41 km) of sandy beach have been modified by sediment placement from Sea Bright to Manasquan. Ninety-eight percent (98%) of this ~21 mile (~34 km) stretch of sandy beach has been modified by armoring as well, with several new armoring projects initiated or planned since Hurricane Sandy. A new steel 370 ft. (113 m) bulkhead was constructed by the state near River Street in Sea Bright in early 2016. Repairs and 1,074 ft. (327 m) of extensions to the seawall in Sea Bright and Monmouth Beach are anticipated to start in late 2016. Three groins are being notched in Deal as part of the Elberon to Loch Arbour beach fill project. The bulkhead on Shark River Inlet in Avon-by-the-Sea was repaired in 2015-16. The jetty on the north side of Manasquan Inlet in Manasquan was repaired in 2013. In addition to the 100% sediment placement and 98% armoring modifications, sand fencing has modified 32% of these sandy beaches and beach scraping has modified 38% in the last three years.

Another 13.89 miles (22.35 km) contiguous to the south (Point Pleasant Beach to the north end of Island Beach SP) has been proposed and funded for sediment placement. When constructed, a contiguous stretch of 34.62 miles (55.72 km) of sandy beach will have been modified with sediment placement, bracketed by public lands to the north (Sandy Hook Unit of Gateway NRA) and south (Island Beach SP). Nineteen percent (19%) of this ~35 mile (56 km) stretch of sandy beach has been modified by armoring as well. Sand fencing modified 45% of these sandy beaches and beach scraping modified 42% in the last three years.

On Long Beach Island, the cumulative impacts of sandy beach habitat modifications in the three years following Hurricane Sandy are also significant. Historically 51% of the island has been modified with sediment placement, with the federal Barnegat Inlet to Little Egg Inlet: Long Beach Island Shore Protection Project divided into 3 sections that were constructed prior to Sandy and 4 sections that were not constructed (Loveladies, North Beach, Ship Bottom and Long Beach Township-Beach Haven). Each of the previously constructed sections (Harvey Cedars, Surf City and part of Brant Beach) received fill in 2013 following Hurricane Sandy. The USACE initiated sediment placement on the unconstructed, new sections of fill in 2015 along 12.07 miles (19.42 km) of Long Beach Island beaches. When the sediment placement in the new areas is complete in 2016, 84% of the barrier island's sandy beach habitat will have been modified by sediment placement in a 3-year time period. Altogether these sediment placement projects have modified 18.12 miles (29.16 km) of Long Beach Island's sandy beaches with 10.548 mcy (8.065 million m^3) of sediment in the last three years (USACE Philadelphia District unpublished data). This volume of sediment is more than three times the volume of sediment placed on the island following the Ash Wednesday Storm in 1962, when federal, state and municipal projects placed only 3.092 mcy (2.364 million m^3) of sediment on nearly the same length (17.41 miles or 28.01 km) of Long Beach Island (USACE 1999). In addition, 78% of the island's beaches have been modified by armor, 64% by sand fencing, and 42% by beach scraping.

A number of habitat modifications also have generated significant cumulative impacts on the sandy beach habitat of Ocean City, Strathmere and Sea Isle City since Hurricane Sandy. The northern portion of Ocean City has received fill as part of a federal shore protection project since 1990, with its most recent sediment placement episode prior to Hurricane Sandy taking place in

2010. After Hurricane Sandy, the northern Ocean City project area received 1.746 mcy (1.335 million m^3) of fill in 2013. Then just two years later, another 968,000 cy (740,089 m^3) of sediment were placed on the northern Ocean City project area in 2015 as part of its 7th periodic nourishment episode.

The USACE constructed a new federal beach and dune fill project in 2015 along 9.40 miles (15.13 km) of beach in south Ocean City, Strathmere and Sea Isle City using 4.628 mcy (3.538 million m^3) of material dredged from an offshore borrow area. Portions of Strathmere and Sea Isle City had been modified by a state sediment placement project in 2009, but the federal project expanded the length of sandy beach modified by sediment placement by 6.29 miles (10.12 km). Then in early 2016, an additional 1.023 mcy (782,140 m^3) of sediment was mined from Corson's Inlet and placed on the same beaches as emergency repairs resulting from the offshore passage of Hurricane Joaquin in October 2015. A second set of emergency repairs placed yet another 916,000 cy (700,332 m^3) of sediment on the project area's beaches at the same time, again mining the sediment from Corson's Inlet, to repair damages from a January 2016 storm. Altogether 6.567 mcy (5.021 million m^3) of sediment were placed on 9.40 miles (15.13 km) of beach in two years. Furthermore, the USACE Philadelphia District has solicited bids to place another ~700,000 cy (535,188 m^3) on the north Ocean City between Seaview Road and 36th Street area in late 2016 – early 2017.

Eighty-five percent (85%) of this 15.33 mile (24.67 km) stretch of sandy beach from Ocean City to Sea Isle City has been modified by armoring as well. Sand fencing modified 62% of these sandy beaches and beach scraping modified 7% in the last three years. Corson's Inlet SP at the south end of Ocean City is the only unmodified stretch of beach for 17.16 miles (27.62 km) extending from Ocean City to northern Avalon. (It should be noted, however, that the mining of Corson's Inlet for beach fill indirectly modifies the sandy beaches of Corson's Inlet SP.)

The sandy beach habitat along the New Jersey oceanfront continues to be threatened by development, sediment placement projects, armoring, beach scraping and sand fencing. Although some beachfront development that was destroyed by Hurricane Sandy has not yet been rebuilt, the magnitude of the habitat modifications in the three years following the storm is very high. The length of sandy beach modified by sediment placement increased significantly, from 50 to 63%, with three federal projects proposed and awaiting final approval to initiate construction in the near future that would increase the scale of the modification to 78%. Over 4 miles (6.4 km) of hard shoreline stabilization structures have been constructed. At least 20% of the sandy beachfront was scraped between 2012 and 2015, with a number of communities having state permits to modify their entire beachfronts with beach scraping as conditions allow. And sand fencing modifies nearly half of the New Jersey's sandy beaches, with several additional miles of fencing proposed in the near future. The cumulative impacts of these habitat modifications are particularly significant in several locations, if not the entire New Jersey oceanfront shoreline.

Delaware

Beachfront Development

In 2015 there were 24.65 miles (39.67 km) of sandy shoreline on the Atlantic Ocean shoreline of Delaware (Table K-1). The entire shoreline is sandy beach, with no sections of armored shoreline where sandy beach was absent in 2015. The length of sandy beach was essentially unchanged from 2012 (Rice 2015c), with only a slight reduction at Cape Henlopen due to a shifting of the spit in 2015.

Rice (2015c) estimated that the beachfront in Delaware was 43% developed and 57% undeveloped in 2012 before Hurricane Sandy. Three years after Hurricane Sandy, 45% of the beachfront was estimated developed and 55% undeveloped. This apparent increase in development on the beachfront is due to a revision to the methodology for identifying developed versus undeveloped beachfront. The methodology was revised to be consistent with that used in Rice (2015b) along the shoreline from Maine to the Long Island Sound and Peconic Estuary shorelines of New York. That is, the distance from the beach in which development was evaluated was limited to the area from the vegetation line to a shore parallel road or 500 ft (152.4 m), whichever was closer to the beach; this refinement in the methodology resulted in a slight increase in the level of beachfront development calculated for Rehoboth Beach (see the Methods section for more information). No new significant development is visible in aerial imagery during the three years after Hurricane Sandy; one large lot that was vacant in 2012 in Dewey Beach was developed in 2015, but otherwise only a small number of vacant, solitary oceanfront lots are present in Bethany Beach and the Delaware beachfront is nearly fully developed outside of public or NGO-owned lands.

Almost $10 million worth of improvements were made to the recreational facilities and beach access at Delaware Seashore SP in 2014. Facilities were renovated and enhanced, parking lots were replaced, relocated and expanded, and campgrounds renovated and expanded both north and south of Indian River Inlet. New pavilions and a promenade along Indian River Inlet were constructed. One new beach access was also created (DNREC 2013). The improvements resulted in some small portions of the park being reclassified as developed.

The length of beachfront in public and/or NGO ownership did not significantly change in the three years following Hurricane Sandy (Table K-2). In 2012, 56% of the Delaware beachfront was in public or NGO ownership (Rice 2015b). No new sandy beachfront lands are known to have been placed in public or NGO-ownership in the three years after Hurricane Sandy, but the spit at Cape Henlopen shifted slightly and shortened by 240 ft (73 m). In 2015, 14.28 miles (22.98 km) of sandy beach were present within public or NGO-owned beachfront lands, a slight increase due to the availability of land parcel ownership data for Sussex County, which allowed for the identification of Deauville Beach (owned by the state and managed by the City of Rehoboth Beach) and public beach owned by the City of Rehoboth Beach. The proportion of sandy beach within public or NGO-ownership increased slightly with the new data to 58%.

Table 22. Approximate number of each type of armoring visible on the oceanfront beach in each community within Sussex County, Delaware, visible on aerial imagery between March 1992 and October 2015. Note that multiple seawalls, bulkheads or revetments are counted as one structure if they are continuous with no separations; for example, if five individual properties each have an individual seawall protecting their property and the seawalls are attached to each other with no gaps, the armoring is counted as one seawall structure and its overall length is counted in Table K-3 in Appendix K.

Community	Number of Groins	Number of Jetties	Number of Seawalls, Bulkheads and/or Revetments	Number of Breakwaters
Cape Henlopen	4	0	0	0
Rehoboth Beach[1]	11	0	0	0
Dewey Beach	1	0	2	0
Delaware Seashore SP	0	2	0	0
Bethany Beach	9	0	2	0
South Bethany	0	0	0	0
Fenwick Island	0	0	0	0
TOTAL	**25**	**2**	**4**	**0**

1 – Rehoboth Beach also has at least 4 storm water outfalls located on the beach, 3 of which were extended by the USACE in 2013 to prevent burial and clogging during federal beach fill events. These 4 outfalls were erroneously identified as groins in Rice (2015c); new information correctly identified them as outfalls.

Beach Armor Modifications

The length of sandy beach known to be modified by hard shoreline stabilization structures, or armoring, along the Delaware oceanfront did not change between 2012 and 2015. As of the end of 2015, 3.67 miles (5.91 km), or 15%, of Atlantic Ocean shoreline of Delaware was armored (Table K-3). The north jetty (300 ft or 91 m) at Indian River Inlet was repaired in 2013 by the USACE following damages from Hurricane Sandy (USACE Philadelphia District website), but no new armor structures were constructed in the three years after Hurricane Sandy.
One (1) of the 7 communities listed in Table K-3 on the Delaware oceanfront was more than 50% armored in 2015 – Rehoboth Beach, which is 100% armored with groins. Neither South Bethany or Fenwick Island are known to be modified with any beachfront armor. Altogether there were 25 groins, 2 jetties and 4 contiguous sections of seawalls, bulkheads and/or revetments on the Delaware oceanfront in 2015 (Table 22).

Sediment Placement Modifications

The length of sandy beach in oceanfront Delaware modified by sediment placement increased slightly between 2012 and 2015 to 11.67 miles (18.78 km), or 49% of the state's sandy oceanfront beaches (Table K-4). The federal beach fill projects at Rehoboth Beach, Dewey Beach, Bethany Beach, South Bethany, and Fenwick Island all received beach fill after Hurricane Sandy in 2013. In addition to the annual bypassing of sediment from south to north at

Indian River Inlet, the USACE also placed sediment mined from the flood tidal shoals of Indian River Inlet along 5,500 ft (1,676 m) of beach immediately north of the inlet in 2013 (USACE 2013n). The previously known sediment placement area for this project was 3,500 ft (1,067 m) in length. Thus the overall length of known sediment placement areas along the Delaware oceanfront increased by 2,000 ft (610 m), although historically additional beaches were modified by sediment placement following the Ash Wednesday Storm of 1962 but specific location data remains unavailable (Rice 2015c).

Cape Henlopen SP is the only oceanfront beach in Delaware that is not known to have been modified by sediment placement projects. The sandy beaches of Dewey Beach and South Bethany have been 100% modified by sediment placement, and Bethany Beach 98% (Table K-4). The only developed beachfront in Delaware that has not been modified by sediment placement are the northern end of Rehoboth Beach (including Henlopen Acres), the areas of Delaware Seashore SP that have been developed with recreational facilities, the north end of Bethany Beach and the developed inholding within Fenwick Island SP.

Proposed and Anticipated Habitat Modifications

In November 2015 the USACE proposed a new offshore borrow area for the federal beach fill project at Rehoboth and Dewey Beaches, and the redesignation of existing offshore borrow areas for interchangeable use for all Delaware federal beach fill projects; the previous borrow area for Rehoboth and Dewey Beaches was no longer suitable due to incompatible sediment (USACE 2015i).

The Rehoboth Beach and Dewey Beach federal beach fill project is scheduled to receive renourishment and FCCE repairs from Hurricane Joaquin (October 2015) in late 2016, with an anticipated 424,000 cubic yards (cy; 324,171 cubic meters [m^3]) of fill mined from the new borrow area (Area B) to be placed on the beach (FedBizOpps.gov website). The Bethany / South Bethany federal beach fill project is anticipated to receive sediment placement in 2016 or 2017, and the Fenwick Island federal beach fill project is anticipated to receive sediment in 2017.

Beach Scraping Modifications

Beach scraping was limited along the Delaware oceanfront in the three years after Hurricane Sandy to Delaware Seashore SP and one pair of private properties in Fenwick Island, totaling 1.47 miles (2.37 km) of sandy beach (Table K-5). Extensive beach scraping was conducted immediately following Hurricane Sandy along Route 1 north of Indian River Inlet in Delaware Seashore SP and south of the lifesaving station. No evidence of beach scraping was visible in USGS aerial photography taken in Delaware after Hurricane Joaquin in October 2015. The presence of the large, federal beach fill projects that reconstructed artificial dunes (which were stabilized with sand fencing and vegetation plantings) in 2013 likely contributes to the lack of recent beach scraping along developed beachfront in Delaware. Overall 6% of the Delaware oceanfront beaches were modified by beach scraping in the three years after Hurricane Sandy.

Sand Fencing Modifications

Sand fencing is a significant threat to sandy beach habitat in Delaware. Of the 24.65 miles (39.67 km) of sandy oceanfront beach in Delaware, 14.85 miles (23.90 km), or 60%, were modified with sand fencing from 2012 to 2015. Five (5) of the 7 oceanfront communities were at least 59% modified by sand fencing, with South Bethany 100% modified, Rehoboth and Dewey Beaches 99%, and Bethany Beach 88% (Table K-6). Only the state parks at Cape Henlopen and Delaware Seashore were less than half modified with 29% and 35% of their beaches, respectively, modified by sand fencing. Altogether 116 contiguous sections of sand fencing lined the Delaware oceanfront from 2012 to 2015, nearly all of it in continuous lines parallel to the ocean.

Nearly all of the beaches modified by sand fencing have also been modified by vegetation plantings. Delaware Seashore SP, for example, hosts an annual beach grass planting event that solicits volunteers from the public. In 2013, the 24th year of the dune grass planting event, volunteers planted over 150,000 stems of beach grass along 4 miles (6 km) of beach on both the Atlantic Ocean and Delaware Bay shorelines. From 1989 to 2013 more than 5 million stems of beach grass were planted in the program (DNREC 2014). These manual plantings and others are visible in 2015 Google Earth imagery nearly the entire developed beachfront in Delaware and some sections of undeveloped beachfront. The combined use of sand fencing and vegetation plantings has significantly modified 14.85 miles (23.90 km) of sandy beach habitat along Delaware's oceanfront, establishing and maintaining dunes in artificial locations and landforms.

Summary

Delaware's oceanfront sandy beach habitat is most threatened by development (45%), sediment placement (49%) and sand fencing (60%). Outside of beachfront lands in public or NGO-ownership, there are 10.37 miles (16.69 km) of privately-owned beachfront along Delaware's oceanfront. Only 2% of the privately-owned beachfront is undeveloped, with one lot in Dewey Beach at Silver Lake and another area owned by the Henlopen Acres Property Owners' Association in Rehoboth Beach north of Deauville Beach.

In 2015, 60% of the Delaware oceanfront sandy beach habitat was modified by sand fencing, much of it placed on large artificial dunes that had been created as part of sediment placement projects and that were planted with vegetation. One of the federal beach fill projects (Bethany / South Bethany) had received sediment placement just prior to Hurricane Sandy; after these areas received beach and dune fill in 2013 after the hurricane, 2.82 miles (4.54 km) of sandy beach habitat had been modified by sediment placement twice in 3 years. All 3 of the large federal beach fill projects are anticipated to receive sediment placement in 2016 or 2017. If constructed, 6.61 miles (10.64 km), or 27%, of the sandy oceanfront beach habitat in Delaware will have been modified twice by sediment placement in 3 years (2013 and 2016-17).

The cumulative impacts of habitat modifications to the sandy oceanfront beaches of Delaware are significant (Table 23). In Rehoboth Beach, 77% of the sandy beach habitat has been modified with development, 100% by armor, and 99% by sand fencing. In Dewey Beach, 97%

of the sandy beach habitat has been modified by development, 100% by sediment placement, and 99% by sand fencing. In Bethany Beach, 100% of the sandy beach habitat has been modified by development, 98% by sediment placement, and 88% by sand fencing. In South Bethany, 100% of the sandy beach habitat has been modified by development, sediment placement and sand fencing. The public and NGO-owned sandy oceanfront beach habitat are the only areas along the Delaware oceanfront that do not have significant cumulative impacts due to the types of habitat modification included in this assessment[40].

Table 23. The proportion of sandy beach habitat modified by each type of habitat modification within each oceanfront community in Delaware (from north to south) in 2015.

	Type of Habitat Modification				
Community	**Development**	**Armor**	**Sediment Placement**	**Beach Scraping**	**Sand Fencing**
Cape Henlopen	2%	9%	0	0	29%
Rehoboth Beach	77%	100%	35%	0	99%
Dewey Beach	97%	15%	100%	0	99%
Delaware Seashore SP	8%	0%	31%	23%	35%
Bethany Beach	100%	17%	98%	0	88%
South Bethany	100%	0%	100%	0	100%
Fenwick Island	42%	0%	52%	0.80%	59%
TOTAL	**45%**	**15%**	**49%**	**6%**	**60%**

Maryland

Beachfront Development

The length of sandy beach in Maryland is not dynamic unless a new inlet or breach were to open. The sandy beaches are constricted by the Delaware state line at the north end, the Virginia state line at the south end, and the dual jetties at Ocean City Inlet. Thus the length of sandy beach habitat in oceanfront Maryland remained the unchanged in 2015, at 31.10 miles (50.05 km), with 29% of the beachfront developed and 71% undeveloped (Table L-1). North of Ocean City Inlet, in Ocean City, the sandy beachfront is 100% developed. South of the inlet, on Assateague Island, the sandy beachfront is 100% undeveloped.

The length of beachfront in public and/or NGO ownership did not change in the three years following Hurricane Sandy either (Table L-2). In 2012, 22.10 miles (35.57 km), or 71%, of the Maryland beachfront was in public or NGO ownership (Rice 2015c). No new sandy beachfront lands are known to have been placed in public or NGO-ownership in the three years after

[40] These beaches may be modified by other activities, such as off-road vehicle use, that contribute to overall cumulative impacts.

Hurricane Sandy. In 2015, 22.10 miles (35.57 km) of sandy beach remained present within public or NGO-owned beachfront lands. The proportion of sandy beach within public or NGO-ownership was unchanged at 71% in 2015.

Beach Armor Modifications

In 2012 there were 1.62 miles (2.61 km) of sandy beach habitat modified in Maryland by armor, or hard shoreline stabilization structures. The seawall on the north side of Ocean City Inlet was repaired in late 2014 following damages from Hurricane Sandy (USACE Baltimore District website). No new armor structures were constructed in the 3 years after Hurricane Sandy, but the hurricane exposed 7 groins in Ocean City that were previously buried and not identified. All 7 groins were located seaward of the seawall, however, so the length of sandy beach modified by armor remains the same in 2015 as it was in 2012 at 1.62 miles (2.61 km), or 5% (Table L-3). Altogether there were 7 groins, 2 jetties, 2 contiguous sections of seawalls or bulkheads, and 3 breakwaters along Maryland's oceanfront beaches in 2015 (Table 24).

Sediment Placement Modifications

Historically 100% of Maryland's oceanfront beaches have been modified by sediment placement (Rice 2015c). In recent years sediment placement activities have been limited to nearly all of the entire 9 mile (14.48 km) length of Ocean City and to portions of Assateague Island. After Hurricane Sandy, the federal beach and dune fill project in Ocean City received sediment placement between July 2013 and May 2014 (USACE 2015j). The federal North End Restoration Project at Assateague Island NS continued to receive annual bypassing of sediment

Table 24. Approximate number of each type of armoring visible on the oceanfront beach in each community in Maryland visible on Google Earth imagery between April 1989 and March 2016 and/or identified in Schupp and Coburn (2015). Note that multiple seawalls, bulkheads or revetments are counted as one structure if they are continuous with no separations; for example, if five individual properties each have an individual seawall protecting their property and the seawalls are attached to each other with no gaps, the armoring is counted as one seawall structure and its overall length is counted in Table L-3 in Appendix L.

Community	Number of Groins	Number of Jetties	Number of Seawalls, Bulkheads and/or Revetments	Number of Breakwaters
Ocean City	7	1	1	0
Assateague Island	0	1	1†	3‡
TOTAL	**7**	**2**	**2**	**3**

† The bulkhead located on Assateague Island is presumed to be an old bayside structure that is now buried within the island as the island has migrated landward; it was briefly exposed in 1962 when a breach in the island revealed it (Schupp and Coburn 2015).

‡ Note that the three breakwaters are on the Assateague Island shoulder of Ocean City Inlet and are not oceanfront structures; thus their lengths are not included in the total listed in Table L-3. One breakwater is attached to the southern jetty.

at Ocean City Inlet after Hurricane Sandy, but no sandy beach habitat is directly modified by the project because the sediment is placed in two nearshore sites (Schupp and Coburn 2015; Bill Hulslander, NPS, pers. communication, October 31, 2016). Sediment was placed along much of the 2-mile (3.22 km) artificial dune at Assateague SP in the three years after Hurricane Sandy (Bill Hulslander, NPS, pers. communication, October 31, 2016). Because 100% of Maryland's oceanfront beaches have historically been modified by sediment placement, the proportion of sandy beach habitat modified by sediment placement in 2015 remains 31.10 miles (50.05 km), or 100% (Table L-4).

Proposed and Anticipated Habitat Modifications
In 2016 the Town of Ocean City and the state of Maryland requested a USACE regulatory permit for 10 years of annual sediment placement activities along the entire 9-mile (14 km) length of Ocean City's beaches (USACE 2016d). An anticipated ~200,000 cubic yards (cy; 152,911 cubic meters [m^3]) of sand would be mined from offshore and placed along the entire Ocean City beachfront, on an annual basis as necessary. USACE (2016d) states that this state and local sediment placement project has occurred periodically since 1988.

Beach Scraping Modifications

Two areas in Maryland have been modified by beach scraping – much of the Ocean City sandy beach seaward of the seawall and Assateague SP. Beach scraping occurred on 20% of Ocean City's beaches immediately after Hurricane Sandy in November 2012 and after the offshore passage of Hurricane Joaquin in October 2015. Assateague SP maintains a 2 mile (3.21 km) artificial dune through periodic beach scraping, beach fill, sand fencing, and vegetation plantings (Schupp and Coburn 2015). Altogether 3.79 miles (6.10 km), or 12%, of Maryland's oceanfront beaches are known to have been modified by beach scraping in the three years after Hurricane Sandy (Table L-5).

Proposed and Anticipated Habitat Modifications
The two areas in Maryland that have been modified by beach scraping are likely to continue to be modified by beach scraping. In Ocean City, the beach scraping has modified the beach seaward of the boardwalk and seawall where no dunes exist. The Town of Ocean City scraped the beach after both Hurricane Sandy and the offshore passage of Hurricane Joaquin and is likely to scrape after future storms as well. Beach scraping has a long history in Ocean City, with beach scraping modifying the beach in certain areas since the 1970s (Morgan 2011).

At Assateague SP, the maintenance of an artificial dune protects the campground and developed area of the state park. The beaches of Assateague Island are migrating with sea level rise, however, and the state park's artificial dune is not sustainable in its current location. Schupp and Coburn (2015) state that as a result of Hurricane Sandy the state park is planning to relocate the southern part of the artificial dune landward (west) 115 ft (35 m) sometime after October 2015. The relocated and pre-existing dune sections are likely to continue to be maintained by beach scraping, sand fencing, vegetation plantings, and beach fill as necessary.

Sand Fencing Modifications

Sand fencing is a significant threat to the developed beachfront of Maryland's coast, as well as some areas of Assateague Island. In Ocean City, an artificial dune from 27th Street north to the Delaware line is maintained by the USACE as part of a federal shore protection project (USACE 2015j). The entire artificial dune was modified with sand fencing in 2015, with the only gaps in the shore-parallel fencing occurring at beach access paths. The only portion of Ocean City's beaches not modified with sand fencing was where dunes were absent south of 27th Street, seaward of the seawall; 75% of the sandy beach habitat in Ocean City was modified by sand fencing in 2015.

On Assateague Island, a 2 mile (3.21 km) long artificial dune is maintained with sand fencing at Assateague SP. The NPS also has used sand fencing to maintain an artificial dune along its developed zone to protect park infrastructure (Schupp and Coburn 2015). Between 2012 and 2015, 10.05 miles (16.17 km), or 32%, of sandy beach habitat in Maryland was modified by sand fencing (Table L-6).

Summary

The Maryland oceanfront is the least armored of the states in this assessment, with only 5% (1.62 miles or 2.61 km) of the sandy oceanfront beaches having hard stabilization structures (Table L-3). The sandy beaches of Maryland's oceanfront shoreline are historically one of the most modified by sediment placement, however, with 100% of the shoreline modified at one point or another with beach and/or dune fill. Some areas have historically been modified by sediment removal as well. During the 1920s and 1930s sand (including overwash sand that had inundated city streets following a 1933 hurricane) was actually removed from Ocean City beaches and undeveloped areas for inland construction projects until the city passed and strictly enforced an ordinance requiring one truck load of mainland dirt be deposited on the island for every truck load of sand removed (Morgan 2011).

The length of sandy beach along Maryland's oceanfront will not change in the future unless a new inlet or breach opens. While inlets have historically been present in Ocean City north of the current Ocean City Inlet (Rice 2014, 2016), the complete development of the Ocean City oceanfront and its associated beach and dune fill project restrict the opportunity for new inlets to form within the community. South of Ocean City Inlet, on Assateague Island, at least 11 inlets have historically been open at one time or another in Maryland (Rice 2014, 2016). Because Assateague Island NS is undeveloped and impacted by downdrift erosion from the dual jetties at Ocean City Inlet, the north end of the island is narrow and vulnerable to the formation of a new inlet or breach. If a new inlet or breach were to open, the length of sandy beach habitat may not significantly change however since new breaches do not necessarily change the overall length of sandy beach habitat (e.g., the 2013 opening of Chatham Inlet at Cape Cod NS, the 2012 breach at Fire Island NS).

Virginia

Beachfront Development

The total length of sandy beach habitat in oceanfront Virginia in 2015 was 105.12 miles (169.17 km), a decrease of 1.29 miles (2.08 km) from the 106.40 miles (171.23 km) present prior to Hurricane Sandy in 2012 (Table M-1; Rice 2015c). Sandy beach habitat availability is highly dynamic on the Virginia oceanfront, with Virginia Beach the only location where the length of sandy beach habitat did not change between 2012 and 2015 (Table 25). On 7 of the 13 barrier islands of the Eastern Shore, the length of sandy beach habitat increased; on the other 6 islands, the length of sandy beach habitat decreased in 2015. A total of 3.61 miles (5.81 km) of sandy beach habitat was lost on 6 barrier islands, while 2.33 miles (3.75 km) of sandy beach habitat was gained on the other 7 barrier islands.

Cobb Island had the largest decline in sandy beach habitat with 1.93 miles (3.11km) lost between 2012 and 2015. The north end of Cobb Island retreated, widening Great Machipongo Inlet and resulting in the loss of over one half a mile of sandy beach habitat between 2011 and 2015. The shoreline continues to retreat on Cobb Island (over 300 ft between September 2011 and March 2013 on the north half of the island) and an increasing length of shoreline is dominated by peat, marsh or forest and lacking sandy beach. Prior to Hurricane Sandy, 0.93 miles (1.50 km) of shoreline on Cobb Island lacked a sandy beach; in 2015, 1.79 miles (2.88 km) of shoreline on the island was dominated by peat, marsh or forest that lacked a sandy beach. The large retreat of the north end of the island, a slightly smaller retreat at the south end of the island, and an increasing length of shoreline where sandy beach was no longer present due to island erosion all combined to result in a significant decrease of sandy beach habitat on Cobb Island in 2015.

The north end of Metompkin Island retreated between 2011 and 2015, widening Gargathy Inlet by nearly 1,800 ft (549 m). More than one-half mile of sandy beach habitat was lost at the south end of Cedar Island as well between 2011 and 2014, when the spit at Wachapreague Inlet retreated significantly to the north, widening the inlet. The offshore passage of Hurricane Joaquin in October 2015 temporarily opened a breach at the north end of Cedar Island but the breach naturally closed by early 2016 (Rice 2016). Nebel et al. (2012) found that Cedar Island has been retreating at an accelerating rate since 1980, possibly due to an increased frequency of tropical storms (Nebel et al. 2013). The long-term (1852-2007) average rate of erosion on Cedar Island is 13.5 feet / year (ft/yr; 4.1 meters / year [m/yr]) but the short-term retreat rate is triple that at 41.3 ft/yr (12.6 m/yr; Nebel et al. 2012). Gaunt (1991), as cited in Nebel et al. (2012), found that Cedar Island is narrowing and lost 32% of its subaerial area between 1910 and 1986. Overwash is actively moving sediment towards the marsh on the backside of the island and creates extensive overwash fans (Nebel et al. 2012, 2013, and Gaunt 1991 and Newman and Munsart 1968 as cited in Nebel et al. 2013), indicating that the island is migrating landward. Aerial imagery available for the three years after Hurricane Sandy indicates that these trends are continuing.

The unnamed islet that was present in Gargathy Inlet in 2012 was still present in 2015 but was reduced in size and in a new location farther southwest. Dawson Shoals, an islet or emergent shoal in Wachapreague Inlet, remained present in 2015 but was highly dynamic in its shape and size; the length of sandy beach habitat increased on the islet in 2015. Two additional islets emerged within New Inlet and Fishermans Inlet in the three years after Hurricane Sandy. The islet within New Inlet emerged sometime between 2013 and 2015 and is located offshore the north end of Ship Shoal Island. The islet within Fishermans Inlet emerged during the same time period offshore the east side of Fisherman Island; the southern tip of the islet welded to Fishermans Island in early 2016 (Rice 2016). Both islets increased the length of sandy beach habitat available on or near Ship Shoal and Fisherman Islands.

The only developed sandy beach habitat along Virginia's oceanfront are a small part of Wallops Island and in Virginia Beach, south of the entrance to Chesapeake Bay. This pattern of development was the same in both 2012 and 2015. In 2015, Virginia's oceanfront sandy beaches remained the least modified by development in the U.S. Atlantic Coast breeding range of the piping plover, with only 14%, or 14.29 miles (23.00 km), of the beachfront developed (Table M-1). Virginia Beach, which includes 27.55 miles (44.34 km) of sandy beach from the entrance to Chesapeake Bay to the North Carolina state boundary, is the most developed community with

Table 25. The length of sandy beach habitat along the oceanfront shoreline of Virginia in 2012 prior to Hurricane Sandy and in 2015 within each community (from north to south). The total length of sandy beach habitat decreased by 1.29 miles (2.08 km) between 2012 and 2015, with some communities increasing sandy beach habitat and others decreasing.

Community	2012 Length of Sandy Beach (miles)	2015 Length of Sandy Beach (miles)	Change in Length from 2012 to 2015 (miles)
Chincoteague Island	16.40	16.55	+0.15
Wallops-Assawoman Island	9.06	9.14	+0.08
Unnamed islet in Gargathy Inlet	0.10	0.09	-0.01
Metompkin Island	6.75	6.24	-0.51
Cedar Island	7.78	7.24	-0.54
Dawson Shoals in Wachapreague Inlet	0.54	0.67	+0.13
Parramore Island	7.81	7.48	-0.33
Hog Island	7.81	8.16	+0.35
Cobb Island[1]	4.23	2.30	-1.93
Wreck Island	3.48	3.27	-0.21
Ship Shoal Island	2.51	2.84	+0.33
Mink Island	0.25	0.44	+0.19
Myrtle Island	1.68	1.88	+0.20
Smith Island	7.45	7.37	-0.08
Firsherman Island	3	3.89	+0.89
Virginia Beach	27.55	27.55	0
TOTAL	**106.40**	**105.12**	**-1.29**

1 – In 2012 there was an additional 0.93 miles (1.50 km) of shoreline on Cobb Island that was dominated by peat, marsh or forest that lacked a sandy beach (Rice 2015c). In 2015, the length of shoreline dominated by peat, marsh or forest that lacked sandy beach increased to 1.79 miles (2.88 km).

51% of its sandy beach habitat modified by development. Twelve (12) of the 13 barrier islands on the Eastern Shore, north of the entrance to Chesapeake Bay, are 100% undeveloped.

The estimated length of beachfront in public and/or NGO ownership slightly changed in the three years following Hurricane Sandy (Table M-2). In 2012, 95.83 miles (154.22 km), or 89%, of the Virginia Atlantic Ocean beachfront was in public or NGO ownership (Rice 2015c). While no new sandy beachfront lands are known to have been placed in public or NGO-ownership in the three years after Hurricane Sandy, five additional beachfront parcels owned by the City of Virginia Beach were identified with a newly available data source. Four public parks were identified in Virginia Beach: 31st Street Park, 24th Street Park, Grommet Island Park, and Croatan Beach Park. The City of Virginia Beach also owns and maintains a remote beach parking lot with public beach access in Croatan known as the Croatan Lot, immediately north of the Dam Neck Naval Base. These five newly identified public beachfront lands total 0.32 miles (0.51 km) of sandy beach habitat. Altogether in 2015, 93.91 miles (151.13 km) of sandy beach were present within public or NGO-owned beachfront lands, a slight decrease due to the dynamic shifting of the Eastern Shore's barrier islands and inlets. The proportion of sandy beach within public or NGO-ownership statewide remained unchanged at 89%.

Beach Armor Modifications

Prior to Hurricane Sandy, there were 11.24 miles (18.09 km) of sandy beach habitat modified by hard shoreline stabilization structures, or armor, on the Virginia oceanfront shoreline in 2012 (Rice 2015c). In the three years after Hurricane Sandy, four new sections of seawalls or bulkheads were constructed in the Sandbridge area of Virginia Beach. Each of the four new seawalls or bulkheads were attached to adjacent pre-existing structures, extending the length of sandy beach modified by contiguous armor in each location. A total of 615 ft (187 m) of new sandy beach habitat was modified by armor in 2015. The total length of sandy beach habitat modified by armor on the Virginia oceanfront shoreline in 2015 was 11.36 miles (18.28 km) (Table M-3).

Maintenance of the rock seawall / revetment and a beach fill project with sand fencing and vegetation planting are the components of the current coastal management plan for the NASA Wallops Island Flight Facility that impacts the sandy beach habitat on the island (Hardaway et al. 2015, NASA 2013). As such, the southern end of the revetment on Wallops Island was repaired following Hurricane Sandy in 2013 (NASA 2013). Whether remnants of any of the 44 groins historically constructed on the island (not an active part of the current shoreline management plan) were present as of 2015 could not be determined. The groins have not been maintained and were in disrepair by the mid-1980s (King et al. 2011, Hardaway et al. 2015). None of the groins on Wallops Island were visible in March 2013 Google Earth imagery or October 2015 USGS aerial imagery; the most recent date of Google Earth imagery when the groins are visible is April 1994.

In 2015 there were 3 jetties, up to 47 groins, 33 contiguous seawalls, bulkheads and/or revetments, and 19 breakwaters on the Virginia oceanfront shoreline (Table 26). Because the 4 newly constructed seawalls or bulkheads were attached to adjacent structures, the total number of contiguous seawalls, bulkheads and/or revetments did not change between 2012 and 2015. A

Table 26. Approximate number of each type of armoring visible on the oceanfront beach in each community in Virginia visible on Google Earth imagery between March 1989 and October 2015. Note that multiple seawalls, bulkheads or revetments are counted as one structure if they are continuous with no separations; for example, if five individual properties each have an individual seawall protecting their property and the seawalls are attached to each other with no gaps, the armoring is counted as one seawall structure and its overall length is counted in Table M-3 in Appendix M.

Community	Number of Groins	Number of Jetties	Number of Seawalls, Bulkheads and/or Revetments	Number of Breakwaters
Chincoteague Island	0	0	0	0
Wallops-Assawoman Island	44†	0	1	0
Metompkin Island	0	0	0	0
Cedar Island	0	0	0	0
Parramore Island	0	0	0	0
Hog Island	0	0	0	0
Cobb Island	0	0	0	0
Wreck Island	0	0	0	0
Ship Shoal Island	0	0	0	0
Mink Island	0	0	0	0
Myrtle Island	0	0	0	0
Smith Island	0	0	0	0
Firsherman Island	0	0	0	0
Virginia Beach	3	3‡	3	19
TOTAL	**Up to 47**	**3**	**33**	**19**

† Historically 44 groins were constructed on Wallops Island but the groins have not been maintained and are not visible in any aerial imagery since 1994; the groins may no longer be present.
‡ The structure on Rudee Inlet's south shoreline identified as a revetment in Rice (2015c) was revised to be categorized as a third jetty as identified in City of Virginia Beach (2013).

new information source did identify both of the armor structures on the south side of Rudee Inlet as jetties, although the southern structure is also sometimes referred to as a groin with a weir and an offshore breakwater. Both structures were revised to be categorized as jetties in this assessment, increasing the total number of jetties in Virginia to 3 in Table 26.

Sediment Placement Modifications

In the three years after Hurricane Sandy, 13.56 miles (21.82 km) of sandy beach habitat on the oceanfront shoreline of Virginia was modified by sediment placement. In 2012, prior to Hurricane Sandy, 30.76 miles (49.50 km), or 29%, of sandy beach habitat on Virginia's oceanfront shoreline was known to be modified by sediment placement (Rice 2015c). As of 2015, a total of 30.91 miles (49.74 km), or 29%, of sandy beach habitat was known to be modified by sediment placement, an increase of 0.15 miles (0.24 km). South of the entrance to

Chesapeake Bay, where most of the sediment placement modifications are concentrated, 47% of the sandy beach habitat has been modified by sediment placement (Table M-4).

Over 5 million cubic yards (mcy; 3.8 million cubic meters [m^3]) of sediment were placed on Wallops Island, Virginia Beach, Dam Neck Naval Base and Sandbridge beaches between 2012 and 2015. At Wallops Island, NASA and the USACE had completed construction of a large beach fill project just prior to Hurricane Sandy in the summer of 2012; after the hurricane, NASA and the USACE placed 800,000 cubic yards (cy; 611,644 cubic meters [m^3]) of sediment along ~2 mile (~ 3 km) of the (larger) project area in 2013. Two projects placed sediment on different portions of Virginia Beach's resort area beaches. The federal Virginia Beach Hurricane Protection and Renourishment Project placed 1.25 mcy (0.96 million m^3) of sediment from 15th to 70th Streets between December 2012 and May 2013 in a project that was scheduled prior to Hurricane Sandy (USACE Norfolk District website). In 2014 the City of Virginia Beach placed between 70,000 and 100,000 cy (53,519 to 76,455 m^3) of sediment dredged from Rudee Inlet on the beach from the inlet to 14th Street (City of Virginia Beach 2013). The City of Virginia Beach renewed its federal and state permits to periodically mine a deposition basin on the ebb shoals of Rudee Inlet and place an anticipated 150,000 cy (114,683 m^3) of sediment on the same area of beach from the inlet to 14th Street (USACE 2015k).

South of Rudee Inlet, two federal shoreline protection projects placed sediment on the beach between 2012 and 2015. At the Naval Air Station Oceana Dam Neck Annex, the U.S. Navy placed 700,000 cy (535,188 m^3) of sediment on 1.90 miles (3.06 km) of beach in the winter of 2013-14 (USACE 2013j). The beach and dune fill project was originally constructed in 1996. The 2013-14 episode placed sediment along 770 ft (235 m) of beach that were not modified in the original 1996 project area. This was the only area in Virginia which was newly modified by sediment placement as of 2015. In Sandbridge, the City of Virginia Beach and the USACE placed 2,134,850 cy (1,632,210 m^3) of sediment along the entire 5-mile (8 km) federal beach fill project area in 2013 (USACE Norfolk District website).

Proposed and Anticipated Habitat Modifications

The U.S. Navy has proposed a shoreline protection project at Joint Expeditionary Base (JEB) Little Creek / Fort Story. Although originally proposed prior to Hurricane Sandy, the project was not constructed and has been modified after the hurricane. In 2014 the U.S. Navy proposed to place sediment at 3 locations within JEB Little Creek / Fort Story, one of which is located on sandy beaches included in this habitat assessment. At the north end of Leyte Road, the project proposes to place beach fill from the stone revetment around Building 734 to the first breakwater to the east, along 435 ft (133 m) of sandy beach that is not known to have been modified by sediment placement (NMFS 2012, USACE 2014l). If constructed, the JEB Little Creek / Fort Story shoreline protection project would increase the length of sandy beach included in this assessment modified by sediment placement by 0.08 miles (0.13 km) to 30.99 miles (49.87 km).

Beach Scraping Modifications

The sandy beaches in only one oceanfront community in Virginia has been modified by beach scraping – Virginia Beach (Table M-5). From 2012 to 2015, 2.89 miles (4.65 km) of sandy beach habitat in Virginia Beach was modified by beach scraping. Most of the beach scraping (2.31 miles or 3.72 km) was located seaward of the seawall in Virginia Beach between 58th Street and Rudee Inlet. The remaining locations (0.58 miles or 0.93 km) modified by beach scraping were in the Sandbridge section of Virginia Beach at 21 private properties and Little Island Park. Altogether 10% of the sandy beach habitat in Virginia Beach was modified by beach scraping during the three years after Hurricane Sandy, for 3% of the sandy beach habitat along the entire state's oceanfront beaches.

Sand Fencing Modifications

The sandy beach habitat in only two oceanfront communities in Virginia were modified by sand fencing between 2012 and 2015 (Table M-6). On Wallops Island, sand fencing was present along 3.38 miles (5.44 km), or 38%, of the sandy beach habitat. All 3 contiguous sections of sand fencing on Wallops Island were located seaward of the seawall / revetment. In Virginia Beach, 4.77 miles (7.68 km), or 17%, of the sandy beach habitat was modified by sand fencing. Sand fencing was present between 2012 and 2015 on the sandy beaches of JEB Little Creek / Fort Story, in 3 sections between 58th and 62nd Streets, and in longer sections of Croatan, Dam Neck, and Sandbridge. There were 12 contiguous sections of sand fencing in Croatan along a total of 0.56 miles (0.90 km) of sandy beach. At the Naval Air Station Oceana Dam Neck Annex, 2.68 miles (4.31 km) of sandy beach were modified by 21 contiguous sections of sand fencing. Fifty-five (55) contiguous sections of sand fencing modified 1.11 miles (1.79 km) of sandy beach habitat in Sandbridge, including Little Island Park. Altogether there were 97 sections of contiguous sand fencing modifying 8.15 miles (13.12 km), or 8%, of the sandy beach habitat in oceanfront Virginia between 2012 and 2015.

Summary

The majority (89%) of Virginia's sandy oceanfront beaches are in public and/or NGO ownership (Table M-2). The Nature Conservancy (TNC) owns and manages most of the barrier islands along the Eastern Shore as part of its Virginia Coast Reserve: Hog Island, Ship Shoal Island, Mink Island, Myrtle Island, Smith Island, Parramore island, Cobb Island, and portions of Metompkin and Cedar Islands. The Chincoteague NWR owns and/or manages the Virginia portion of Assateague Island, the Assawoman Island portion of Wallops Island, and sections of Metompkin and Cedar Islands (USFWS 2014d). The state manages the Wreck Island Natural Area Preserve. Fishermans Island NWR is the southernmost of the Eastern Shore barrier islands in public and/or NGO ownership. Just north of the North Carolina state boundary, the state owns False Cape State Park and the USFWS owns Back Bay NWR.

The barrier islands of the Eastern Shore of Virginia are highly dynamic, continuously gaining and losing sandy beach habitat. Cobb Island in particular appears vulnerable to disintegration in the near future as sea level continues to rise and the island lacks the sediment supply to sustain sandy beach habitat. In the 3 years after Hurricane Sandy, the length of shoreline dominated by peat, marsh or forest eroding directly into the surf zone of Cobb Island increased significantly and is likely to continue to do so. The north end of the island is dominated by peat outcrops visible in the surf zone in October 2015 aerial photography with a thin veneer of sand on top of the marsh farther landward. The central part of Cobb Island is dominated by a forest that is actively eroding into the surf zone; only a narrow band of forest remained in October 2015 and once the forest has completed eroded the shoreline will be dominated by peat and marsh outcrops like the north end of the island. The south end of Cobb Island is the only part of the island with significant sandy beach habitat present in 2015; this part of the barrier island appears to be highly vulnerable to overwash with few areas of higher elevation such as dunes.

Peat outcrops also were present in 2015 along sections of Parramore, Wreck, Mink, Myrtle and Smith Islands as the barrier islands migrate and retreat into backbarrier marsh. Richardson and McBride (2007), as cited in Nebel et al. (2012), found that erosion rates on Parramore Island have accelerated since 1994, from a long-term rate (1852-2006) of 11.8 ft/yr (3.6 m/yr) to a short-term (1998-2006) rate of 28.9 ft/yr (8.8 m/yr). "Cedar and Parramore Islands are retreating at a rate that is anomalously high for the mid-Atlantic shoreline" (Nebel et al. 2012, p. 339). The long-term sustainability of large areas of sandy beach habitat on some of the Eastern Shore's barrier islands like Cobb, Cedar, Metompkin, Wreck, Mink and Myrtle Islands appears questionable. The Nature Conservancy has recently initiated a research effort to develop a Barrier Island-Inlet Evolution Model that will model natural barrier island migration on the Eastern Shore that may yield valuable information about the future availability and sustainability of sandy beach habitat on many of the Eastern Shore's barrier islands (Hardaway et al. 2015).

Virginia's oceanfront beaches are less threatened by habitat modification than most, if not all, of the other states within the U.S. Atlantic Coast breeding range of the piping plover. Sandy beach habitat along Virginia's oceanfront is minimally threatened by beach scraping (3%), sand fencing (8%), armor (11%), and development (14%). Habitat modification from sediment placement is the largest threat, with 29% of the oceanfront beaches modified in this manner. Habitat modifications are not uniformly distributed along Virginia's sandy beaches, with Wallops Island and Virginia Beach disproportionally modified.

North Carolina

Beachfront Development

In 2015 there were 323.00 miles (519.82 km) of sandy shoreline on the Atlantic Ocean shoreline of North Carolina (Table N-1). Rice (2012b) and NC DENR (2011) identified 326.00 miles (624.65 km) of sandy oceanfront beach in North Carolina prior to Hurricane Sandy. The slight decrease in length of sandy beach habitat present on the oceanfront shoreline of North Carolina between 2012 and 2015 is due to the shifting position of inlets and their associated barrier island shorelines, including the closure of the inlet at Pea Island NWR and the opening of New Old Drum Inlet at Cape Lookout NS (Rice 2016).

In 2012 before Hurricane Sandy, the beachfront in North Carolina was classified 49% developed and 51% undeveloped (Rice 2012b, NC DENR 2011). Three years after Hurricane Sandy, 41%

of the beachfront was classified developed and 59% undeveloped (Table N-1). This net decrease in estimated development on the beachfront is due to a revision to the methodology for identifying developed versus undeveloped beachfront. The methodology was revised to be consistent with that used in Rice (2015b), which was not utilized in the NC DENR (2011) assessment. That is, the distance from the beach in which development was evaluated was limited to the area from the vegetation line to a shore parallel road or 500 ft (152.4 m), whichever was closer to the beach (see the Methods section for more information); this refinement in the methodology resulted in a net decrease in the level of beachfront development calculated for communities such as Sunset Beach, where much of the beachfront development is set back more than 500 ft (152.4 m) from the beach.

Of the 37 coastal communities along the North Carolina oceanfront, the sandy beach habitat of 14 communities were more than 75% modified by beachfront development in late 2015 or early 2016[41]. These 14 communities contained 71.72 miles (115.42 km), or 22%, of the sandy beach habitat in North Carolina in 2015. In another 9 communities, beachfront development had modified between 50 and 75% of the sandy beach habitat (Table N-1); these 9 communities contained 81.49 miles (131.15 km), or another 25%, of the sandy beach habitat present in 2015 in North Carolina. Altogether 47% of the sandy beach habitat present in North Carolina in 2015 was at least 50% modified by development.

Beachfront development has not modified any sandy beach habitat in 5 communities, all of which are in public or NGO ownership: the 3 islands of Cape Lookout NS, Ocracoke Island, Bear Island (Hammocks Beach SP, in Swansboro Township), Lea-Hutaff Island in Topsail Township (Twp.), and Masonboro Island. The sandy beach habitat in an additional 3 communities is less than 5% modified by beachfront development: Buxton, the 2 islands of the Camp Lejeune Marine Corps Base, and Federal Point Twp., which includes the Fort Fisher State Recreation Area and Zeke's Island Reserve. These 8 communities contained 118.54 miles (190.77 km), or 37%, of the sandy beach habitat in North Carolina in 2015

Development continues to be a threat to North Carolina's sandy beach habitat, with several segments of beachfront converted from undeveloped to developed between 2012 and 2015, particularly on North Topsail Beach where at least 710 ft (216 m) of sandy beach habitat was developed during the 3-year period. In Corolla, several new homes were constructed as well; the new Pine Island Reserve subdivision converted 1,000 ft (305 m) of undeveloped beachfront to developed beachfront between 2013 and early 2016. On Oak Island, new homes constructed near Southeast 73rd and 74th Streets converted 435 ft (133 m) of undeveloped beachfront to developed between 2013 and 2015.

In a few localized areas, developed beachfront was converted to undeveloped. In Nags Head, the Beacon Motor Lodge was removed in 2015, converting 450 ft (137 m) of developed beachfront to undeveloped; future plans for the site are unknown but are likely to include redevelopment of the site. In Rodanthe, several homes have been removed in the Mirlo Beach area near where NC 12 has been breached in recent storms; nearly 400 ft (122 m) of sandy beach habitat was converted from developed to undeveloped by early 2016. At Cape Hatteras NS in Buxton, a

[41] Aerial imagery within Google Earth is not available for the entire state for 2015. In locations where 2015 aerial imagery was not available, imagery from early 2016 was used.

developed area with around 20 buildings along Schooner Es Newman Drive north of the Cape Hatteras Lighthouse was converted to undeveloped beachfront (~520 ft or 158 m) when all of the buildings were removed. Altogether the length of sandy beach habitat modified by new development exceeds the length of beach converted from previously developed beachfront to undeveloped. Due to the revision in methodology to identify beachfront development described above, however, there was an overall net decrease in the level of sandy beach habitat identified as modified by development between NC DENR (2011) and this assessment for 2015.

The length of beachfront in public and/or NGO ownership did not significantly change in the three years following Hurricane Sandy (Table N-2). Prior to Hurricane Sandy, 178.70 miles (287.59 km), or 55%, of the North Carolina beachfront was in public or NGO ownership (Rice 2012b). No new sandy beachfront lands are known to have been placed in public or NGO-ownership in the three years after Hurricane Sandy but new information sources allowed new public and NGO-owned parcels to be identified. One NGO-owned tract was converted to private ownership. Altogether in 2015, 179.47 miles (57.21 km) of sandy beach were present within public or NGO-owned beachfront lands, a slight increase from the length identified prior to Hurricane Sandy (primarily from published sources). The proportion of sandy beach within public or NGO-ownership increased slightly to 56% in 2015 (Table N-2).

New information sources (i.e., county level parcel ownership data) allowed for the identification of numerous municipal and state owned parcels of beachfront land that were not identified in Rice (2012b) for North Carolina. As the beach has receded up against North Virginia Dare Trail (NC 12) in Kitty Hawk, the town and other public and NGO entities have purchased or become owners of several vacant beachfront properties. Some of these parcels are adjacent to one another, connecting sandy beach habitat in public / NGO ownership, while others remain narrow parcels isolated among privately owned parcels. The contiguous parcels total over 2,270 ft (692 m) of sandy beach habitat as of 2015.

Other beachfront lands in public or NGO ownership were newly identified using new information sources as well. The state owns a tract directly adjacent to the Monkey Island Unit of Currituck NWR in Corolla that includes 0.65 miles (1.05 km) of sandy beach habitat. The USACE owns the Duck Field Research Facility, which includes 0.64 miles (1.03 km) of sandy beach habitat that is the only undeveloped sandy beach habitat in Duck. The state of NC owns a large (~23 acres) beach and dune parcel in Salter Path that includes 0.52 miles (0.84 km) of sandy beach habitat. The Town of Oak Island owns The Point at the west end of the island adjacent to Lockwood's Folly Inlet, with 0.64 miles (1.03 km) of sandy beach habitat in 2015. In addition, numerous beach access parcels are owned by the Towns of Kill Devil Hills and Nags Head on the Outer Banks, the three communities on Topsail Island, and several communities in New Hanover and Brunswick Counties; most of the beach access parcels have only 0.01 miles (0.02 km) of sandy beach habitat each, but cumulatively they total at least 3.41 miles (5.49 km) of sandy beach habitat in public ownership that were not identified in Rice (2012b).

One NGO-owned beachfront tract was converted to private ownership in recent years. Since 2012, the National Audubon Society sold a 13-acre oceanfront parcel containing 1,000 ft (305 m) of undeveloped sandy beach habitat at Pine Island in Corolla. The oceanfront tract converted from NGO to private ownership and was subdivided into the Pine Island Reserve subdivision, with 11 of 13 parcels developed with new homes and a new street between 2013 and 2015. As a result, the length of sandy beach habitat in public or NGO ownership decreased by 0.19 miles (0.31 km) in Corolla. Altogether, more than half of the sandy beach habitat (56%) in North Carolina is within public or NGO ownership, tied for fourth highest of the states within the U.S. Atlantic Coast breeding range in terms of proportion and second only to Massachusetts in terms of total length.

Proposed and Anticipated Habitat Modifications
Development continues to threaten sandy beach habitat in NC, with several beach segments proposed for development or under construction after 2015. In October 2016, the east end of Sunset Beach near Tubbs Inlet initiated development of a previously undeveloped area. Eight (8) lots were under construction with new buildings, converting nearly 700 ft (213 m) of undeveloped beachfront to developed beachfront; one of these lots had been cleared but not built upon as of October 2015. At the west end of Sunset Beach, the Sunset Beach West subdivision has proposed to develop 21 lots along 1,860 ft (567 m) of currently undeveloped beachfront (Talton 2016a).

Beach Armor Modifications

Altogether, as of 2015, 9.05 miles (14.56 km), or 47,767 ft (14,559 m), of the sandy beach habitat on North Carolina's oceanfront had been modified by armor, with 8.30 miles (13.36 km) where sandy beach habitat was present in 2015 and 0.74 miles (1.19 km) where sandy beach habitat was absent seaward of the armor (Table N-3). The proportion of sandy beach habitat modified by beachfront armor in North Carolina as of 2015 was 3%. The majority of coastal communities (24 of 37) in North Carolina have been modified by armor. At the community level, the proportion of sandy beach habitat that has been armored ranges up to 18%, with four communities exceeding 10%: Kitty Hawk (18%), Bald Head Island (13%)[42], Kure Beach (11%), and Ocean Isle Beach (10%).

The length of sandy shoreline modified by armor in North Carolina prior to Hurricane Sandy was unknown due to a large number of sandbag revetments on individual private properties (Rice 2012b, 2015d). Prior to Hurricane Sandy, the North Carolina oceanfront was known to be modified by 21 groins, 2 jetties, and up to 352 contiguous sections of seawalls, bulkheads and/or revetments (Rice 2015d).

During the three years after Hurricane Sandy, from 2012 through 2015, several new armor structures were constructed in North Carolina. The North Carolina Department of Transportation (NC DOT) has constructed a series of sandbag revetments to protect NC Highway 12 on the Outer Banks. In Kitty Hawk, a section of NC 12 near Kitty Hawk has been washed out during recent storms, including Hurricane Joaquin in October 2015. In 2015 NC DOT constructed two sandbag revetments near Kitty Hawk Road in Kitty Hawk, connecting with

[42] The proportion of Bald Head Island's sandy beach habitat that has been modified by armor is 13% when the Smithville Twp. portions of Zeke's Island Reserve and Bald Head Island State Natural Area are included. When only the Village of Bald Head Island is included, the proportion of sandy beach habitat modified by armor increases to 23%.

a sandbag revetment that had been constructed in 2003-2004 to the north (NC DOT 2015a, b; Town of Kitty Hawk et al. 2016). Assuming that the north end of the buried sandbag revetment is near Starfish Lane, the contiguous NC DOT sandbag revetment has modified approximately 2,680 ft (819 m) of sandy beach habitat in Kitty Hawk.

After Hurricane Sandy, the NC DOT installed a sandbag revetment to protect another section of NC 12 in Rodanthe near the southern boundary of the Pea Island NWR (NC DOT 2012a, b). This section of NC 12 and the barrier island were breached during Hurricane Irene in 2011, and the breach was closed artificially by NC DOT. The sandbag revetment constructed after Hurricane Sandy in late 2012 and early 2013 was buried within an artificial dune and has modified a total of 2,110 ft (643 m) of sandy beach habitat in Rodanthe.

A sandbag revetment was constructed on the south side of New River Inlet at North Topsail Beach in February 2015 (Town of North Topsail Beach 2015a, b). The south jetty at Masonboro Inlet was repaired by the USACE in 2013-14 (USACE 2013y, 2014r). Construction of a terminal groin was completed on Bald Head Island on the east side of the Cape Fear River inlet in January 2016, with a possible future extension of the groin in the future if conditions warrant (Talton 2016b, USACE 2014q, USFWS 2014c). A sandbag revetment was installed along 4 properties at the west end of Oak Island in 2014 (USFWS 2015a). The sandbag revetment modified nearly 250 ft (76 m) of sandy beach habitat in the Town of Oak Island.

Sandbag revetments have been constructed at both ends of Ocean Isle Beach, resulting in periodic loss of sandy beach habitat seaward of both revetments. At the east end of the island, near Shallotte Inlet, the Town of Ocean Isle Beach and private property owners installed 1,400 ft (427 m) of sandbag revetments along East 3rd Street around 2005 (Town of Ocean Isle Beach 2015). Subsequently, the NC DOT extended the sandbag revetment 400 ft (122 m) to the west to protect East 2nd Street, connecting the eastern sandbag revetment with a sandbag revetment protecting two homes near Charlotte Street. The contiguous sections of sandbag revetments at the east end of Ocean Isle Beach had modified 1,885 ft (575 m) of shoreline as of 2015.

At the west end of the Ocean Isle Beach, near Tubbs Inlet, a contiguous section of sandbag revetment was constructed in 2007, when approximately 275 ft (84 m) of barrier spit separated the private properties from Tubbs Inlet. Tubbs Inlet has shifted position towards the east since then, and the sandbag revetment was located directly on the inlet shoreline as of 2012 (Gona 2016, USFWS 2016d). Sandy beach habitat periodically is present and absent seaward of the sandbag revetment at Tubbs Inlet, being present through 2013 but absent in October 2014. In October 2015, sandy beach habitat was present but very narrow seaward of the revetment; the sandbag revetment modified 356 ft (109 m) of sandy beach habitat in 2015.

As of 2015, a total of 34 groins, 4 jetties, 1 breakwater, and 152 contiguous sections of seawalls, bulkheads and/or revetments were identified along North Carolina's oceanfront beaches (Table 27). New information sources and aerial imagery identified a number of armor structures that were not identified by Rice (2012b). In Kill Devil Hills, for example, the Avalon Pier is protected with a bulkhead and 7 groins that are typically buried and not visible. One new groin was constructed on Bald Head Island in 2015, and 6 new groins were identified on Bald Head Island's West Beach on either side of the inlet to the marina and on the beach north of there, near

Bald Head Creek. A century-old breakwater / jetty was identified at Cape Lookout near Barden Inlet, and a landlocked jetty / breakwater was identified on the former Beaufort Inlet shoreline of Shackleford Banks (Coburn et al. 2010).

Finally, assessment of sandbag revetments identified 140 sandbag revetments known to be or assumed to be present in 2015. These sandbag revetments had modified an estimated 23,108 ft (7,043 m) of sandy beach habitat in 2015. The length of North Carolina sandy beach habitat modified by sandbag revetments was **not** included in the 2012 beach armor inventory (Rice 2012b).[43]

Proposed and Anticipated Habitat Modifications

In 2015 the North Carolina state legislature expanded its 2011 reversal of its previous decades-long ban on hard shoreline stabilization structures, bringing the authorization for new terminal groins to a total of six. Changes enacted in 2011 allowed up to four terminal groins to be constructed at inlets in the state. One such terminal groin was recently completed on Bald Head Island on the east side of the Cape Fear River inlet, and three others are in the permitting process to construct terminal groins at Rich Inlet on Figure Eight Island, at Lockwoods Folly Inlet on Holden Beach, and at Shallotte Inlet on Ocean Isle Beach (Talton 2016b; USACE 2014q, 2015r, 2015s, 2015q, 2016k and 2016l; USFWS 2015c, 2016a). In 2015 the state legislature further expanded the existing hard shoreline stabilization legislation to allow two additional terminal groins at Bogue Inlet and New River Inlet, but neither Emerald Isle nor Carteret County had proposed the construction of a terminal groin at Bogue Inlet as of 2016. The Town of North Topsail Beach and Onslow County have initiated a feasibility study to construct a terminal groin at New River Inlet, however.

The sandbag revetment initially constructed in 2007 near the east side of Tubbs Inlet, on a private property in Ocean Isle Beach, was expanded in 2009 but remained set back from the inlet shoreline. By 2012 the inlet had shifted position to the east and the revetment was directly on the inlet shoreline. The state permit for the sandbag revetment expired in 2014 but the revetment was not removed and remains directly on the inlet shoreline. The private property owner requested and received a permit variance and an expansion of the revetment, doubling it in height, in July 2016 (Gona 2016, USFWS 2016d). The sandbag revetment is contiguous with 3 other sandbag revetments at adjacent properties to the east. Sandy beach habitat is periodically present and absent seaward of the contiguous sandbag revetment; in October 2015 sandy beach habitat was present (although very narrow), but in October 2016 no sandy beach habitat was present along ~215 ft (~66 m) of shoreline seaward of the sandbag revetment.

Private sandbag revetments have been constructed on Figure Eight Island and Ocean Isle Beach near but not directly on the south side of Rich Inlet and the west side of Shallotte Inlet

[43] Sandbag revetments are frequently buried or located under buildings (which are on pilings) and not visible in aerial imagery. In order to estimate the length of sandy beach habitat modified by sandbag revetments in North Carolina as of 2015, two assumptions were made: 1) sandbag revetments identified in a 2008 North Carolina Division of Coastal Management (NC DCM) inventory were assumed to be present if the building at the site was still present in 2015, and had not been relocated or removed; and 2) the length of beach modified by the sandbag revetment was assumed to be, at a minimum, the width of the building on the property. This assessment of sandbag revetments then combined the number of sandbag revetments present in 2008 that were assumed to be present in 2015 with the number of new sandbag revetments constructed after 2008 and identified in aerial imagery.

Table 27. Approximate number of each type of armoring visible on the oceanfront beach in each community in North Carolina visible on Google Earth imagery between 1993 and late 2015 / early 2016. Note that multiple seawalls, bulkheads or revetments are counted as one structure if they are continuous with no separations; for example, if five individual properties each have an individual sandbag revetment protecting their property and the sandbags are attached to each other with no gaps, the armoring is counted as one revetment structure and its overall length is counted in Table N-3 in Appendix N.

Community	Number of Groins	Number of Jetties	Number of Seawalls, Bulkheads and/or Revetments	Number of Breakwaters
Corolla	0	0	2	0
Duck	0	0	0	0
Southern Shores	0	0	0	0
Kitty Hawk	0	0	12	0
Kill Devil Hills	7	0	11	0
Nags Head	0	0	29	0
Rodanthe	1	0	4	0
Salvo	0	0	0	0
Avon	0	0	0	0
Buxton	3	0	1	0
Frisco	0	0	0	0
Hatteras	0	0	0	0
Ocracoke	0	0	0	0
Cape Lookout NS (Portsmouth Island to Shackleford Banks)[1]	0	1	0	1
Atlantic Beach[2]	0	1	10	0
Pine Knoll Shores	0	0	6	0
Indian Beach	0	0	0	0
Salter Path	0	0	0	0
Emerald Isle	0	0	4	0
Swansboro Township (Hammocks Beach SP)	0	0	0	0
Camp Lejeune	0	0	0	0
North Topsail Beach[3]	0	0	9	0
Surf City	0	0	10	0
Topsail Beach	0	0	14	0
Topsail Township (Lea-Hutaff Island)	0	0	0	0
Figure 8 Island[3]	0	0	3	0
Wrightsville Beach	0	1	0	0
Masonboro Island	0	1	0	0
Carolina Beach	0	0	1	0
Kure Beach	0	0	2	0
Federal Point Township	0	0	0	0
Bald Head Island	23	0	1	0

Community	Number of Groins	Number of Jetties	Number of Seawalls, Bulkheads and/or Revetments	Number of Breakwaters
Caswell Beach	0	0	1	0
Oak Island	0	0	17	0
Holden Beach[3]	0	0	5	0
Ocean Isle Beach[3]	0	0	10	0
Sunset Beach[4]	0	0	0	0
TOTAL	**34**	**4**	**152**	**1**

1 – A breakwater / jetty structure constructed in 1914-17 is present near Barden Inlet at Cape Lookout. A landlocked jetty / breakwater structure was constructed on the Beaufort Inlet shoreline of Shackleford Banks in 1882 but is currently landlocked (Coburn et al. 2010).
2 – The jetty at Fort Macon SP in Atlantic Beach is referred to as a terminal groin by some sources. One additional groin is located on the inlet shoreline of Fort Macon SP but was buried in 2015 and is not included here due to its location on the inlet shoreline, rather than the oceanfront shoreline.
3 – Terminal groins have been proposed or are under investigation for the inlet shorelines of North Topsail Beach, Figure 8 Island, Holden Beach and Ocean Isle Beach.
4 – One jetty at Little River Inlet is located on the southern tip of Bird Island / Sunset Beach, but is located within the state of South Carolina.

respectively. If either of the two inlets shift significantly in position, those revetments could modify the inlet shorelines and their sandy beach habitat in the future.

Sandbag revetments are prohibited in the Town of Duck, so no new sandbag revetments are anticipated in the future within that community (Town of Duck et al. 2016).

Sediment Placement Modifications

In the three years following Hurricane Sandy, 42.46 miles (68.01 km) of sandy beach habitat were modified with sediment placement, 29.10 miles (46.83 km) of which had previously been modified by sediment placement and 13.36 miles (21.50 km) of which were newly modified areas. As of the end of 2015, a total of 100.97 miles (162.50 km) of sandy beach, or 31%, had been modified by sediment placement, an increase of 3% from the estimated 2012 level[44] (Table N-4). Prior to Hurricane Sandy, an estimated 91.37 miles (147.05 km) of sandy beach habitat, or 28%, had been modified in NC by sediment placement (Rice 2015d). At least 11.626 million cubic yards (mcy; 8.89 million cubic meters [m^3]) of sediment were placed on the oceanfront beaches of NC as part of projects that began construction between 2012 and 2015.

Before Hurricane Sandy, the sandy beaches in 28 of the 37 oceanfront communities in North Carolina were known to be modified to varying proportions by sediment placement projects (Rice 2012b). Three years after Hurricane Sandy, the number of communities where sandy beaches have been modified by sediment placement projects remained the same (Table N-4).

[44] New information sources revised the estimate of 91.37 miles (147.05 km) identified in Rice (2015d) by identifying additional project overlap areas. Removal of the overlapping project areas revised the pre-Hurricane Sandy length of sediment placement to 87.75 miles (141.22 km).

A number of sediment placement projects modified North Carolina's sandy beach habitat during the three years after Hurricane Sandy. In Rodanthe the NC DOT constructed a sediment placement project to protect an area of NC 12 known as the "S-Curves" near the southern boundary of the Pea Island NWR. The sediment placement project modified 11,250 ft (3,429 m) of sandy beach habitat, 8,215 ft (2,504 m) of which had not previously been modified.

In Pine Knoll Shores 2.4 miles (3.9 km) of beach received sediment placement in 2013 as repairs from Hurricane Irene. Two sections of Emerald Isle totaling 4.2 miles (6.8 km) also received sediment placement as repairs from Hurricane Irene in 2013 (USACE 2014s). All three areas had previously been modified by sediment placement.

The Town of North Topsail Beach initiated a five Phase Beach Restoration Project in 2012. In the winter of 2012-2013, the inlet channel of New River Inlet was relocated as part of Phase 1, with the dredged material (566,244 cy) used as beach fill on adjacent North Topsail Beach (Town of North Topsail Beach 2015a, USACE 2015t). Phase 5 of the Beach Restoration Project was completed between December 2014 and June 2015, placing 1.25 mcy (0.96 million m^3) of sediment from offshore along the southernmost 3.5 miles (5.6 km) of the town's beaches (North Topsail Beach 2015b, USACE 2014t, USFWS 2015d). The other phases of the project are pending funding and plan to place sediment on the remaining central portions of sandy beach within the town.

New Topsail Inlet and its associated federal navigation channels were mined and/or dredged in 2010-11, 2012 and 2015 by the Town of Topsail Beach, with at least the latter two using funding from the Federal Emergency Management Agency, for beach fill along 4.7 miles (7.6 km) of beach north of the inlet (USACE 2013z, Town of North Topsail Beach 2015b). Mason Inlet was mined in 2013 to provide beach fill for Figure Eight Island and to maintain Mason Inlet within a specific location, a cycle that is anticipated to occur every 3 years; the inlet had previously been mined in 2011 (USFWS 2015b and 2016c; Lindsay Addison, Audubon North Carolina, pers. communication, June 14, 2016).

In 2015 Bald Head Island began construction of a terminal groin at the Cape Fear River; the project was completed in early 2016 and the project design included placement of sediment along 2,500 ft (762 m) of beach, either as part of federal dredged material placement or as a locally sponsored event; all of the sand fillet for the terminal groin had previously been modified by sediment placement (USACE 2014q, USFWS 2014c).

Also in 2015 the Town of Oak Island constructed the Lockwoods Folly River Habitat Restoration Project, Phase 1 – Eastern Channel. The Town of Oak Island dredged Eastern Channel, part of the Lockwoods Folly Inlet complex, in 2015 and removed over 3 acres of emergent shoal habitat; the beach-compatible portion of the dredged material was placed on 3,148 ft (960 m) of beach at the west end of the island, where a sandbag revetment protects 4 private properties (USFWS 2015a).

In addition to the locally-sponsored beach fill projects that were constructed in the three years after Hurricane Sandy, all four existing federal coastal storm damage reduction projects in the state received sediment placement in the same time period. The federal coastal storm damage reduction project at Wrightsville Beach received sediment in 2014 (USFWS 2016c). The coastal storm damage reduction projects at Carolina Beach and Kure Beach received sediment placement in 2013 (USFWS 2016b). The east end of the federal beach fill project on Ocean Isle Beach received sediment placement in 2014, with sediment dredged from Shallotte Inlet (Town of Ocean Isle Beach 2015, USFWS 2015c).

Sediment was also placed on a number of North Carolina beaches through dredging of navigation channels. Beaufort Inlet was dredged in 2013 and 2014, with ~1.1 mcy (0.84 million m^3) of dredged sediment placed on Bogue Banks to the west in the 2014 dredging episode (Hibbs 2013, 2014; Carteret County Shore Protection Office website). Dredging of the Bogue Inlet crossing with the Atlantic Intracoastal Waterway (AIWW) placed sediment along ~840 ft (256 m) of the undeveloped spit next to the inlet in Emerald Isle (Carteret County Shore Protection Office website). Maintenance dredging of navigation channels in the Cape Fear River placed 1.525 mcy (1.166 million m^3) of sediment along 12,500 ft (3,810 m) of sandy beach on Bald Head Island in 2013 and 11,250 ft (3,429 m) of beach in 2015-16 (USACE 2014q, Village of Bald Head Island 2016). Material dredged from the intersection of the AIWW with the Lockwoods Folly River was placed along 3,200 ft (975) of eastern Holden Beach in 2014 by the USACE; the Town supplemented the placement of the dredged material with additional sediment, extending the placement area 2,300 ft (701 m) to the west (Applied Technology & Management [ATM] 2015).

Proposed and Anticipated Habitat Modifications

In 2016 several sediment placement projects were constructed in North Carolina (Table 28). The Onslow County Navigation Project placed material dredged by Onslow County from federal navigation channels in and near New River Inlet and placed the sediment along the beach at the north end of North Topsail Beach (USFWS 2015d). At Mason Inlet periodic mining and maintenance of the inlet in its relocated position occurred in early 2016, placing sediment along the southern end of Figure 8 Island (USACE 2016i). Kure Beach was scheduled for its next episode of federal beach fill placement in 2016.

Several other sediment placement projects are scheduled to be constructed along North Carolina's oceanfront beaches in 2017 (Table 28). The Town of Duck has proposed to place ~1.416 mcy (1.083 million m^3) of sediment dredged from offshore along 1.7 miles (2.7 km) of beach (Town of Duck et al. 2016). The Town of Kitty Hawk has proposed to place ~2.118 mcy (1.619 million m^3) of sediment dredged from offshore along the town's entire 3.58 miles (5.76 km) of beach plus a taper into Southern Shores, for a total project area of 3.75 miles (6.04 km; Town of Kitty Hawk et al. 2016). The Town of Kill Devil Hills has proposed to place ~1.008 mcy (0.771 million m^3) of sediment dredged from offshore along 2.57 miles (4.14 km) of beach, contiguous with the sediment placement area in Kitty Hawk (Town of Kill Devil Hills et al. 2016). Dare County would construct all three projects concurrently on behalf of the three communities, with construction scheduled in 2017 (Town of Kitty Hawk et al. 2016). Only a fraction of the 8.02 mile (12.91 km) project area has previously been modified, with an unknown length of sandy beach in Kitty Hawk and Kill Devil Hills previously modified by sediment placement; no sandy beach habitat is known to have previously been modified by sediment placement in Duck (Rice 2012b).

Table 28. Several sediment placement projects were constructed in North Carolina in 2016 or scheduled for construction in 2017. The projects known to have been constructed or scheduled for construction after 2015 are listed in geographical order from north to south.

Community	Project	Construction Date	Project Length (ft)	New Length of Sandy Beach Habitat Modified by Project (ft)
Duck	Town of Duck Shoreline Protection Project	2017	8,970	8,970
Kitty Hawk[1]	Town of Kitty Hawk Shoreline Protection Project	2017	19,774	19,774
Kill Devil Hills[1]	Town of Kill Devil Hills Shoreline Protection Project	2017	13,552	13,552
Buxton	Beach Restoration to Protect NC 12	2017	15,500	5,980
North Topsail Beach	Onslow County Navigation Project	2016	13,200	5,465
Figure 8 Island	Mason Inlet Relocation Project	2016	10,000	0
Kure Beach	Kure Beach Coastal Storm Damage Reduction (CSDR) Project	2016	18,000	0
Holden Beach	Holden Beach Central Reach Project	2017	21,433	0
		TOTALS	**120,429**	**53,741**

1 – Both Kitty Hawk and Kill Devil Hills placed sediment along an unknown length of each town's respective beaches in 2004 (NC DENR 2011).

Dare County also plans to construct a sediment placement project along 2.9 miles (14.7 km) of beach in Buxton to protect NC 12, including a portion of Cape Hatteras NS, in 2017. Up to 2.6 mcy (2.0 million m^3) of sediment dredged from offshore will be placed on the beach from the groin at the Cape Hatteras Lighthouse north to the area known as "The Haulover" along NC 12 (NPS 2016). Up to 1.5 miles (2.4 km) of the 2.9 mile (14.7 km) project area may have been modified by sediment placement historically (1966 to 1973).

The Town of Holden Beach initiated construction of a large sediment placement project along 4.1 miles (6.6 km) of beach in January 2017, anticipated to place ~1.31 mcy (1.00 million m^3) of sediment as part of the Holden Beach Central Reach Project (Town of Holden Beach 2017, Walsh 2016). Altogether, in 2016 and 2017 at least 120,429 ft (36,707 m), or 22.8 miles (36.7 km) of sandy beach habitat in North Carolina will receive sediment placement; approximately 10

Table 29. Several sediment placement projects have been proposed but not scheduled for construction in North Carolina as of 2016. The projects are listed in geographical order from north to south. Both the proposed (potential) project length and the length of sandy beach habitat that would be newly modified by the project, if constructed, are listed.

Location(s)	Project	Project Length (ft)[1]	New Length of Sandy Beach Habitat Modified by Project (ft)
Southern Shores	Extension of Town of Kitty Hawk Shoreline Protection Project	1,500	1,500
Kitty Hawk, Kill Devil Hills, Nags Head	Dare County Beaches (Bodie Island Portion) Hurricane and Storm Damage Reduction Project	75,240	1,300
Hatteras and Ocracoke Islands	Dare County Beaches (Hatteras and Ocracoke Islands) CSDR Project	Up to 52,800	Up to 52,800
Atlantic Beach, Pine Knoll Shores, Indian Beach, Salter Path, Emerald Isle	Bogue Banks CSDR Project	121,670	6,670
North Topsail Beach	North Topsail Beach Shoreline Protection Project, Phase 2	10,120	6,670
North Topsail Beach	North Topsail Beach Shoreline Protection Project, Phase 4	6,880	6,880
North Topsail Beach	North Topsail Beach Shoreline Protection Project, Phase 3	11,500	11,500
North Topsail Beach	North Topsail Beach Shoreline Protection Project, Phase 5 (authorized but not constructed area)	1,840	1,840
Surf City, North Topsail Beach	Surf City and North Topsail Beach CSDR Project	52,150	32,860
Topsail Beach	West Onslow Beach and New River Inlet (Topsail Beach) CSDR Project	26,200	0
Figure 8 Island	Figure Eight Island Shoreline Management Project	4,500	790
Wrightsville Beach	Mason Inlet Relocation Project South (authorized but not constructed area)	10,000	4,310
Holden Beach	Holden Beach East End Shore Protection Project	4,000	675
Ocean Isle Beach	Ocean Isle Beach Shoreline Protection Project	3,214	0
Ocean Isle Beach	Ocean Isle Beach West Shoreline Protection Project	7,000	7,000

Location(s)	Project	Project Length (ft)[1]	New Length of Sandy Beach Habitat Modified by Project (ft)
Caswell Beach, Oak Island, Holden Beach, Ocean Isle Beach	Brunswick County Beaches CSDR Project	Up to 158,400	Up to 46,185
Emerald Isle, Topsail Beach, Carolina Beach, Holden Beach, Ocean Isle Beach	Shallow Draft Inlets (SDI)-5 Projects[2]	Up to 105,100	Up to 10,160
	TOTALS	**Up to 650,214 ft**	**Up to 186,230 ft**[†]

1 – Some project areas overlap. Overlapping project areas are not deducted in this column. See the far right column for the length of the overall proposed project area that would place sediment along new beach segments.

2 – The Emerald Isle SDI-5 sediment placement area includes oceanfront (30,800 ft) and inlet (1,900 ft) shoreline. The 1,900 ft inlet shoreline was deducted when calculating the total proposed project length because this assessment includes only oceanfront sandy beach habitat.

† – Overlapping proposed project areas total 1,630 ft on North Topsail Beach, 320 ft at Ocean Isle Beach and 2,960 ft at two of the five proposed SDI-5 sediment placement areas, both of which are deducted from the total.

miles (16 km) of that habitat has not previously been modified by sediment placement (Table 28).

Several other sediment placement projects have been proposed recently for North Carolina's oceanfront beaches but are not currently scheduled for construction (Table 29). The Town of Southern Shores has proposed to extend the Town of Kitty Hawk Shoreline Protection Project an additional 1,500 ft (457 m) north in Southern Shores, none of which has previously been modified by sediment placement (Kathy Matthews, USFWS, pers. communication, January 25, 2017). The USACE proposed to construct a sediment placement project in the communities of Kitty Hawk, Kill Devil Hills and Nags Head in 2000, known as the Dare County Beaches (Bodie Island) Hurricane and Storm Damage Reduction Project. An anticipated 12.34 mcy (9.43 million m^3) of sediment would be dredged from offshore and placed along ~14.2 miles (~22.9 km), which overlaps the local-sponsored projects in Nags Head (2010-11), Kitty Hawk (2017) and Kill Devil Hills (2017); if constructed, approximately 0.25 miles (0.40 km) of the federal project area would modify sandy beach habitat that had not previously been modified by sediment placement (USACE 2000).

The Town of Nags Head has initiated planning the next sediment placement episode within the town, which may be as early as late 2018; the Town previously placed 4.6 mcy (3.5 million m^3) of sediment along 10 miles (16 km) of shoreline in 2010-11. Ongoing federal beach fill projects anticipate placing sediment on Wrightsville Beach in FY2018.

On Hatteras and Ocracoke Islands, the USACE has proposed to construct a coastal storm damage reduction project(s) to address erosional "hot spots" in Dare County, known as the Dare County Beaches (Hatteras and Ocracoke Islands) Coastal Storm Damage Reduction (CSDR) Project. Up to 10 miles (16 km) of sandy beach habitat, most of it already modified by previous and on-going sediment placement activities, could be proposed for a 50-year federally maintained sediment placement project(s) using sediment from offshore sources (USACE 2014s). The NC DOT is also considering both short- and long-term options to protect NC 12 on Hatteras Island, and some options under consideration include sediment placement (beach nourishment) along sections of the island (NC DOT 2015c, 2016).

The Bogue Banks CSDR Project was proposed by the USACE in 2013 and would place sediment along 121,670 ft (111,255 m) of beach in Atlantic Beach, Pine Knoll Shores, Indian Beach, Salter Path and Emerald Isle. Initial sediment placement is anticipated to place 2.45 mcy (1.87 million m^3) of sediment from offshore on the beach and along 5.9 miles (9.5 km) of dunes. Sediment placement is anticipated to be needed every 3 years for the ~23 mile (~37 km) long project (USACE 2014t), the second longest[45] federal sediment placement project on the Atlantic coast from Maine to Florida (PSDS 2016). Only 6,670 ft (2,033 m) of the proposed Bogue Banks CSDR Project area, if constructed, has not previously been modified by sediment placement.

In 2013 the USACE proposed a CSDR project at North Topsail Beach and Surf City that would place 11.855 mcy (9.064 million m^3) of sediment along 52,150 ft (15,895 m) of beach (USACE 2010, 2013aa). The Towns of North Topsail Beach and Topsail Beach placed sediment along 19,290 ft (5,880 m) of the proposed federal project area in two locally-sponsored sediment placement projects in the three years following Hurricane Sandy (USFWS 2015d). If constructed, the federal CSDR project at North Topsail Beach and Surf City would modify 32,860 ft (10,016 m) of sandy beach habitat that has not previously been modified.

The Town of North Topsail Beach has proposed to place sediment along 11,500 ft (3,505 m) of beach as part of Phase 3 of their Shoreline Protection Project, using 394,000 to 560,000 cy (301,235 to 428,151 m^3) of sediment mined from New River inlet or offshore (USACE 2014t, Town of North Topsail Beach 2015b). Phases 2 and 4 of the Shoreline Protection Project would place sediment along the remaining sections of beach in North Topsail Beach, but are undergoing further project development due to environmental considerations for nearby hardbottoms; Phase 2 includes 10,120 ft (3,085 m) of beach and Phase 4 includes 6,880 ft (2,097 m) (Town of North Topsail Beach, http://www.ntbnc.org/Pages/ProposedProjects.aspx). Once complete, the entire developed beachfront of the community of North Topsail Beach will have been modified by sediment placement (with only the inlet shoreline not modified).

The USACE also proposed in 2013 a CSDR project at Topsail Beach, known as the West Onslow Beach and New River Inlet (Topsail Beach) CSDR Project. The proposed project would place sediment along 26,200 ft (7,986 m) of beach, spanning the entire developed beachfront in the community of Topsail Beach and transitioning into the southern end of Surf City to the north (USACE 2009, 2013aa). The Town of Topsail Beach placed sediment along 24,700 ft (7,529 m)

[45] According to PSDS (2016), the longest sediment placement project on the U.S. East Coast is at Myrtle Beach, which has a ~26 mile (~42 km) federal shore protection project.

of the proposed federal project area in a locally-sponsored sediment placement project in 2010-11 and again in 2015 (USACE 2013z, Town of North Topsail Beach 2015b). Another small portion of the proposed federal project area has previously been modified by dredged material placement by the USACE. If constructed, the federal CSDR project at Topsail Beach would modify ~1,250 ft (~381 m) of sandy beach habitat that has not previously been modified.

The Figure Eight Island Homeowners' Association has proposed to construct a terminal groin at Rich Inlet on the north end of the island; the proposed project includes two sediment placement areas, one on the bayside shoreline of Nixon Channel and the other along 4,500 ft (1,372 m) of oceanfront beach (USACE 2015s, 2016k). On the oceanfront, most of the proposed sediment placement area has previously been modified by sediment placement; approximately 790 ft (241 m) of sandy beach habitat would be newly modified by the proposed project.

In addition to the Holden Beach Central Reach Project under construction in 2017, the Town of Holden Beach has proposed to place between 100,000 and 150,000 cy (76,455 to 114,683 m^3) of sediment along 4,000 ft (1,219 m) of beach at the east end of the island as part of a shore protection project to construct a terminal groin (USACE 2015u, USFWS 2016a). Most of the proposed sediment placement area has previously been modified by sediment placement; approximately 675 ft (206 m) of sandy beach habitat would be newly modified by the proposed project.

The Town of Ocean Isle Beach also has proposed to construct a terminal groin (at Shallotte Inlet) with associated sediment placement. Approximately 264,000 cy (201,842 m^3) of sediment would be placed along 3,214 ft (980 m) of beach to the west of the terminal groin, if constructed (Town of Ocean Isle Beach 2015, USACE 2015q, USACE 2016l, USFWS 2015c). The Ocean Isle Beach West sediment placement project has also been proposed in Ocean Isle Beach. This project would place sediment along 7,000 ft (2,134 m) of beach immediately west of the federal beach fill project on the island (Town of Ocean Isle Beach 2015). None of the proposed sediment placement area has previously been modified by sediment placement. Altogether the Town of Ocean Isle Beach has proposed a 30-year beach nourishment program that would place sediment along a total of 27,650 ft (8,428 m) of beach, including the terminal groin sediment placement, federal CSDR project area, dredged material placement area, and Ocean Isle Beach West sediment placement project; sediment mined from Shallotte Inlet would be placed on the beach every 5 years (Kathy Matthews, USFWS, pers. communication, January 25, 2017).

The USACE has proposed to construct a coastal storm damage reduction project in the communities of Caswell Beach, Oak Island, Holden Beach and Ocean Isle Beach in Brunswick County, known as the Brunswick County Beaches CSDR Project. Up to 30 miles (48 km) of sandy beach habitat, most of it already modified by previous and on-going sediment placement activities, could be proposed for a 50-year federally maintained sediment placement project using sediment from offshore sources (USACE 2014s).

Sediment dredged from Beaufort Inlet will continue to be placed at Fort Macon SP on Bogue Banks to the west, but has also been proposed for placement on or in the nearshore of Shackleford Banks, part of Cape Lookout NS, to the east as part of a draft Dredged Material Management Plan for the inlet (USACE 2013bb). After initially requesting to be considered for dredged material placement, the NPS withdrew consideration for sediment placement on Shackleford Banks and nearshore waters (Schupp et al. 2015).

Finally, in 2016 New Hanover County and the Towns of Emerald Isle, Topsail Beach, Holden Beach and Ocean Isle Beach proposed and requested authority to dredge federal navigation channels within the AIWW and inlets at 5 locations, collectively known as the Shallow Draft Inlets (SDI)-5 Projects (USFWS 2016e). The SDI-5 Projects would allow the 4 towns and 1 county to dredge channels that have been maintained by the USACE, and place the dredged material along oceanfront beaches.

The Town of Emerald Isle periodically would dredge the AIWW and channels associated with Bogue Inlet and place the dredged material along up to 32,700 ft (9,967 m) of oceanfront and inlet beach. The Town of Topsail Beach would periodically dredge the AIWW and channels associated with New Topsail Inlet and place the dredged material along up to 23,900 ft (7,285 m) of beach, which encompasses the entire developed beachfront of the community. New Hanover County would periodically dredge the AIWW and Carolina Beach Inlet and place the sediment along up to 4,900 ft (1,494 m) of beach at Freeman Park at the north end of Carolina Beach. The Town of Holden Beach would periodically dredge the AIWW and Lockwoods Folly Inlet and place the dredged material along up to 23,700 ft (7,224 m) of beach, all of which has already been modified by sediment placement. And the Town of Ocean Isle Beach periodically would dredge the AIWW and Shallotte Inlet, placing the sediment along up to 19,900 ft (6,066 m) of beach. Altogether the SDI-5 Projects are authorized to place sediment along 105,100 ft (32,034 m) of sandy beach habitat, although typical sediment placement would occur along only 13,400 ft (4,084 m) of beach (USFWS 2016e). Up to 10,160 ft (3,097 m) of the authorized sediment placement areas would be newly modified by the proposed sediment placement projects, 2,960 ft (902 m) of which has also been proposed for sediment placement in other projects.

The USACE conducted a statewide cumulative impacts assessment for sediment placement projects in North Carolina as part of the development of the Surf City and North Topsail Beach CSDR (Appendix J in USACE 2010) and Bogue Banks CSDR Projects (Appendix I in USACE 2014s). This cumulative impacts assessment also has been incorporated into the environmental analyses for the proposed Figure 8 Island Shoreline Management Project (USACE 2016k). The USACE (2014s) cumulative impacts assessment found that ~93 miles (~150 km) of beach had been modified by existing sediment placement activities and up to 131 miles (211 km) could be impacted by existing or proposed sediment placement projects in North Carolina, modifying 41% of the state's beaches. The USACE (2014s) cumulative impacts assessment included sediment placement projects anticipated to occur through 2015, but the assessment was completed prior to the construction of or proposals for the Town of Duck Shoreline Protection Project, Town of Kitty Hawk Shoreline Protection Project, the Beach Restoration to Protect NC 12 Project in Buxton, and the Figure Eight Island Shoreline Management Project to construct a terminal groin, which were not included in the USACE assessment; nor were the sediment placement project lengths known at the time for the terminal groin projects proposed on Bald Head Island, Holden Beach, and Ocean Isle Beach.

In summary, at least 100.97 miles (162.50 km) of North Carolina sandy beach habitat had been modified by sediment placement as of 2015. In 2016 and 2017, an additional 10.18 miles (16.38

km) of sandy beach habitat that has not previously been modified by sediment placement will have been modified (Table 28). Altogether, a total of 111.15 miles (178.88 km), or 34%, of sandy beach habitat will have been modified by sediment placement as of 2017. Up to another 35.27 miles (56.76 km) of new sandy beach habitat have been proposed for sediment placement (Table 29). A total of 45% of the sandy beach habitat (146.42 miles, or 235.64 km) in North Carolina will soon have been modified or has been proposed to be modified by sediment placement.

Beach Scraping Modifications

In the three years after Hurricane Sandy, beach scraping along the North Carolina oceanfront to, totaled more than 4.84 miles (7.79 km) of sandy beach in 11 out of the state's 37 coastal communities (Table N-5). No evidence of beach scraping was visible in USGS aerial photography taken in North Carolina after Hurricane Joaquin in October 2015. Sandy beach habitat in the communities of Kure Beach (18%), Southern Shores (11%), Corolla (10%), and Kitty Hawk (10%) were the most modified by beach scraping between 2012 and early 2016. Beach scraping also modified sandy beach habitat on Figure Eight Island (>6%), North Topsail Beach (5%) and Surf City (>5%). Sandy beach habitat was also modified by beach scraping in Atlantic Beach, Rodanthe, Kill Devil Hills and Duck, with up to 1% of each community's sandy beach habitat modified between 2012 and early 2016. The Town of Kill Devil Hills does not have a municipal beach scraping program or project, but individual private property owners have occasionally used beach scraping to create artificial dunes following storms (Town of Kill Devil Hills et al. 2016). The majority of Figure Eight Island's developed beachfront was modified by beach scraping in 2015 (where scraping also occurred in 1987, 1990, 1994, 1996, 1998, 2000 and 2001); the precise length of sandy beach modified was not available, however (USACE 2016k). The Town of Surf City regularly scrapes its oceanfront beaches as well (USFWS 2016e).

The presence of large, federal and local beach fill projects that maintain artificial dunes in recent years likely contributes to the relative lack of beach scraping along developed beachfront in North Carolina between 2012 and 2015. Historically beach scraping was more widespread. At least one community has prohibited the use of beach scraping to create or maintain artificial dunes. Beach scraping is prohibited in the Town of Nags Head, but sand that has accumulated on the landward side of the dune (typically within 6 ft or 1.8 m of structures) may be relocated back to the seaward side of the dune (Town of Nags Head 2016). Overall at least 2% of the North Carolina oceanfront beaches were modified by beach scraping in the three years after Hurricane Sandy.

Proposed and Anticipated Habitat Modifications

Beach scraping is not uncommon on North Carolina's developed beachfronts following major storm events. The Town of Oak Island periodically scrapes the beach along 47,000 ft (14,326 m) of beach (USFWS 2015a), although none was observed in aerial imagery in the three years after Hurricane Sandy. Similarly, the Town of Surf City has a municipal beach scraping program that scrapes up to 6.1 miles (9.8 km) of beach (USFWS 2015d). The NC DOT often scrapes overwash material off of roadways like NC 12 back to the beach to create artificial dunes, but rarely scrapes the beach to do so. Thus it is reasonable to assume that beach scraping will continue to occur after future storms and will remain a localized threat to the state's sandy beach habitat.

Hurricane Matthew affected the North Carolina coast in October 2016, flooding large regions inland and eroding many beaches. Vegetated dune systems were eroded and lost in some communities, such as areas along East Beach Drive in Oak Island. As a result, some communities may use beach scraping to reconstruct dunes following the October 2016 storm. The Town of North Topsail Beach, for example, approved municipal beach scraping to be conducted in February and March 2017 along up to 29,031 ft (8,849 m) of beach following Hurricane Matthew (Town of North Topsail Beach, http://www.ntbnc.org/Pages/DunePush2016.aspx).

Sand Fencing Modifications

Sand fencing is a significant threat to sandy beach habitat along the developed beachfront of North Carolina's coast. Between 2012 and early 2016, 62.69 miles (100.89 km), or 19%, of sandy beach habitat in North Carolina was modified by sand fencing (Table N-6). Sand fencing modified more than 50% of the sandy beach habitat in 6 communities: Pine Knoll Shores (97%), Kill Devil Hills (67%), Atlantic Beach (64%), Southern Shores (63%), Corolla (53%) and Nags Head (53%). In 14 other coastal communities, between 20 and 50% of the sandy beach habitat was modified by sand fencing between 2012 and early 2016. A total of 1,199 contiguous sections of sand fencing (as defined in the Methods section) were identified on North Carolina's oceanfront beaches in the three years after Hurricane Sandy; only New Jersey had more contiguous sections of sand fencing (1,305), but had a slightly lower total length of sandy beach modified by fencing (60.26 miles, or 96.98 km).

No sand fencing was identified within only 8 of the 37 coastal communities in North Carolina during the three years after Hurricane Sandy: Salvo, Ocracoke, Cape Lookout NS, Hammocks Beach SP (Swansboro Twp.), Lea-Hutaff Island (Topsail Twp.), Masonboro Island, Federal Point Twp. (Fort Fisher State Recreation Area and Zeke's Island Reserve), and Sunset Beach. Only 2 of these 8 communities are developed communities not in public or NGO ownership (Salvo and Sunset Beach).

Numerous sections of sand fencing identified along the North Carolina coast from 2012 to early 2016 were older sections within vegetated dunes, indicating that sand fencing is a persistent threat to sandy beach habitat that is not removed as the fencing traps sand and becomes covered in vegetation. Although sand fencing modified only 19% of the total oceanfront beach length in North Carolina during the three years after Hurricane Sandy, more sandy beach habitat (62.69 miles or 100.89 km) has been modified by sand fencing in North Carolina than in any other state within the U.S. Atlantic Coast breeding range of the piping plover (Table 7). Furthermore, the many large sediment placement projects anticipated to be constructed within the next few years are likely to include installation of new sand fencing, increasing effects of sand fencing on sandy beach habitat in North Carolina in the future.

Summary

North Carolina's sandy beach habitat is significantly threatened by sediment placement (31 - 45%), development (41%) and sand fencing (19%) as of 2015. Beach scraping (> 2%) is a localized threat to the state's sandy beach habitat, localized to developed communities along the oceanfront shoreline. Armor has historically been a minor threat (3%) but has increased as a localized threat with recent changes to the state's policy allowing more hard shoreline stabilization structures[46].

Sediment placement had modified more than half (50%) of the sandy beach habitat in 18 of North Carolina's 37 coastal communities as of 2015. By the end of 2017, after sediment placement projects scheduled for construction in 2016 and 2017 are completed, two more communities will have more than 50% of their sandy beach habitat modified by sediment placement.

Within the U.S. Atlantic Coast breeding range of the piping plover, significantly more beach habitat (100.97 miles or 162.50 km) had been modified by sediment placement in North Carolina as of 2015 than in any other state (Table 5), a length that is anticipated to increase by 10% (10.18 miles or 16.38 km) by the end of 2017 with projects scheduled for construction in 2016 and 2017. In 2015, more than 75% of the sandy beach habitat in the 11 communities of Pine Knoll Shores, Indian Beach, Salter Path, Emerald Isle, Topsail Beach, Figure Eight Island, Wrightsville Beach, Carolina Beach, Kure Beach, Caswell Beach, and Oak Island had been modified by sediment placement; 100% of the beach habitat in Frisco is authorized to be modified by sediment placement, but is not likely to have fully been modified as of 2015.

North Carolina also has more sandy beach habitat modified by sand fencing (62.69 miles or 100.89 km) than any other state within the U.S. Atlantic Coast breeding range of the piping plover (Table 7). More sandy beachfront is within public or NGO ownership in North Carolina than every other state in the breeding range except for Massachusetts (Table 2). Nearly 180 miles (290 km), or 56%, of the beachfront in the state is within public or NGO ownership, much of it within National Wildlife Refuges, National Seashores, and state lands.

DISCUSSION

Sand beach ecosystems are threatened by a number of human activities, including development, armor, dredging, sediment placement projects, invasive vegetation, pollution, beach grooming, recreation, ORV, beach mining, energy development, oil spills, military operations, climate change, and sea level rise (Defeo et al. 2009, National Marine Fisheries Service [NMFS] and USFWS 2009, NOAA 2015, USFWS 2012).

As of 2015, a substantial proportion of the sandy beaches within the U.S. Atlantic Coast breeding range of the piping plover had been developed (44%), armored (at least 27%), filled with sediment (at least 23%), fenced (14%), and scraped (4%). At least 90.88 miles (146.26 km) of

[46] The state of North Carolina is also revising the regulations regarding sandbag revetments, which may lead to increased impacts to sandy beach habitat.

sandy beach habitat was absent seaward of armoring in 2015. These habitat modifications tend to occur in the same locations as each other, resulting in adverse cumulative effects in those locations. When combined with the habitat modifications to the tidal inlets, significant cumulative loss and degradation of piping plover habitat has resulted (see Rice 2015d, 2016). In New Hampshire, for example, 100% of the inlets had been armored and/or dredged, 84% of the beachfront had been developed, 72% of the beach had been armored, at least 14% of the beaches had received sediment placement, and at least 2% of the beaches had been modified by beach scraping or sand fencing as of 2015. In New Jersey, all but one inlet had been armored and/or dredged, 64% of the beachfront had been developed, 62% of the beach had been armored, 61% of the beaches had received sediment placement, 47% of the beach had been modified by sand fencing, and at least 20% by recent beach scraping.

This habitat assessment did not include other forms of habitat modification, such as vegetation plantings, the maintenance and protection of coastal roads, and the alterations caused by driving ORVs on beaches and dunes. However, all of these activities occur throughout the assessment area and cumulatively they increase the adverse effects on habitats used by piping plovers and other wildlife that use sandy oceanfront beach habitat.

Development

"Intense coastal development, the inevitable consequence of economic progress, has resulted in widespread modification of sandy beach ecosystems" (Defeo et al. 2009, p. 1). In most cases, the presence of beachfront development leads to other human modifications of sandy beach habitat. The construction of beachfront armor, sediment placement projects, beach scraping and sand fencing are nearly always a result of efforts to protect coastal development, including roads. Sandy beach habitat that is undeveloped and roadless is rarely modified by armor, sediment placement, beach scraping or sand fencing. Notable locations within the U.S. Atlantic Coast breeding range of the piping plover that are not directly modified by any human activity other than passive recreation (which excludes the use of ORV and presence of feral horses) include Reid SP, the Bates-Morse Mountain Conservation Area and Little Chebeague Island SP in Maine; sections of Cape Cod NS (where ORV are not permitted) and all of Monomoy NWR in Massachusetts; sections of Bluff Point SP & Coastal Reserve and Cockenoe Island in Connecticut; Hither Woods Preserve, most of Hither Hills SP, Elizabeth A. Morton NWR, most of Gardiner's Island, and most of Mashomack Preserve on Shelter Island in New York; the Assawoman Island Unit of Chincoteague NWR, Metompkin Island, Cedar Island, Parramore Island, the Virginia Coast Reserve, Wreck Island, and Fishermans Island NWR in Virginia; and sections of Cape Lookout NS north of Cape Lookout (where ORVs are not permitted), Hammocks Beach SP, Brown's Island, and Lea-Hutaff Island in North Carolina. Some of these areas may be indirectly modified by adjacent human activities including dredging, however.

In the 1970s, the Heritage Conservation and Recreation Service (HCRS) evaluated how developed the barrier islands of the New England and Mid-Atlantic Coasts were (HRCS 1980 as cited in NJ DEP 1981). Although the HCRS analysis evaluated the acreage of barrier islands developed at the time, the data can serve as an approximate comparison to the level of beachfront development in 2015 (Table 30). Development increased in every state except Rhode Island

Table 30. Comparison of the levels of development modifying sandy beach habitat in the 1970s (HCRS 1980 as cited in NJ DEP 1981) and in 2015 from Maine to Virginia. Data from North Carolina were not available in HCRS (1980) as cited in NJ DEP (1981).

State	Development of Barrier Islands circa 1970s from HCRS (1980)	Development of Sandy Shoreline circa 2015
Maine	62%	65%
New Hampshire	63%	86%
Massachusetts	22%	41%
Rhode Island	37%	34%
Connecticut	28%	55%
New York	39%	44%
New Jersey	47%	65%
Delaware	29%	45%
Maryland	17%	29%
Virginia	2%	15%

over the 3 to 4 decades, indicating that development is a long-term and increasing threat to sandy beach ecosystems.

Development directly modifies sandy oceanfront beach habitat, leading to habitat loss, fragmentation and degradation. McCormick et al. (1984, p. 73) state that "From Long Beach [NY] west to the tip of Coney Island, unrestrained development has buried marsh, dunes and beach beneath a layer of pavement and buildings … The city of Long Beach is a remarkable example of the speed with which a natural barrier can be obliterated by development."

Mitteager et al. (2006, p. 890) describe how private oceanfront property owners in developed areas of New Jersey have modified the natural dune system and its vegetation, including how structures such as bulkheads, boardwalks and walls "interrupt the natural environmental gradient." They found that "The landward portions of natural dunes and their vegetation were eliminated in many municipalities to accommodate development. Dunes that are now seaward of buildings are truncated portions of natural dunes or, more commonly, new dunes created artificially using sand fences, vegetation plantings, or earth-moving equipment" (Mitteager et al. 2006, p. 890). "Dunes on private lots are generally lower and less mobile than municipally managed foredunes, and contain more shrubs than natural dunes would have at similar distances from the sea" (Mitteager et al. 2006, p. 890). Mitteager et al. (2006) provides recommendations on how to minimize some of the direct impacts of development on a local, lot-by-lot, basis.

In the *National Assessment of Shoreline Change: Historical Shoreline Change along the New England and Mid-Atlantic Coasts*, Hapke et al. (2010, p. 52) state that:

> *As coastal communities continue to grow along the New England and Mid-Atlantic coast, potential conflicts will continue to arise between preservation of property (typically privately owned) and conservation of the beach (typically*

publicly owned). Past social responses indicate that these conflicts will likely be resolved through a combination of beach nourishment projects and shoreline protection structures. Both of these engineering responses to erosion alter the natural beach processes and eventually lead to artificial shoreline positions. … Many beaches are already altered by shoreline protection projects and more are likely to be altered in the future.

As of 2015, more than 775 miles (1,247 km), or 45%, of sandy shoreline had been modified by beachfront development from Maine to North Carolina. Many oceanfront communities in the U.S. Atlantic Coast breeding range of the piping plover have 100% development along their oceanfronts (Rice 2015d). Even more have more than 75% of their beachfront modified by development. In numerous communities, the developable beachfront is nearly "built out," or fully developed with very few, if any, vacant lots in private ownership. Although beachfront development has been a persistent and increasing threat for decades, there is a physical limit to how much of the oceanfront can be developed. Assuming that beachfront lands in public or NGO ownership remain so, all private beachfront land may be fully developed at some point in the future and the only significant undeveloped beaches will be in public or NGO ownership. As development continues to modify sandy beach ecosystems, the threat of habitat modification from armor, sediment placement, beach scraping and sand fencing will also persist and likely increase as climate changes and sea level rises.

Armor

The impacts of shoreline armoring can be adverse, far-reaching and long-term. The impacts of hard stabilization structures on oceanfront beaches have been described by McCormick et al. (1984), Pilkey and Wright (1988), Terchunian (1988), Weggel (1988), Ward et al. (1989), Hall and Pilkey (1991), Bush et al. (1996), USACE (2002), NRC (2014) and many others. Shore-parallel structures such as seawalls, bulkheads and revetments often lead to the loss of the beach in front of the seawall (McCormick et al. 1984, Pilkey and Wright 1988, Hall and Pilkey 1991, Bush et al. 1996, USACE 2002, Hapke et al. 2010, NRC 2014). In both 2012 and 2015, significant beach losses were identified seaward of seawalls, bulkheads and revetments in the U.S. Atlantic Coast breeding range of the piping plover, with ~91 miles (~146 km) of beach completely absent seaward of armor in 2015. Ward et al. (1989, p. 59) state that "In most settings, if a beach is desired in front of a wall, it most likely will have to be nourished from time to time, as the wall cuts off the immediate sand source for the beach."

Tanski (2012, p. 21) states that while shore parallel structures like seawalls, bulkheads and revetments may not have adverse impacts on natural beach processes in areas where the shoreline is accreting or stable in the long-term and the sediment supply is adequate, in areas where there is a sediment deficit and chronic erosion, "armoring the shoreline can adversely affect the beach and adjacent areas unless other measures are also taken to mitigate their impacts. These measures might include bringing in additional sand to make up for the sand impounded or retained by the structure. … [S]hore armoring structures usually lead to a narrowing of loss of the beach … because they prevent the beach from migrating landward." When the shore parallel structure is eventually flanked by a receding shoreline on either side, the wall structure then protrudes onto the beach and can act as a groin and cause downdrift erosion by blocking sediment transport along the beach (Tanski 2012).

"The New Jersey shoreline, in many places stabilized for longer than a century, provides evidence of the degradational effect of hard stabilization on recreational beaches. The impact is apparent whether structures involved are shore parallel or shore perpendicular. On the other hand, there are a number of areas where no beach would exist at all if it were not for sand retention behind groins or jetties" (Hall and Pilkey 1991, p. 782). In their New Jersey study, Hall and Pilkey (1991, p. 782) concluded that:

> *For the open ocean coast of New Jersey, the dry beach width is narrower on beaches stabilized by hard structures compared to unstructured beaches. The width of dry beach also appears to be a function of the density of hard stabilization: the greater the density of stabilizing structures, the narrower the beach. Dry beaches with seawalls, bulkheads, and revetments are the narrowest. Groins are also present on most of these seawalled beaches. Due to simultaneous occurrences of both types of structures, we were not able to separate the effects of shore parallel from shore perpendicular structures, it is interesting to note that approximately 51% of areas that are seawalled have no beach, except in a few cases where groins have trapped sand on the updrift side.*

It should be noted that the Hall and Pilkey (1991) findings predate the large scale beach fill projects on the New Jersey shore, which reconstructed beaches in the most of the areas they surveyed. Pilkey and Wright (1988, p. 41) also found that "dry beach width is consistently and significantly narrower in front of walls. The more dense the hard stabilization, the narrower the beach."

McCormick et al. (1984) describes a process they call the "New Jerseyization" of beaches, where shoreline armoring leads to more and larger armoring until eventually the shoreline is lined with armored structures with no beaches or only small pockets of beaches on the updrift sides of groins. "Each groin, each seawall, each revetment reduces the sand supply, which results in increased shoreline erosion somewhere else in the system" (McCormick et al. 1984, p. 31). McCormick et al. (1984, p. 38) list a series of "Truths of the Beach," one of which is "Shoreline engineering destroys the beach it was intended to save."

Weggel (1988, p. 32) states that "It is clear that the shoreline at Seabright [sic] would today be significantly different if the seawall had not been built. It would undoubtedly be located much further landward and the existing houses and roadway would long ago have been destroyed … [but] it can be deemed a success from an engineering viewpoint" since the wall's purpose was to protect buildings and the roadway. "By halting erosion at Seabright [sic], the wall has reduced the supply of sediment reaching Sandy Hook and caused erosion there" (Weggel 1988, p. 33). This finding was made prior to the massive beach fill project, which constructed a new beach in front of the seawall in 1995.

Terchunian (1988, p. 65) characterizes the coastal armoring issue by stating "On a chronically eroding shoreline, coastal armoring structures may lead to degradation of the beach/dune system in front of and adjacent to these structures resulting in a loss of both the recreational and natural protective values of the beaches and dunes." Terchunian (1988, p. 65) outlines a process for calculating "the amount of beach sand which would be required to mitigate the potential adverse impacts of the coastal armoring structures," thereby allowing for beach fill requirements to be estimated in advance to offset the erosion impacts of the structures.

Many seawalls, bulkheads and revetments in New York and New Jersey are a century old, as noted by Hall and Pilkey (1991) and Dallas et al. (2013), clearly documenting that the impacts of shore-parallel armoring structures can be long-term. In more recent decades, sediment placement projects have been undertaken to reconstruct lost beaches in front of these walls. Large scale sediment placement projects modify sandy, oceanfront beaches as well as those downdrift from the individual project areas. Beck and Kraus (2010), for example, describe how the stabilization, dredging and geologic setting of Shark River Inlet, NJ, precluded the inlet from having an ebb tidal delta until adjacent beaches began to receive beach fill in 1997 (beaches to the south) and 2000 (beaches to the north). This led to the formation of an ebb tidal delta in the early 2000s, which has formed a sediment transport pathway around the dual jetties at the inlet. The beach fill altered the system from sediment-starved to one in which shoaling has increased maintenance dredging needs at the inlet. The authors predict that it will take more than a decade for the ebb tidal delta to reach equilibrium, noting that the periodic dredging with mechanical bypassing to the beaches to the north interrupts the delta's evolution. Thus the beach fill project generated positive and negative downdrift impacts – positive in that sediment transport is being restored at a stabilized inlet and restoring adjacent habitats, negative in the increased dredging needs and their concomitant habitat disturbances.

Armoring structures that are built perpendicular to the beach, namely groins and jetties, also adversely impact sandy, oceanfront beaches. Groins cause downdrift erosion (McCormick et al. 1984, Ward et al. 1989, USACE 2002, Rankin et al. 2004). This invariably results in groins being constructed in fields, where the downdrift impact can be shifted farther down the beach. Tanski (2012, p. 20) discusses the impacts of groins, stating that "The magnitude of the impact increases as the length and height of the [groin] structure and the rate of longshore transport increase. To help minimize adverse impacts of these structures, sand should be placed on the … updrift side of the [groin] structure to create a protective beach. This helps minimize the disruption of the flow of sand along the coast (but does not necessarily eliminate all the impacts)." McCormick et al. (1984) and Rankin et al. (2004) also describe how the larger a groin is, the greater the downdrift erosion impacts.

Rankin et al. (2004, p. 237) states that "Unacceptable erosion of the downdrift beaches can occur if the groins are sufficiently long so that alongshore-moving sediment cannot bypass the structure. Attempts have been made to reduce the erosion in the lee of a groin by shortening, notching, or removing the entire groin to increase the bypassing of sand to downdrift beaches." The USACE *Coastal Engineering Manual* (USACE 2002, pp. V-3-59 to V-3-78) describes the downdrift impact of groins and states that even when filled with beach fill, groins will still cause some amount of downdrift erosion.

Ward et al. (1989) recommend that if groins are constructed, they should be low-profile; that is, the groins are highest in elevation on land and their height tapers lower as you move offshore. In this way, longshore sediment transport can be less interrupted after the groin cell is roughly half full, decreasing downdrift erosion impacts.

Another recent method to reduce the downdrift impacts of groins is to notch them. Donohue et al. (2004) and Rankin et al. (2004) monitored the effectiveness of notching 35 groins that were located within the Sandy Hook to Barnegat Inlet Beach Erosion Control Project, Section 1 – Sea Bright to Ocean Township, New Jersey. The New York District of the USACE notched groins that were identified as too long and potentially deleterious to the massive fill project along 8.56 miles of shoreline. The groins were notched in order to minimize their downdrift erosional impacts and increase the groins' ability to allow sediment to move downdrift. The monitoring concluded that notching can be effective in bypassing sediment depending on the location and design of the notches.

In 2015, beachfront armor modified sandy beach habitat in every state from Maine to North Carolina (Table 3 & Table 4). More than 476 miles (766 km) of sandy shoreline had been modified by armor, with up to 5,145 groins, 235 jetties, 96 breakwaters, and 2,886 contiguous sections of bulkheads, seawalls and/or revetments. Even with states like Rhode Island and North Carolina that prohibit most beachfront armor, structures constructed prior to those coastal policies remain in place and continue to modify sandy beach habitat.

Seven of the 11 states in the U.S. Atlantic Coast breeding range of the piping plover allow the construction of new hard shoreline stabilization structures on oceanfront or soundfront beaches, and two others (Maine and North Carolina) allow sandbags that act as revetments (Table 31). North Carolina also passed legislation allowing the construction of up to 6 terminal groins recently. Connecticut revised its regulations in 2012 to allow more buildings to potentially construct seawalls and other hard structures, updating the building construction date from 1980 to 1995 where erosion control structures could be installed. As a result, future additional habitat modifications due to shoreline armoring threatens all three recovery units and may pose an increasing threat in the future as state regulators face increasing pressure to allow more armoring as sea level rises.

Sediment Placement

Long-term trends show that the number of beach nourishment projects is increasing in virtually every state (Trembanis et al. 1998, Bush et al. 2004, USFWS 2009), resulting in an increasing magnitude of habitat modification. This long-term trend held true during the short-term as well. In the three years after Hurricane Sandy, the length of sandy beach habitat modified by sediment placement projects increased by ~50 miles (~80 km) within the U.S. Atlantic Coast breeding range of the piping plover. As of 2015, nearly 399 miles (642 km) of sandy shoreline from Maine to North Carolina had been modified by sediment placement and another ~76 miles (122 km) or more had been proposed for sediment placement (Table 5).

Table 31. Regulations regarding the construction and maintenance of hard shoreline stabilization structures on sandy beaches in the U.S. Atlantic Coast breeding range vary by state and are listed here.

State	New Hard Shoreline Stabilization Structures Allowed?
ME	• NO new structures since 1983 • Sandbags or riprap may be allowed in emergency situations • Maintenance or repair of existing structures with <50% damage does not require a permit
NH	• YES with conditions
MA	• POSSIBLE with conditions[1]
RI	• NO for Type 1 Waters (all oceanfront beaches) • POSSIBLE with conditions for other Type Waters • Repair of existing structures allowed by permit if >50% damaged
CT	• NO for buildings constructed after 1995 • Nonstructural methods preferred, including dune creation and sandbags • New rules in 2012 modified the regulations[2]
NY	• YES if designed to have at least a 30-year effective lifespan • Nonstructural methods preferred
NJ	• YES with conditions • Nonstructural methods preferred
DE	• YES with conditions • Nonstructural methods preferred, including beach fill
MD	• YES with conditions • Nonstructural methods and "living shorelines" preferred
VA	• POSSIBLE – regulations are local • State-preferred "living shorelines" methods since 2011
NC	• NO new structures since 1974 with the exception of up to 6 terminal groins allowed since 2011 • Temporary sandbag revetments allowed[3]

1 - The Massachusetts Wetlands Protection Act contains specific conditions under which erosion control structures may be considered and generally prohibits groins in areas designated "barrier beaches," limits jetties to those areas with existing navigation channels, and has performance standards for seawalls, revetments and bulkheads that may prevent their approval in many areas (MA Barrier Beach Task Force 1994). Shoreline stabilization structures may be approved by local permits for buildings constructed prior to August 1978 along coastal banks or bluffs if the shoreline stabilization structures are the only feasible means of protection and if adverse impacts to adjacent and downdrift beaches such as reduced sediment supply are minimized (O'Connell and Leatherman 1999, O'Connell 2010).

2 - In 2012 Connecticut modified its regulations to define less environmentally damaging preferred alternatives, including relocation, elevation of structures, dune creation and/or vegetation, and "living shorelines" methods; buildings constructed prior to 1995 are now allowed to construct hard shoreline stabilization structures with conditions, including mitigation such as beach fill intended to offset anticipated sediment source losses and to have no net increase in armoring (i.e., removal of other erosion control structures).

3 – The regulations for sandbag revetments were under revision in 2016, potentially extending the period of time and conditions under which they are allowed to be constructed and maintained.

NRC (2014, p. 90) concluded that "Beach nourishment can have both positive and negative effects on environmental resources, but negative effects dominate in the short term." Sediment placement buries invertebrates living in the sand, resulting in immediate mass mortality and a loss of ecosystem function (Peterson et al. 2006, NRC 2014). Recovery of the invertebrate fauna may take 1 to 2 years, but can be significantly longer if the newly placed sediment is incompatible with the native sediment (NRC 2014). The long-term ecological impacts of sediment placement projects are uncertain and hindered by inadequate monitoring and sampling designs (Peterson and Bishop 2005).

Prior to Hurricane Sandy in October 2012, the Ash Wednesday Storm of 1962 was the most damaging storm to affect the New York to Virginia shoreline. Following the storm, the USACE undertook "Operation Five-High," named after the five high tides that the storm lasted. Emergency projects to reconstruct dunes and beaches and fill in storm breaches were undertaken in the five states of NY, NJ, DE, MD and VA (USACE 1963). In New York, approximately 23 miles (37 km) of shoreline received sediment to rebuild dunes and beaches (Table 30; USACE 1963, Coburn et al. 2010, USACE New York District website). In New Jersey, approximately 20 miles (32 km) of artificial dunes were constructed in 1962 (USACE 1999) and well more than 23 miles (37 km) of beaches received fill material in 1962 and 1963, much of it overlapping the dune construction project areas (PSDS 2016). In Delaware, 12.59 miles (20.26 km) of beaches and dunes were constructed (PSDS 2016). In Maryland, two storm breaches on Assateague Island were closed and 8.00 miles (12.87 km) of beach and dune were constructed in Ocean City (PSDS 2016). In Virginia, a storm breach on Wallops Island was closed (King et al. 2010) and 5.60 miles (9.01 km) of beaches and dunes were constructed by Operation Five-High; additional dune reconstruction took place along ~21.8 miles (35.08 km) of Assateague Island in MD and VA (PSDS 2016). The emergency response to the Ash Wednesday Storm of 1962 placed sediment along a total of more than 143.54 miles (231.01 km) of shoreline in these five states.

After Hurricane Sandy, a total of 165.09 miles (265.69 km) of sediment placement took place within the same five state area (Table 32). The USACE placed 26.272 mcy (20.086 million m^3) of sediment along beaches from Rhode Island to Virginia after Hurricane Sandy (USACE 2014u). The length of sandy beach habitat modified by sediment placement in response to Hurricane Sandy was significantly greater along the South Shore of Long Island than after the Ash Wednesday Storm of 1962, more than doubling. Likewise, the length of sandy beach habitat in New Jersey modified by emergency response to Hurricane Sandy was more than 1.5 times higher than the Operation Five-High response to the Ash Wednesday Storm of 1962. In Delaware, Maryland and Virginia, the length of sandy beach habitat modified in the three years following Hurricane Sandy was significantly less than during the three years after the Ash Wednesday Storm of 1962 – cut nearly in half in Delaware and Maryland. The reductions in Maryland and Virginia were primarily due to the lack of dune reconstruction along Assateague Island within Assateague Island NS and Chincoteague NWR, respectively, following Hurricane Sandy. Sandy beach habitat, therefore, appears to be significantly threatened by sediment placement projects constructed in response to major storm events.

Table 32. A comparison of the extent of sediment placement projects modifying sandy beach habitat in a number of states within the U.S. Atlantic Coast breeding range of the piping plover in the three years following the Ash Wednesday Storm of 1962 and Hurricane Sandy of 2012.

State	Length of Sediment Placement after Ash Wednesday Storm of 1962 (miles)	Length of Sediment Placement after Hurricane Sandy of 2012 (miles)
NY (Atlantic Ocean)	17.21	44.98
New Jersey	42.05	68.36
Delaware	14.18	7.65
Maryland	29.10	10.32
Virginia	19.90	12.68
TOTALS	**143.54**	**165.09**

Artificial dunes are often constructed to protect development along the oceanfront, including more than 72 miles (116 km) of beaches and dunes during the federal Operation Five-High following the Ash Wednesday Storm of 1962 alone. Artificial dunes were constructed along entire barrier islands in the 1950s and 1960s, including both the Maryland and Virginia portions of Assateague Island. Artificial dune lines are maintained and protected by local or state laws in many places. Federal sediment placement projects typically include the construction of artificial dunes. Local communities construct artificial dunes with fill material hauled in by truck or pumped in with dredged material, use armoring to protect dune faces, or scrape sand from the beach to rebuild dunes. Miles of sand fencing and vegetation plantings are used to maintain these artificial dunes in place. Mitteager et al. (2006, p. 892) state that the regulation in New Jersey protecting dunes "is written for shore protection, not habitat, aesthetic or heritage value. Direct disturbance to the dunes that would reduce their dimensions is prohibited, but sand can be added by earth-moving equipment, and vegetation may be planted."

Magliocca et al. (2011, p. 918) describe these type of modifications to sandy oceanfront barrier islands:

> *Interactions between human manipulations and landscape processes can form a dynamically coupled system because landscape-forming processes affect humans, and humans increasingly manipulate landscape-forming processes. Despite the dynamic nature of sandy barrier islands, economic incentive and recreational opportunities attract humans and development. Storm-driven sediment-transport events that build barrier islands constitute hazards to humans and infrastructure, and manipulations aimed at preventing or mitigating such events link human actions and long-term island morphodynamics.*

Magliocca et al. (2011, p. 918) investigated "how the behavior of a natural barrier island differs from one in which humans are dynamic system constituents," focusing on the impacts of removing overwash deposits following storms and rebuilding artificially high and continuous dunes. They conclude that (Magliocca et al. 2011, p. 928):

> *(1) Artificially high dunes filter out high-frequency, small-scale storm impacts, which result in less overwash deposition over time. The introduction of artificially high dunes drives the overwash regime toward less-frequent and higher-amplitude overwash events. Storms that finally overtop artificial dunes impact a back-barrier environment that is lower than it would otherwise have been, which amplifies the severity of the overwash or inundation.*
> *(2) The long-term exclusion of overwash from the back-dune environment tends to amplify the effects of sea level rise because island elevation landward of the dune line is fixed despite continuously rising sea levels. Reconstruction of artificial dunes, by mining the overwash deposits, reinforces relatively low island elevations for long periods. In the [human/barrier island] coupled system, flooding frequency increases as the difference between storm-induced water levels and island elevations relative to sea level grows.*
> *(3) The obstruction of overwash decreases the availability of on-site sand for dune reconstruction. As the heights of maintained dunes increase, sand must be imported from off-site and at a higher rate …. Road relocation— the consequence of significant coverage or washout of the roadbed due to overwash—occurs more frequently as artificial dune height increases ….*
> *(4) The natural system migrates landward relatively continuously …, but the [human/barrier island] coupled system's back-barrier shoreline is fixed for long periods. The disruption of overwash promotes thinning of the island as the seaward shoreline migrates landward (caused by sea-level rise, gradients in alongshore sediment flux, and low-frequency overwash events), whereas the back-barrier shoreline moves very little.*

The authors found that the construction and maintenance of artificial dunes block minor and moderate overwash events, resulting in a narrower and lower island in the long-term. Then "when dunes are overtopped, the sediment redistributions are more severe. …Increasing the height of artificially maintained dunes increases the rate of island narrowing and, therefore, infrastructure relocation, and increases the need for sediment to be imported from outside the system" (Magliocca et al. 2011, p. 918).

Large scale sediment placement projects may have similar long-term impacts. Tanski (2012, p. 23) states that for Long Island's oceanfront beaches, "Since inlets are the primary mechanisms for transferring sediment landward along Long Island's barrier island systems, nourishment projects that cover large areas and are maintained for very long periods of time could lower the rate of cross shore sand transport and, eventually, affect barrier island migration … [but] it [is] very difficult to determine how a nourishment project might alter long-term barrier migration rates or how long it would take." These so-called "soft" stabilization methods of using fill material to modify sandy oceanfront beaches and dunes therefore may result in long-term, landscape-level impacts to the natural system.

The preference for nonstructural alternatives[47] to erosion control by most of the states in the U.S. Atlantic Coast breeding range of the piping plover (Table 31) suggests that sediment placement projects, including the building and maintenance of artificial dunes and beach nourishment projects, will increase as sea level continues to rise at an accelerating rate and storm intensity is expected to increase with climate change.

Beach Scraping

Beach scraping alters the profile of the beach and creates dunes that are not structured internally like natural dunes, resulting in artificial dunes that do not function the same as natural dunes. Removing the top layer of sediment from the beach removes the invertebrate prey base for foraging shorebirds, including the piping plover. Beach scraping with bulldozers alters the microtopography of the beach, both by leaving ruts or scrape marks but also by compacting the surface with the heavy equipment. The beach berm profile is lowered, which may increase the vulnerability of shorebird and waterbird nests to flooding. In one study on Bogue Banks, NC, Conaway and Wells (2005) found that beach scraping resulted in altered dune morphology, increased aeolian (windblown) sediment transport rates, modified dune sediment characteristics, and denuded dune faces; long-term potential impacts included accelerated migration of the dunes and a depleted longshore sediment budget. Peterson et al. (2000, p. 368) found that beach scraping reduced the width of the intertidal beach, replacing "it with a wedge of coarser, shellier sand taken from the lower beach." The beach scraping reduced densities of mole crabs (*Emerita talpoida*) by 35-37%, significantly lowered (55-65%) counts of active burrows of ghost crabs (*Ocypode quadrata*), and showed mixed results for densities of *Donax* spp. (Peterson et al. 2000).

At least 68 miles (109 km) of sandy beach habitat from Maine to North Carolina was modified by beach scraping between 2012 and 2015, with the heaviest concentrations occurring along the South Shore of Long Island and in New Jersey (Table 6). In this habitat assessment, beach scraping was found to be rare to nonexistent on beaches backed by bluffs or armor, and much more common on beaches where dunes are present. Some municipalities have 10-year permits to scrape the beach whenever necessary and conditions allow. In other instances, individual property owners, including some state lands, conduct beach scraping to construct artificial dunes in localized areas. Cumulatively these individual and municipal beach scraping activities have modified at least 6% of the sandy beach habitat in the U.S. Atlantic Coast breeding range of the piping plover. Immediately after Hurricane Sandy, overwash material was scraped off of paved surfaces and developed areas in Rhode Island, Connecticut, New York, New Jersey and Delaware, the areas most affected by the storm. This overwash material was almost always returned to the beach, creating artificial dunes from the landward side rather than the seaward

[47] Nonstructural alternatives to hard shoreline stabilization structures (i.e., bulkheads, seawalls, revetments, groins) typically include relocation of structures, elevation of structures, beach fill, dune building or vegetation planting, or the construction of "living shorelines" which include marsh creation, slope grading, creation or restoration of oyster reefs, the installation of offshore sills with marsh plantings and/or fill landward of the sill(s), and may also include the use of coir fiber logs in some states. In several states, including RI, CT, NY, NJ, DE, MD and VA, the use of nonstructural alternatives must be shown to be infeasible or impractical before hard shoreline stabilization alternatives may be considered.

side. The NC DOT regularly scrapes overwash material off of NC 12 on the Outer Banks and reconstructs artificial dunes to protect the roadway. NRC (2014, p. 90) found that “this procedure [scraping overwash material back to the beach] hinders the natural migration of the beach.” Both types of scraping modify the natural profile of the beach and eliminate flat, bare sand overwash flats that are highly valuable to shorebirds and waterbirds. As climate changes and sea level rises, with the potential to increase the frequency or magnitude of storm events, the threat of beach scraping to sandy beach habitat is likely to increase.

Sand Fencing

The use of sand fencing to modify sandy beach habitats dates back to the 15th century (Grafals-Soto 2012). While less invasive than other types of habitat modification, since fencing harnesses natural aeolian (windblown) sediment to construct dunes, sand fencing nevertheless alters the beach profile by creating dunes in a location and configuration dictated by humans rather than natural processes. When fences are installed seaward of houses, as they commonly are, the sand fencing displaces the dune crest farther seaward than would naturally occur (Nordstrom and McCluskey 1985). Sand fencing is not often removed after accumulating sediment and can remain in place for long periods of time, becoming exposed and leaving debris on the beach after major storm events. Partially buried sand fencing can alter the distribution of vegetation (Grafals-Soto 2012). The installation of sand fencing in overwash areas following major storms such as Hurricane Sandy hastens the conversion of flat, bare overwash areas to elevated, vegetated dune habitat. The presence of sand fencing on the beach, particularly if oriented in continuous straight lines without gaps, can pose an impediment to the movement of unfledged chicks as well as sea turtles (which may nest in some parts of the Southern Recovery Unit).

Nordstrom and McCluskey (1985, p. 44) found that sand fencing, particularly when located close to houses, “considerably reduce the volume of sand which passes the dune crest,” reducing the aeolian sediment budget landward of the beach. The study concludes that “The implementation of controls on house construction and other uses of the dune without consideration of the changes induced by sand fences would be shortsighted, and planners should consider implementing stricter controls on the use of sand fences” (Nordstrom and McCluskey 1985, p. 45).

While Grafals-Soto (2012, p. 45) determined that the impacts of sand fencing can be minimized by prioritizing “the creation of topographically diverse dunes within a restricted space [that] may increase the diversity and density of the vegetation, and the resilience and value of developed [artificially-created] dunes,” such a prioritization favors the dune ecosystem rather than the sandy beach ecosystem with sparsely vegetated, flatter topography utilized by beach-nesting birds. Nordstrom et al. (2012) found that sand fencing and beach raking resulted in higher dune crest heights than naturally formed dunes at an unmanaged site, but the volume of sediment within the dune and beach was greater at the site without sand fencing and beach raking; an additional dune ridge was present at the site without sand fencing as well. Species diversity and concentration was higher, particularly in the dune swales, at the site without sand fencing and beach raking; the number and types of microhabitats were greater at the unmanaged sites (Nordstrom et al. 2012).

Sand fencing was identified along sandy beaches in every state of the U.S. Atlantic Coast breeding range of the piping plover between 2012 and 2015, but was rare on narrow beaches backed by bluffs or armor. Where barrier islands dominate the coast, sand fencing was much more common. Altogether at least 246 miles (396 km) of sandy beach habitat was modified by sand fencing between 2012 and 2015, with the heaviest concentrations occurring along the South Shore of Long Island and in New Jersey and Delaware (Table 7).

Habitat Sustainability

A sustainable coastal ecosystem is one which can continue to provide a full suite or range of ecosystem services in the long term with climate change, particularly with sea level rise. Sustainable coastal systems maintain their full mosaic of habitats and ecosystem functions over time, adapting to climate change and sea level rise in particular. Sandy beach habitat is maintained over time, moving or migrating in space as natural processes and conditions warrant. Sustainable coastal systems are physically and ecologically resilient to climate change and sea level rise, able to adapt in location (and potentially size) but always providing the full range of ecosystem services.

Beaches that have been modified with hard shoreline stabilization structures, or armoring, are not sustainable in the long term. As sea level rises, sandy beaches will be lost seaward of shore-parallel structures. Beaches that are armored are slower to recover following a major storm, perhaps not able to recover fully at all (Morton et al. 1994). The presence of the armoring interferes with the natural processes of profile recovery and prevents the landward migration of the beach profile (and thus the habitats along the profile).

Sandy beaches modified with sediment placement may be sustainable in the short-term, but may not be sustainable in the long-term. Beach compatible sediment is a finite resource that is not equally or uniformly distributed along the U.S. coast. As sea level rises, increasing volumes of sediment will be necessary to maintain or sustain a beach in its historical location and dimensions. Barrier islands and spits must increase their elevation to be sustainable with sea level rise – a process that naturally occurs through overwash and Aeolian (windblown) movement of sediment inland. In locations where these natural processes are blocked, through the construction and artificial maintenance of dune ridges or levees (whether that be through sediment placement, beach scraping, sand fencing and/or planting of vegetation), the barrier island or spit will not be naturally elevated as sea level rises and will be less physically resilient to flooding events and storms. In the long term, these locations will need to be artificially elevated as Jones Beach (NY), Long Beach (NY), Miami Beach (FL) and Galveston (TX) were nearly a century ago when they were originally developed (or recovering from a major hurricane in the case of Galveston). The presence of existing infrastructure – roadways, recreational facilities, buildings, boardwalks, utilities – will make such artificial elevation projects very difficult, if not impossible, to construct. Nevertheless, in a few locations (i.e., Sea Isle City, NJ, and Miami Beach, FL) have begun to artificially elevate low-lying roadways. The extraordinarily high volumes of sediment required to raise the elevation of a barrier island or spit artificially also limits the viability of sediment placement projects to sustain beaches and barrier islands; the elevation of Jones Beach (NY) involved over 40 million cubic yards (30.6 million cubic meters) of sediment, an order of magnitude higher than the typical federal large-scale beach nourishment project. As a result, sediment placement is only likely to be sustainable to maintain sandy beaches in a very small number of locations as sea level rises over the long-term.

The habitat modifications inventoried in this assessment quantify the cumulative impacts to sandy beach habitat from Maine to North Carolina, providing the opportunity to evaluate the sustainability of the habitat as climate changes and sea level rises at an accelerating rate. The cumulative impacts of the habitat modifications evaluated in this habitat assessment are significant, major, widespread and long-term within the U.S. Atlantic Coast breeding range of the piping plover. Future impacts of human modifications to sandy beach ecosystems can be avoided, minimized and mitigated, as described in Rice (2009) and USFWS (2012). Best management practices to avoid impacts from proposed habitat modifications include avoiding the construction of new development, armor or sediment placement projects in areas of sandy beach habitat that support high populations of nesting, foraging or roosting shorebirds, waterbirds, other wildlife of conservation concern, or vulnerable plants. Shore protection projects can be scheduled to avoid seasons of high biological productivity, such as during nesting and migration (NRC 2014). Overwash material can be allowed to remain in place, naturally elevating the back beach and interior areas, reducing the vulnerability of the areas to future flooding events and sea level rise. The artificial closure or opening of new inlets can be avoided, sustaining valuable sandy beach habitat on inlet shoulders and barrier spits. Avoid installation of sand fencing at current or potential piping plover breeding sites (USFWS 1996).

For habitat modifications that cannot be avoided, human impacts to sandy beach habitat can be minimized in a number of ways. Sediment placement episodes can be scheduled farther apart to allow full recovery of all ecosystem functions between placement episodes. Sediment placement projects can be designed to more closely mimic natural geomorphology that includes dune gaps and overwash areas. Constructing large sediment placement projects in several small projects can reduce the magnitude of the impact; the deposition of repeated thin layers of sediment (< 30 centimeters) can minimize the risk of killing all invertebrate fauna with deep burial (Defeo et al. 2009, NRC 2014). Gaps can be incorporated within large sediment placement project areas that can serve as refugia for invertebrate fauna (Bishop et al. 2006, Defeo et al. 2009, Schlacher et al. 2012, NRC 2014). Ensuring that sediment placed on the beach is compatible, or as close as possible in grain size, shape, color and composition, with the native sediment on the beach can minimize impacts of sediment placement projects (Peterson et al. 2006, Defeo et al. 2009, NRC 2014). Groins can be notched or designed to be "leaky" to allow for more passage of sediment from one side of the groin to the other (USACE 2002). Dredged material can be placed in the nearshore or on adjacent beaches to retain the sediment within the local system, minimizing impacts to adjacent sandy beach habitat that may have increased erosion rates resulting from the creation of sediment sinks within dredged inlets. Sand fencing can be installed in a manner that does not block faunal passage and in a location that mimics natural site selection of dune development. Sand fencing and sufficient time can be used to build dunes rather than sediment placement and/or heavy equipment. Cumulative impacts to localized areas can be minimized by avoiding or removing some of the human modifications contributing to those cumulative impacts.

Human modifications to sandy beach habitat also may be mitigated by enhancing or restoring habitat. Peterson and Bishop (2005) called for compensatory mitigation of injury to public trust resources resulting from sediment placement projects and beach scraping, including remediation of sediment placement projects that used incompatible material, which increase the adverse impacts of sediment placement. A compensatory mitigation banking system such as the one used in many states for wetlands could be developed to mitigate human habitat modifications to sandy beach ecosystems (Peterson and Bishop 2005). Mitigation for proposed habitat modifications can include the removal of habitat modifications, ideally as close to the site of new proposed habitat modifications as possible to maximize benefits to species with high site fidelity or limited range.

Armor can be removed as happened in some areas of Rhode Island following Hurricane Sandy. Nordstrom and Jackson (2013, p. 171) state that "Coastal landforms and habitats require space to reform in response to storm damage to increase the likelihood of long-term sustainability." Their study evaluated the removal of hard shoreline stabilization structures to facilitate the migration of landforms and their habitats with rising sea level along the bayside shoreline of a barrier spit in the Sandy Hook Unit of Gateway National Recreation Area in New Jersey. They found that if widespread removal of structures is undertaken, new sediment sources would be restored to the shoreline and the "slightly wider breaches and higher dunes that would form in locations downdrift of new sediment sources would reduce the likelihood of overwash and breaches, which could result in a more homogenous suite of landforms and habitats alongshore and greater sheltering of the coves landward of them" (Nordstrom and Jackson 2013, p. 190). Removal of smaller structures may be costly but "can result in the most rapid reversion to a fully functioning natural ecosystem" (Nordstrom and Jackson 2013, p. 190).

Sandy beach habitat can be restored not only through the removal of hard stabilization structures, but also by the abandonment or purchase of private property and removal of buildings and associated infrastructure. This restoration of the entire barrier spit ecosystem has recently taken place in at least 3 locations between southern Maine and northern Long Island. At what is now Sound Views Dune Park in Southold, NY, the Town of Southold and Suffolk County purchased a 57-acre single family residence in 2008 that had approximately 0.27 miles (0.43 km) of LIS beach shoreline. In 2009 the County and Town sought "to undevelop the entire property" and removed the residential structures, swimming pool, septic tank, underground oil tank and 310 ft (94.49 m) of timber bulkhead that surrounded the residence, which protruded out into Long Island Sound across the beach, acting like a groin (Town of Southold 2012, p. 5). The disturbed areas were subsequently planted with native beach and dune species to restore the double dune system[48]. Further plans have been made (and perhaps implemented) to remove utility poles and the section of the long driveway closest to the beach, restoring even more of the landscape (Town of Southold 2012).

At West Meadow Beach near Stony Brook, NY, there were 94 summer cottages and buildings, a parking lot and a single road on a barrier spit visible in 2004 Google Earth imagery. By 2006-07, only 5 buildings and the road remained with the rest of the spit restored to natural conditions. The Town of Brookhaven owns West Meadow Beach and with the restoration of the southern portion of the barrier spit, the public lands protect 1.34 miles (2.16 km) of contiguous sandy beach habitat.

[48] A double dune system occurs where two rows of dunes (primary and secondary) separated by a swale are found at the back of a beach instead of a solitary line of dunes.

More recently, in Connecticut, the Long Beach West Restoration Project restored a barrier spit in Stratford near the Bridgeport town boundary. The 2011 restoration project removed the remnants of 37 cottages, 25 outbuildings, retaining walls, 4 docks, debris and trash from Long Beach West, which is adjacent to the Great Meadows Unit of the Stewart B. McKinney NWR (US DOI 2015). The spit had been cut off from mainland Bridgeport when a bridge connecting the two burned in 1996, eventually necessitating the abandonment of the seasonal cottages and their leases on the spit due to a lack of access for emergency services. Restoration of the spit was a collaborative effort (led by the USFWS) between the federal government, state of CT, Town of Stratford and several private and NGO partners (Motavalli 2012, US DOI 2015).

Other forms of mitigation can include alterations to existing management practices and policies. Management practices can be modified to no longer include installation of sand fencing or the use of beach scraping to construct artificial dunes in overwash areas following storm events, which USFWS (1996) recommends avoiding to the extent possible to allow the characteristics of preferred piping plover habitat to continue unimpeded. Where overwash has been prevented by previous management practices or habitat modifications, dunes can be notched to allow future overwash events, which was done at Assateague Island NS in 2008 and 2009 (Schupp and Coburn 2015). Sand fencing that has been buried can be removed. Where appropriate, thick vegetation can be thinned or removed to restore sparsely vegetated nesting habitat for shorebirds and waterbirds. In areas where all sandy beach habitat has been lost due to armor, and it is not possible to remove the armor or development behind it, sandy beach habitat can be restored through sediment placement projects (NRC 2014). In some locations of New Jersey, such as Sea Bright, sandy beach habitat was lost for a long period of time seaward of armor but was restored through construction of a large, federal sediment placement project.

Sandy beach ecosystems are highly dynamic. Sediment is continually exchanged between the beach and dune systems. Overwash deposits allow barrier islands to migrate and raise their elevation as sea level rises. Inlets open, migrate and close, creating new sediment deposits on the bayside of barrier islands. “Natural dynamism thus is not a threat to maintenance of barrier islands and spits under natural conditions; however, it is a threat to human facilities with a fixed position on inherently mobile landforms” (National Research Council [NRC] 2014, p. 86). If the rate of change increases in the future from accelerating rates of sea level rise, or from declining sediment supplies, sandy beach habitats may be less sustainable and vulnerable to the fragmentation of barrier islands (through new inlet formation) or submergence (Fenster et al. 2011, NRC 2014, Riggs et al. 2011).

The maintenance of development and beaches in place threatens the sustainability of sandy beach habitat as sea level rises. “An important adverse environmental effect of building unnaturally high dunes on barrier islands is that by protecting against overwash, the dunes prevent natural accretion processes that help the island sustain itself. Barrier islands and spits are prevented from keeping pace with sea-level rise or from reestablishing now-rare dynamic habitats, such as washover fans that are favored environments for piping plovers (Maslo et al., 2011; Schupp et al., 2013” (NRC 2014, p. 93). Sims et al. (2013, p. 339) found that sandy beach habitat valuable to the piping plover will be sustainable in Rhode Island, migrating landward, “if unconstrained by future development.” The migration, and sustainability, of sandy beach habitat has been and will continue to be blocked by development, including roadways and armor (Sims et al. 2013). The impacts of this future habitat loss can be mitigated through the restriction of ORV, limiting future development, avoiding installation of new armor, abandoning non-paved roads and allowing overwash to occur (Sims et al. 2013). Where sand overwash is allowed in undeveloped areas, there is the potential to increase the extent of sandy beach habitat as sea level rises (Sims et al. 2013).

The NPS released a Coastal Adaptations Strategy Handbook (CASH) in 2016 that includes a continuum of adaptation options and strategies for coastal resources (physical, cultural and facilities) to adapt to climate change and rising sea level (Beavers et al. 2016). The CASH describes how coastal adaptation strategies are park- and resource-specific but may require collaborating with partners at the landscape level (e.g., Landscape Conservation Cooperatives) in order to best manage for change. Sims et al. (2013) also found that collaboration among partners and landowners will be necessary to sustain sandy beach habitat with rising sea level, as habitats migrate landward across jurisdictional boundaries.

Shoreline stabilization, or armor, "can protect resources in place but are not long-term solutions and have trade-offs, including disruption of natural processes" (Beavers et al. 2016, p. x). "Beach nourishment can be a costly short-term effort … [with] ecological and physical consequences … on intertidal and nearshore habitats" (Beavers et al. 2016, p. x). The CASH recommends that the redesign and relocation of facilities and infrastructure, including their replacement with portable structures, need to be considered when developing strategies for coastal change. One of the lessons learned from Hurricane Sandy cited in the CASH is that "After an event, there is an immediate and strong push to return park assets to pre-storm conditions, which can leave resources vulnerable to similar impacts in the future" but that "Post-storm recovery is a critical opportunity to adapt to climate change" (Beavers et al. 2016, p. x). A number of coastal adaptation strategies that have been implemented at various locations in the NPS system are described in detail in the companion *Coastal Adaptation Strategies: Case Studies*, providing a knowledge base of experience and evaluation of the effectiveness of strategies that have already been implemented (Schupp et al. 2015). The CASH and its companion case studies should serve as a valuable tool to all coastal resource managers and stakeholders to improve the sustainability of sandy beach habitat as climate changes and sea level rises.

Coastal adaptation strategies to foster sustainability of sandy beach ecosystems will vary by location. In 5 states within the U.S. Atlantic Coast breeding range of the piping plover, ownership of coastal property (including lands owned by public entities) extends to the mean low water mark or tide line, whereas state ownership begins at the mean high water mark or tide line (regardless of the upland ownership) in the other 6 states (Table 33). In some areas individual deeds specify a particular property boundary line on a map instead of a dynamic water line as the seaward boundary of beachfront property, and as sandy beaches erode or migrate onto adjacent private property with rising sea level, development and private beach ownership may increasingly threaten the sustainability of sandy beach habitat. Feagin et al. (2010, p. 988) found that "static legal definitions of the coastal zone enforce linear restrictions to the natural interplay of sediments and represent a threat to ecosystem functioning. Also, inevitable conflicts ensue once sea levels rise or [extreme episodic storm events] strike." Instead, Feagin et al. (2010)

Table 33. Coastal property ownership of beaches in the U.S. Atlantic Coast breeding range of the piping plover. In some states, state ownership of the beach begins at the mean high water or tide line, and in other states it begins at the mean low water or tide line. Note that public entities or non-governmental organizations may own extensive sections of beach but not the adjacent upland properties, providing public access to the beach in many areas.

State	Upland Ownership to Mean High Water (MHW)	Upland Ownership to Mean Low Water (MLW)
Maine		X
New Hampshire		X
Massachusetts		X
Rhode Island	X	
Connecticut	X	
New York†	X	
New Jersey	X	
Delaware‡	X	X
Maryland	X	
Virginia		X
North Carolina	X	

† The Andros Patent of 1676 granted the Town of Southold ownership of the lands under its creeks, inlets, bays and harbors as well as other common lands and natural resources. The Dongan Patent of 1686 granted several of the Towns on Long Island ownership of the waters and beaches (amongst other natural resources) within their boundaries, which the Towns manage via Boards of Trustees. We were unable to determine whether the Towns' ownership and management of the beaches (through the Dongan Patent) will move along with the beaches as they migrate with rising sea level, or if the adjacent private property will affect that ownership and/or management of the sandy beaches.

‡ Private property may extend to the high water line, lower water line, or some other location specified in a deed in Delaware.

recommend ecologically defined boundaries between public and private property on beaches, such as the one used in Texas where the native vegetation line serves as the public-private property line, which is allowed to shift landward with natural processes.

Feagin et al. (2010) also recommend the public purchase of the remaining undeveloped coastal barriers to preserve their ecological sustainability. The inventory of public and NGO-owned sandy beaches within the U.S. Atlantic Coast breeding range of the piping plover (see Appendices B to N for lists of individual public and NGO beach tracts for each state) can serve as a basis for future conservation opportunities to maximize the sustainability of sandy beach and tidal inlet habitat as sea level rises and climate changes. Sims et al. (2013, p. 347) found that in Rhode Island, "In general, habitat has more space to retreat landward on the state and federally controlled beaches studied" in their habitat migration modeling with sea level rise.

As of 2015, more than 828 miles (1,332 km) of sandy oceanfront beaches between Georgetown, ME, and the North Carolina-South Carolina border are in public and/or NGO ownership (Table 2). These lands are not uniformly distributed throughout the region however. Virginia has the highest number of miles of land in public or NGO ownership, covering 89% of the state's shoreline. From Ocean City Inlet, MD, to the mouth of the Chesapeake Bay, the Delmarva Peninsula has 13 contiguous barrier islands in public and/or NGO ownership. At least half of the sandy beach habitat present in 2015 was in public or NGO ownership in NH, RI, the South Shore of Long Island (NY), DE, MD, VA and NC. Federal and state lands have been especially important as limiting development of sandy oceanfront beach habitat in the U.S. Atlantic Coast breeding range of the piping plover. This protection does not equate to pristine, undisturbed, and unmodified habitat, however, because many public lands have been and continue to be modified by armoring, beach nourishment and placement of dredge disposal, permitted ORV use, protection and maintenance of coastal roadways and historic structures, the potential for incompatible activities on non-federal inholdings, creation and maintenance of artificial dune ridges, and closure of new inlets. Although they are generally shorter in length than the federal and state lands, lands owned by county and local governments collectively make an important contribution to the total inventory of publicly and NGO-owned lands. The inventory of public and NGO-owned lands provided in this assessment can be used to identify geographic gaps where conservation efforts may be prioritized to maintain and increase overall habitat availability and quality as sea level rises and climate changes.

In order to ensure habitat sustainability of sandy beach ecosystems in the near and long-term future, the cumulative impacts identified in this habitat assessment should be fully addressed in all future proposed projects that would modify sandy beach habitat. Future habitat modifications in sensitive areas should be avoided. The incremental increases in length of sandy beach habitat proposed to be modified should be minimized and mitigated. If the recovery of the piping plover, or other beach-nesting birds or wildlife of concern, are habitat-limited, this habitat assessment can serve as an environmental baseline that identifies where habitat can be enhanced or restored.

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USACE. 2013m. Saco River and Camp Ellis Beach, Saco, Maine, Section 111 Shore Damage Mitigation Project, Draft Decision Document and Environmental Assessment, including Finding of No Significant Impact and Section 404(b)(1) Evaluation. New England District, U.S. Army Corps of Engineers, Concord, MA. 95 p.

USACE. 2013n. Delaware Coast Protection Project, Flood Control and Coastal Emergency Repair, Indian River Inlet North Shore, Sussex County, Delaware. Public Notice No. CENAP-PL-E-13-01, March 25, 2013. Philadelphia District, U.S. Army Corps of Engineers, Philadelphia, PA. 10 p.

USACE. 2013o. Application by the Suffolk County Department of Public Works for Dredging of Meetinghouse Creek with 10 Years Maintenance, Beach Nourishment and Upland Disposal, Village of Aquebogue, Town of Riverhead, Suffolk County, NY. 30-Day Public Notice, Public Notice No. NAN-2011-01142-EST, August 13, 2013. New York District, U.S. Army Corps of Engineers, New York, NY. 12 p.

USACE. 2013p. Application by the Suffolk County Department of Public Works for Dredging of East Creek with 10 Years Maintenance and Beach Nourishment, Hamlet of Jamesport, Town of Riverhead, Suffolk County, NY. 30-Day Public Notice, Public Notice No. NAN-2013-00021-EBO, dated July 10, 2013. New York District, U.S. Army Corps of Engineers, New York, NY. 10 p.

USACE. 2013q. 10-Year Maintenance Dredging with Beach Nourishment of Greenport Harbor/Stirling Basin, Greenport, NY. 30-Day Public Notice, Public Notice No. NAN-2011-01318-ETA, dated August 15, 2013. New York District, U.S. Army Corps of Engineers, New York, NY. 10 p.

USACE. 2013r. 10-Year Maintenance Dredging with Beach Nourishment at 500 Beach Court, East Marion, NY. 30-Day Public Notice, Public Notice No. NAN-2013-00301-EST, dated September 4, 2013. New York District, U.S. Army Corps of Engineers, New York, NY. 10 p.

USACE. 2013s. 10-Year Maintenance Dredging with Beach Nourishment of Coecles Harbor, Ram Island, Town of Shelter Island, NY. 30-Day Public Notice, Public Notice No. NAN-2013-00500-EBO, dated May 22, 2013. New York District, U.S. Army Corps of Engineers, New York, NY. 9 p.

USACE. 2013t. Breakwater Rehabilitation, Sag Harbor, New York, Federal Navigation Project. 30-Day Public Notice, Public Notice No. SAG HARBOR, dated May 8, 2013. New York District, U.S. Army Corps of Engineers, New York, NY. 5 p.

USACE. 2013u. Jetty Rehabilitation, Jones Inlet, New York, Federal Navigation Project. 30-Day Public Notice, Public Notice No. JONES INLET, NEW YORK, JETTY REHABILITATION 2013, dated May 9, 2013. New York District, U.S. Army Corps of Engineers, New York, NY. 4 p.

USACE. 2013v. Jetty Rehabilitation, East Rockaway Inlet, New York, Federal Navigation Project. 30-Day Public Notice, Public Notice No. EAST ROCKAWAY INLET, NEW YORK, JETTY REHABILITATION 2013, dated May 9, 2013. New York District, U.S. Army Corps of Engineers, New York, NY. 4 p.

USACE. 2013w. Misquamicut Beach, Westerly, Rhode Island, Beach Erosion Control Project Restoration. 30-Day Public Notice, dated November 5, 2013. New England District, U.S. Army Corps of Engineers, Concord, MA. 7 p.

USACE. 2013x. North Carolina Department of Transportation Emergency Beach Repair / Beach Nourishment along NC Highway 12 in Dare County, NC. 30-Day Public Notice, dated July 1, 2013. Wilmington District, U.S. Army Corps of Engineers, Wilmington, NC. 21 p.

USACE. 2013y. Masonboro Inlet, NC (Shallow Draft Navigation) (O&M) Fact Sheet. Dated April 8, 2013. Wilmington District, U.S. Army Corps of Engineers, Wilmington, NC. 2 p.

USACE. 2013z. Town of Topsail Beach Beach Nourishment Project, Pender County, NC. 30-Day Public Notice, Public Notice No. SAW-2013-00404, May 1, 2013. Wilmington District, U.S. Army Corps of Engineers, Wilmington, NC. 10 p.

USACE. 2013aa. Environmental Assessment, West Onslow Beach and New River Inlet (Topsail Beach) and Surf City and North Topsail Beach Coastal Storm Damage Reduction Projects, Pender and Onslow Counties, North Carolina. Wilmington District, U.S. Army Corps of Engineers, Wilmington, NC. 56 p. + appendices.

USACE. 2013bb. Morehead City Harbor, Morehead City, NC, Draft Integrated Dredged Material Management Plan and Environmental Impact Statement. Wilmington District, U.S. Army Corps of Engineers, Wilmington, NC. 339 p. + appendices.

USACE. 2013cc. "Army Corps Responds to Hurricane Sandy: Corps Carries Out Emergency Response Missions Throughout New York/New Jersey Region." *New York District Times*. Newsletter of the U.S. Army Corps of Engineers, New York District. Special Hurricane Sandy Edition. New York, NY. 16 p.

USACE. 2013dd. Great Egg Harbor Inlet to Townsends Inlet Storm Damage Reduction Project, Cape May County, NJ. Draft Environmental Assessment (EA). December 2013. Philadelphia District, U.S. Army Corps of Engineers, Philadelphia, PA. 149 p.

USACE. 2013ee. Shrewsbury River, New Jersey, Federal Navigation Project Maintenance Dredging. 30-Day Public Notice No. SHREWSBURY RIVER 14, dated October 11, 2013. New York District, U.S. Army Corps of Engineers, New York, NY. 6 p.

USACE. 2013ff. Sandy Hook Channel, New York Harbor Federal Navigation Project Maintenance Dredging. 30-Day Public Notice No. NY HARBOR, SHC 13, dated May 3, 2013. New York District, U.S. Army Corps of Engineers, New York, NY. 10 p.

USACE. 2013gg. Application by the Town of Oak Bluffs, Massachusetts, to Modify Permit NAE-2009-01128 to Dredge Sengekontacket Pond at Little Bridge. 15 Day Public Notice NAE-2009-01128, December 17, 2013. New England District, U.S. Army Corps of Engineers, Concord, MA. 11 p.

USACE. 2013hh. Town of Falmouth, Massachusetts, Permit Application for Maintenance Dredging and Beach Nourishment. Public Notice NAE-2010-145, dated November 12, 2013. New England District, Concord, MA. 11 p.

USACE. 2013ii. Town of Chatham, Massachusetts, Permit Application for Comprehensive Dredging and Disposal Project. Public Notice NAE-2011-488, dated April 30, 2013. New England District, Concord, MA. 48 p.

USACE. 2014a. Downtown Montauk Stabilization Project – Evaluation of a Stabilization Plan for Coastal Storm Risk Management in Response to Hurricane Sandy & Public Law 113-2. Draft Environmental Assessment. New York District, U.S. Army Corps of Engineers, New York, NY. 55 p.

USACE. 2014b. Tiana Beach Emergency Levee Project, Town of Southampton, Hampton Bays, NY. Public Notice Number NAN-2014-01327-EYR, dated November 14, 2014. New York District, U.S. Army Corps of Engineers, New York, NY. 8 p.

USACE. 2014c. Fire Island Inlet to Moriches Inlet, Fire Island Stabilization Project. Evaluation of a Stabilization Plan for Coastal Storm Risk Management in Response to Hurricane Sandy & Public Law 113-2. Final Environmental Assessment. New York District, U.S. Army Corps of Engineers, New York, NY. 123 p.

USACE. 2014d. Fire Island Inlet to Moriches Inlet, Fire Island Stabilization Project. Hurricane Sandy Limited Reevaluation Report. Evaluation of a Stabilization Plan for Coastal Storm Risk Management in Response to Hurricane Sandy & Public Law 113-2. Main Report. New York District, U.S. Army Corps of Engineers, New York, NY. 134 p.

USACE. 2014e. Suffolk County Department of Public Works Permit Application to Dredge with Ten Years maintenance with Beach Placement, Shelter Island Sound (South Ferry Terminals), Town of Shelter Island, Suffolk County, New York. Public Notice No. NAN-2014-000871-EBO, dated August 27, 2014. New York District, New York, NY. 12 p.

USACE. 2014f. Atlantic Coast of New Jersey, Sandy Hook to Barnegat Inlet Beach Erosion Control Project, Section 1 – Sea Bright to Ocean Township: Elberon to Loch Arbour Reach. Draft Integrated Hurricane Sandy Limited Reevaluation Report and Environmental Assessment. New York District, U.S. Army Corps of Engineers, New York, NY. Various paginations + appendices.

USACE. 2014g. Maintenance Dredging of the Pawcatuck River, Little Narragansett Bay, and Watch Hill Cove Federal Navigation Project, Stonington, Connecticut & Westerly, Rhode Island. 30 Day Public Notice, March 19, 2014. New England District, U.S. Army Corps of Engineers, Concord, MA. 8 p.

USACE. 2014h. Final Environmental Assessment – Barnegat Inlet to Little Egg Inlet (Long Beach Island), New Jersey, Storm Damage Reduction Project. Philadelphia District, U S. Army Corps of Engineers, Philadelphia, PA. 84 p.

USACE. 2014i. Hereford Inlet to Cape May Inlet Final Feasibility Report and Integrated Environmental Assessment. 3 volumes. Philadelphia District, U.S. Army Corps of Engineers, Philadelphia, PA. Various paginations.

USACE. 2014j. Manasquan Inlet to Barnegat Inlet Storm Damage Reduction Project, Ocean County, NJ. Final Environmental Assessment (EA). May 2014. Philadelphia District, U.S. Army Corps of Engineers, Philadelphia, PA. 133 p.

USACE. 2014k. Wreck Pond 10-year Maintenance Dredging, Borough of Spring Lake, Monmouth County, NJ. 30-Day Public Notice No. NAN-2013-01500-EBO, dated March 13, 2014. New York District, U.S. Army Corps of Engineers, New York, NY. 7 p.

USACE. 2014l. Shoreline Restoration and Protection Project, Joint Expeditionary Base (JEB) Little Creek / Fort Story, Virginia Beach, Virginia. 30-Day Public Notice No. NAO-2014-01390, dated August 14, 2014. Norfolk District, U.S. Army Corps of Engineers, Norfolk, VA. 3 p. + attachments.

USACE. 2014m. Application for maintenance dredging of Wading River Creek with beach placement. Wading River Creek, Town of Riverhead, Suffolk County, New York. 30-Day Public Notice, Public Notice No. NAN-2014-00259-EBO. June 23, 2014. New York District, U.S. Army Corps of Engineers, New York, NY. 8 p.

USACE. 2014n. 10-Year Maintenance Dredging of Napeague Harbor with Beach Nourishment, Gardiners Bay, Town of East Hampton, NY. 30-Day Public Notice NAN-2013-01254-ESW, dated January 14, 2014. New York District, U.S. Army Corps of Engineers, New York, NY. 8 p.

USACE. 2014o. Camp Cronin Revetment, Point Judith Harbor of Refuge, Narragansett, Rhode Island. 30-Day Public Notice, dated February 21, 2014. New England District, U.S. Army Corps of Engineers, Concord, MA. 6 p.

USACE. 2014p. Maintenance Dredging of the Pawcatuck River, Little Narragansett Bay, and Watch Hill Cove Federal Navigation Project, Stonington, CT, and Westerly, RI. 30-Day Public Notice, dated March 19, 2014. New England District, U.S. Army Corps of Engineers, Concord, MA. 8 p.

USACE. 2014q. Village of Bald Head Island Shoreline Protection Project, Bald Head Island, NC. 30-Day Public Notice, Public Notice No. SAW-2012-00040, August 1, 2014. Wilmington District, U.S. Army Corps of Engineers, Wilmington, NC. 21 p.

USACE. 2014r. Masonboro Inlet, NC (Shallow Draft Navigation) (O&M) Fact Sheet. Dated March 6, 2014. Wilmington District, U.S. Army Corps of Engineers, Wilmington, NC. 2 p.

USACE. 2014s. Final Integrated Feasibility Report and Environmental Impact Statement, Coastal Storm Damage Reduction, Bogue Banks, Carteret County, North Carolina. Wilmington District, U.S. Army Corps of Engineers, Wilmington, NC. 221 p. + appendices.

USACE. 2014t. North Topsail Beach Beach Restoration Project, Phases 3 and 5. 30-Day Public Notice No. SAW-2005-00344, dated January 10, 2014. Wilmington District, U.S. Army Corps of Engineers, Wilmington, NC. 7 p.

USACE. 2014u. "Army Corps Completes Final Post-Sandy Emergency Beach Repair Project." News Release No. 14-063, dated December 22, 2014. North Atlantic Division, U.S. Army Corps of Engineers, Brooklyn, NY.

USACE. 2014v. Town of Edgartown, Massachusetts, Permit Application for Maintenance Dredging and Beach Nourishment. Public Notice NAE-2011-1511, May 27, 2014. New England District, Concord, MA. 11 p.

USACE. 2014w. Maintenance Dredging of the Federal Navigation Project in Cohasset Harbor, Cohasset and Scituate, Massachusettts. 30 Day Public Notice, March 5, 2014. New England District, U.S. Army Corps of Engineers, Concord, MA. 7 p.

USACE. 2014x. Maintenance Dredging of the Federal Navigation Project in Menemsha Creek, Chilmark & Aquinnah, Massachusetts. 30 Day Public Notice, June 6, 2014. New England District, U.S. Army Corps of Engineers, Concord, MA. 6 p.

USACE. 2014y. Federal Maintenance of East and West Jetty, Nantucket Harbor, Nantucket, Massachusetts. 30 Day Public Notice, November 17, 2014. New England District, U.S. Army Corps of Engineers, Concord, MA. 6 p.

USACE. 2014z. Supplemental Public Notice for Shark River, New Jersey, Federal Navigation Project Maintenance Dredging. 15-Day Public Notice No. SHARK RIVER SUPPLEMENT FY14, dated April 14, 2014. New York District, U.S. Army Corps of Engineers, New York, NY. 9 p.

USACE. 2014aa. Nantasket Beach Coastal Storm Damage Reduction Project, Nantasket Beach, Department of Conservation and Recreation Reservation, Hull, Massachusetts. 30-Day Public Notice, dated May 13, 2014. New England District, U.S. Army Corps of Engineers, Concord, MA. 7 p.

USACE. 2015a. New Jersey Shore Protection, Hereford Inlet to Cape May Inlet, New Jersey. Chief's Report, January 23, 2015. Philadelphia District, U.S. Army Corps of Engineers, Philadelphia, PA. 7 p.

USACE. 2015b. Quogue Beach Restoration Project. Public Notice Number NAN-2012-00011-EHA, dated July 6, 2015. New York District, U.S. Army Corps of Engineers, New York, NY. 13 p.

USACE. 2015c. Borough of Stone Harbor, Great Channel and Lagoons / Basins Dredging. Public Notice No. CENAP-OP-R-2015-167-24. December 2015. Philadelphia District, U.S. Army Corps of Engineers, Philadelphia, PA. 13 p.

USACE. 2015d. Captree State Park, State Boat Channel Dredging Project. Public Notice Number NAN-2015-00768-EBO, dated July 16, 2015. New York District, U.S. Army Corps of Engineers, New York, NY. 12 p.

USACE. 2015e. Atlantic Coast of Long Island: Jones Inlet to East Rockaway Inlet, Long Beach Island, New York, Hurricane and Storm Damage Reduction Hurricane Sandy Limited Reevaluation Report. Final Environmental Assessment. New York District, U.S. Army Corps of Engineers, New York, New York. 60 p. + appendices.

USACE. 2015f. Supplemental Public Notice for Sandy Hook Channel, New York Harbor Federal Navigation Project Maintenance Dredging. 15-Day Public Notice No. NY HARBOR, SHC 15, dated July 17, 2015. New York District, U.S. Army Corps of Engineers, New York, NY. 13 p.

USACE. 2015g. Atlantic Coast of Long Island: Jones Inlet to East Rockaway Inlet, Long Beach Island, New York, Coastal Storm Risk Management Project. Hurricane Sandy Limited Reevaluation Report. New York District, U.S. Army Corps of Engineers, New York, New York. 114 p. + appendices.

USACE. 2015h. North Shore of Long Island, Asharoken, Suffolk County, New York, Coastal Storm Risk Management Feasibility Study. Feasibility Report. November 2015. New York District, U.S. Army Corps of Engineers, New York, NY. 105 p. + appendices.

USACE. 2015i. Draft Environmental Assessment, Proposed Sand Borrow Area B – Delaware Atlantic Coast from Cape Henlopen to Fenwick Island Storm Damage Reduction Project, Sussex County, Delaware. Philadelphia District, U.S. Army Corps of Engineers, Philadelphia, PA. 220 p.

USACE. 2015j. Atlantic Coast of Maryland Shore Protection, Maryland, Fact Sheet. February 1, 2015. Baltimore District, U.S. Army Corps of Engineers, Baltimore, MD. 3 p.

USACE. 2015k. City of Virginia Beach Application to Dredge the Rudee Inlet Outer Channel Deposition Basin. 30-Day Public Notice, Public Notice No. NAO-2004-04041, February 20, 2015. Norfolk District, U.S. Army Corps of Engineers, Norfolk, VA. 4 p. + attachments.

USACE. 2015l. Maintenance Dredging of Mill Creek, Town of Southampton, Suffolk County, NY. 30-Day Public Notice, Public Notice No. NAN-2015-01155-EYR, September 23, 2015. New York District, U.S. Army Corps of Engineers, New York, NY. 9 p.

USACE. 2015m. Maintenance Dredging of Goose Creek, Town of Southold, Suffolk County, NY. 30-Day Public Notice, Public Notice No. NAN-2015-01153-EYR, September 22, 2015. New York District, U.S. Army Corps of Engineers, New York, NY. 8 p.

USACE. 2015n. Maintenance Dredging of Corey Creek, Town of Southold, Suffolk County, NY. 30-Day Public Notice, Public Notice No. NAN-2015-01091-EYR, dated September 15, 2015. New York District, U.S. Army Corps of Engineers, New York, NY. 9 p.

USACE. 2015o. Final Dredged Material Management Plan and Final Programmatic Environmental Impact Statement, Long Island Sound, Connecticut, New York, and Rhode Island. New England District, U.S. Army Corps of Engineers, Concord, MA. 616 p. (DMMP), 760 p. (PEIS) + appendices.

USACE. 2015p. 10-Year Maintenance Dredging of Downs Creek with Beach Placement, Village of Cutchogue, NY. 30-Day Public Notice, Public Notice No. NAN-2014-01272-EYA, dated June 5, 2015. New York District, U.S. Army Corps of Engineers, New York, NY. 9 p.

USACE. 2015q. Ocean Isle Beach Shoreline Protection Project, Town of Ocean Isle Beach, NC. 30-Day Public Notice, Public Notice No. SAW-2011-01241, January 23, 2015. Wilmington District, U.S. Army Corps of Engineers, Wilmington, NC. 14 p.

USACE. 2015r. Holden Beach Shoreline Protection Program, Town of Holden Beach, NC. 30-Day Public Notice, Public Notice No. SAW-2011-01914, August 28, 2015. Wilmington District, U.S. Army Corps of Engineers, Wilmington, NC. 20 p.

USACE. 2015s. Notice of Availability of the Supplemental Environmental Impact Statement, Figure Eight Island Shoreline Management Project, Figure Eight Island, NC. 30-Day Public Notice, Public Notice No. SAW-2006-41158, July 9, 2015. Wilmington District, U.S. Army Corps of Engineers, Wilmington, NC. 8 p.

USACE. 2015t. Maintenance Dredging of Atlantic Intracoastal Waterway (AIWW), New River Inlet and Cedar Bush Cut, Onslow County, NC. 21 Day Public Notice, Public Notice No. SAW-2014-01012, July 8, 2015. Wilmington District, U.S. Army Corps of Engineers, Wilmington, NC. 22 p.

USACE. 2015u. Holden Beach Shoreline Protection Program, Town of Holden Beach, NC. 30-Day Public Notice, Public Notice No. SAW-2011-01914, August 28, 2015. Wilmington District, U.S. Army Corps of Engineers, Wilmington, NC. 20 p

USACE. 2015v. Maintenance Dredging and Advance Maintenance Dredging of the Federal Navigation Project in the Cape Cod Canal, Bourne and Sandwich, Massachusetts, with Beneficial Use of the Dredged Sand as Beach-Fill on Town Neck Beach, Sandwich, Massachusetts. 30-Day Public Notice, February 2, 2015. New England District, U.S. Army Corps of Engineers, Concord, MA. 8 p.

USACE. 2015w. Sandwich Town Beach and Dune Restoration Project, Sandwich, Massachusetts. 30-Day Public Notice, Public Notice No. NAE-2014-259, dated July 28, 2015. New England District, U.S. Army Corps of Engineers, Concord, MA. 16 p.

USACE. 2015x. Dead Neck / Sampson's Island, Dredging and Nourishment Plan, Barnstable (Osterville), Massachusetts. 30-Day Public Notice, Public Notice No. NAE-2013-2073, dated October 27, 2015. New England District, U.S. Army Corps of Engineers, Concord, MA. 8 p.

USACE. 2015y. Town of Mashpee, Massachusetts, Comprehensive Dredging and Disposal Project. 30-Day Public Notice, Public Notice No. NAE-2013-1241, dated December 15, 2015. New England District, U.S. Army Corps of Engineers, Concord, MA. 12 p.

USACE. 2016a. Draft Environmental Assessment, Little Egg Inlet Sand Resource Borrow Area Investigation for the Barnegat Inlet to Little Egg Inlet (Long Beach Island) Storm Damage Reduction Project, Ocean County, New Jersey. Philadelphia District, U.S. Army Corps of Engineers, Philadelphia, PA. 102 p.

USACE. 2016b. North Shore of Long Island, Bayville, New York. Coastal Storm Risk Management Feasibility Study. Draft Integrated Feasibility Report and Environmental Assessment. February 2016. New York District, U.S. Army Corps of Engineers, New York, NY. 107 p. + appendices.

USACE. 2016c. Hashamomuck Cove, Southold, New York, Coastal Storm Risk Management Feasibility Study. Draft Integrated Feasibility Report and Environmental Assessment. July 2016. New York District, U.S. Army Corps of Engineers, New York, NY. 135 p. + appendices.

USACE. 2016d. Ocean City Beach Replenishment, Ocean City, Maryland. 30-Day Public Notice CENAB-OPR-M-2015-61754, dated April 13, 2016. Baltimore District, U.S. Army Corps of Engineers, Baltimore, MD. 10 p.

USACE. 2016e. Maintenance Dredging of the Saco River Federal Navigation Channel, Saco and Biddeford, ME. 30-Day Public Notice, March 30, 2016. New England District, U.S. Army Corps of Engineers, Concord, MA. 8 p.

USACE. 2016f. 10-Year Maintenance Dredging of Noyac Creek with Upland Placement of Dredged Material, Noyac Creek, Southampton, NY. 30-Day Public Notice NAN-2016-00063-EYR, dated February 2, 2016. New York District, U.S. Army Corps of Engineers, New York, NY. 8 p.

USACE. 2016g. Lake Montauk Harbor Feasibility Study, Coastal Storm Risk Management, Public Information Meeting. U.S. Army Corps of Engineers, New York District, and New York State Department of Environmental Conservation. East Hampton, NY. 13 p. Available at http://www.nan.usace.army.mil/Missions/Civil-Works/Projects-in-New-York/Lake-Montauk-Harbor-Feasibility-Study/.

USACE. 2016h. 10-Year Maintenance Dredging of Shinnecock Canal with Beach Placement, Great Peconic Bay, Southampton, NY. 30-Day Public Notice NAN-2016-00293-EYR, dated March 25, 2016. New York District, U.S. Army Corps of Engineers, New York, NY. 12 p.

USACE. 2016i. Update Report for Connecticut. March 31, 2016. New England District, U.S. Army Corps of Engineers, Concord, MA. 8 p.

USACE. 2016j. 10-Year Maintenance Dredging of Fresh Pond with Beach Placement, Little Peconic Bay, Southampton, NY. 30-Day Public Notice NAN-2016-00114-EYR, dated February 10, 2016. New York District, U.S. Army Corps of Engineers, New York, NY. 8 p.

USACE. 2016k. Final Environmental Impact Statement, Figure Eight Island Shoreline Management Project, dated June 24, 2016. Wilmington District, U.S. Army Corps of Engineers, Wilmington, NC. 532 p. + appendices.

USACE. 2016l. Public Notice for the Availability of a Final Environmental Impact Statement for the Town of Ocean Isle Beach, NC, Terminal Groin and Beach Nourishment Project. 30-Day Public Notice, Public Notice No. SAW-2011-01241, April 29, 2016. Wilmington District, U.S. Army Corps of Engineers, Wilmington, NC. 8 p.

USACE. 2016m. Maintenance Dredging of the Chatham Stage Harbor Federal Navigation Project, Chatham, Massachusetts. 30-Day Public Notice, April 29, 2016. New England District, U.S. Army Corps of Engineers, Concord, MA. 6 p.

USACE. 2016n. Update Report for Massachusetts. October 31, 2016. New England District, U.S. Army Corps of Engineers, Concord, MA. 16 p.

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USFWS. 2002. Biological Opinion on the Effects of Completion of Sections I and II of the Atlantic Coast of New Jersey Beach Erosion Control Project Sea Bright to Barnegat Inlet, Monmouth County, New Jersey, on the Piping Plover (*Charadrius melodus*) and Seabeach Amaranth (*Amaranthus pumilus*). Pleasantville, NJ. 156 p.

USFWS. 2002a. Sachuest Point National Wildlife Refuge Comprehensive Conservation Plan. Hadley, MA. 69 p. + appendices.

USFWS. 2002b. Trustom Pond National Wildlife Refuge Comprehensive Conservation Plan. Hadley, MA. 85 p. + appendices.

USFWS. 2002c. Ninigret Pond National Wildlife Refuge Comprehensive Conservation Plan. Hadley, MA. 81 p. + appendices.

USFWS. 2002d. Block Island National Wildlife Refuge Comprehensive Conservation Plan. Hadley, MA. 71 p. + appendices.

USFWS. 2005. Biological Opinion on the Effects of Federal Beach Nourishment Activities Along the Atlantic Coast of New Jersey with the U.S. Army Corps of Engineers, Philadelphia District on the Piping Plover (*Charadrius melodus*) and Seabeach Amaranth (*Amaranthus pumilus*). Pleasantville, NJ. 244 p.

USFWS. 2006a. Long Island National Wildlife Refuge Complex Comprehensive Conservation Plan and Environmental Assessment. Hadley, MA. Various paginations + appendices.

USFWS. 2006b. Pea Island National Wildlife Refuge Comprehensive Conservation Plan. Atlanta, GA. 202 p.

USFWS. 2007. Rachel Carson National Wildlife Refuge Comprehensive Conservation Plan and Environmental Assessment. Hadley, MA. 134 p. + appendices.

USFWS. 2008. Currituck National Wildlife Refuge comprehensive conservation plan. Atlanta, GA. 222 p.

USFWS. 2009. Piping plover (*Charadrius melodus*) 5-year review: summary and evaluation. Northeast Region, Hadley, Massachusetts. 206 p.

USFWS. 2010. Rising to the urgent challenge: Strategic plan for responding to accelerating climate change. Washington, D.C. 32 pp.

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USFWS. 2014a. Fish and Wildlife Coordination Act 2(b) Report, Fire Island Inlet to Moriches Inlet Stabilization Project. Prepared for the New York District, U.S. Army Corps of Engineers, New York, New York. U.S. Fish and Wildlife Service, Long Island Field Office, Shirley, New York. 109 p. + figures and appendices.

USFWS. 2014b. Biological Opinion and Conference Opinion, Fire Island Inlet to Moriches Inlet (FIMI) Federal Stabilization Project, Suffolk County, New York. Hadley, MA. 217 p.

USFWS. 2014c. Biological Opinion and Conference Opinion, Village of Bald Head Island Shoreline Protection Project, Brunswick County, North Carolina. Raleigh, NC. 196 p.

USFWS. 2014d. Momomoy National Wildlife Refuge Draft Comprehensive Conservation Plan and Environmental Impact Statement. Chatham, MA. 556 p. + appendices. Available at http://www.fws.gov/refuge/Monomoy/what_we_do/draftccp.html.

USFWS. 2015a. Amended Biological Opinion, Lockwoods Folly River Habitat Restoration Project – Phase 1 – Eastern Channel, Town of Oak Island, North Carolina. Raleigh, NC. 202 p.

USFWS. 2015b. Biological Opinion, New Hanover County – Mason Inlet Relocation Project, New Hanover County, North Carolina. Raleigh, NC. 193 p.

USFWS. 2015c. Biological Opinion, Town of Ocean Isle Beach Shoreline Management Project, Ocean Isle Beach, North Carolina. Raleigh, NC. 222 p.

USFWS. 2015d. Biological Opinion, Onslow County Navigation Project, Onslow County, North Carolina. Raleigh, NC. 220 p.

USFWS. 2016a. Biological Opinion, Town of Holden Beach - Holden Beach East End Shore Protection Project. Raleigh, NC. 232 p.

USFWS. 2016b. Batched Biological Opinion, Carolina and Kure Beach Coastal Storm Damage Reduction Project. Raleigh, NC. 236 p.

USFWS. 2016c. Batched Wrightsville Beach Coastal Storm Damage Reduction Project, New Hanover County, North Carolina. Raleigh, NC. 235 p.

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Appendix A – Imagery Sources

Table A-1. Several sources of imagery are publicly available and were utilized to document the presence and absence of sandy beach habitat and anthropogenic habitat modifications to sandy beach habitats within the U.S. Atlantic Coast breeding range of the piping plover from 2013 through 2015. The dates and sources of aerial imagery for each state from Maine to North Carolina are listed. Note that not all imagery dates within each state may cover the entire state's shoreline. Imagery sources are Google Earth unless otherwise noted.

State	Imagery Dates and Sources
Maine	May 9, 2016 September 5, 2015 May 7, 2015 September 27, 2014 September 18, 2013
New Hampshire	April 27, 2016 May 23, 2015 October 9, 2014 April 7, 2013
Massachusetts	May 10, 2016 April 27,2016 June 6, 2015 May 23, 2015 May 7, 2015 March 2, 2015 October 9, 2014 September 27, 2014 June 15, 2014 August 24, 2013 April 7, 2013
Rhode Island	August 22, 2016 May 6, 2015 March 2, 2015 September 11, 2014 April 27, 2013 April 17, 2013
Connecticut	April 20, 2016 September 22, 2015 September 6, 2015 October 24, 2014 August 19, 2014 September 19, 2013 April 7, 2013

State	Imagery Dates and Sources
New York – Long Island Sound	May 23, 2015 June 19, 2014 September 19, 2013
New York – Peconic Estuary	May 11, 2016 May 23, 2015 August 19, 2014 June 19, 2014 September 19, 2013
New York – Atlantic Ocean	October 8, 2015 (USGS Hurricane Joaquin) May 23, 2015 October 11, 2014 June 19, 2014 September 19, 2013
New Jersey	April 16, 2016 October 7 to 8, 2015 (USGS Hurricane Joaquin) June 21, 2015 October 5, 2014 April 24, 2014 September 6, 2013 April 25, 2013
Delaware	October 7, 2015 (USGS Hurricane Joaquin) July 9, 2015 May 25, 2015
Maryland	March 8, 2016 October 7, 2015 (USGS Hurricane Joaquin) May 25, 2015 July 9, 2015 March 8, 2013
Virginia	March 8, 2016 November 10, 2015 October 7, 2015 (USGS Hurricane Joaquin) June 7, 2014 April 23, 2014 March 8, 2013 February 23, 2013
North Carolina	August 21, 2016 April 9, 2016 January 20, 2016 November 10, 2015 October 9, 2015 (USGS Hurricane Joaquin) September 23, 2015 April 23, 2014 March 9, 2013 February 24, 2013

Link to Google Earth imagery, plus Google Earth and Google Earth Pro software:

https://www.google.com/earth/

Links to NOAA- NGS imagery:

Hurricane Sandy, October 31 – November 6, 2012 (http://storms.ngs.noaa.gov/storms/sandy/)

Hurricane Matthew, October 7 to 16, 2016 (http://storms.ngs.noaa.gov/storms/matthew/index.html)

Links to USGS imagery:

Hurricane Sandy, November 4 – 6, 2012 (http://coastal.er.usgs.gov/hurricanes/sandy/post-storm-photos/obliquephotos.html)

Hurricane Joaquin, October 7 to 9, 2015 (https://pubs.usgs.gov/ds/0995/)

Appendix B - Maine

Table B-1. Length of sandy beach for each community (from north to south) along the oceanfront shoreline of Maine south of Georgetown and the proportion of each that was developed and undeveloped along the immediate beachfront in September 2015 (north of Wells) or April 2016 (south of Wells).

Community	Length of Sandy Beach (miles)	Percentage of Sandy Beach Developed	Percentage of Sandy Beach Undeveloped
Georgetown	1.64	19%	81%
Phippsburg	5.09	35%	65%
Harpswell	0.56	8%	92%
Chebeague Island	3.60	78%	22%
Little Chebeague Island	1.35	0%	100%
Long Island	1.11	48%	52%
Portland[1]	2.59	96%	4%
Cape Elizabeth	3.27	19%	81%
Scarborough	4.63	80%	20%
Old Orchard Beach	3.06	100%	0%
Saco	2.04	90%	10%
Biddeford	5.26	79%	21%
Kennebunkport	2.63	76%	24%
Kennebunk	2.87	70%	30%
Wells	3.95	87%	13%
Ogunquit	1.46	15%	85%
York	2.14	89%	11%
Kittery	1.51	19%	81%
TOTAL	**48.77**	**64%**	**36%**

1 – Portland includes Great Diamond Island, Little Diamond Island and Peaks Island.

Table B-2. Sandy beaches that are in public or NGO ownership along the oceanfront shoreline of Maine south of Georgetown, the county in which each is located, and the approximate length of sandy beach within each visible in Google Earth imagery in September 2015 (north of Wells) or April 2016 (south of Wells).

Public / NGO Land	County Location	Approximate Sandy Beach Length in 2015 (miles)
Reid State Park	Sagadahoc	1.11
Popham Beach State Park	Sagadahoc	1.00
Bates-Morse Mountain Conservation Area	Sagadahoc	1.55
Small Point Preserve	Sagadahoc	0.11
Upper Flag Island, Petit Menan NWR	Cumberland	0.18
Rose's Point, Chebeague Island	Cumberland	0.24
Higgins Farm, Chebeague Island	Cumberland	0.12
Belvins Easement, Chebeague Island	Cumberland	0.04
Indian Point, Chebeague Island	Cumberland	0.24
Curit Property, Chebeague Island	Cumberland	0.11
Little Chebeague Island State Park	Cumberland	1.35
Andrews Beach	Cumberland	0.16
Deb's Cove	Cumberland	0.04
Crescent Beach State Park	Cumberland	1.02
Scarborough WMA	Cumberland	0.10
Scarborough Beach State Park	Cumberland	0.40
Ferry Beach	Cumberland	0.47
Pine Point Easements	Cumberland	0.35
Hurd Park, Pine Point	Cumberland	0.05
Rachel Carson NWR, Goosefare Brook Division & Adjacent TNC Parcels	York	0.13
Ferry Beach State Park	York	0.10
Biddeford Pool Beach	York	0.15
Goose Rocks Beach	York	0.11
Rachel Carson NWR, Goose Rocks Division (Batson River Inlet)	York	0.19
Vaughn's Island Preserve	York	0.35
Colony Beach	York	0.05
Strawberry Island	York	0.05
Rachel Carson NWR, Mousam River Division (Little River Inlet)	York	0.20
Laudholm Farm, Wells NERR	York	0.41
Crescent Beach	York	0
Ogunquit Beach	York	1.46

Public / NGO Land	County Location	Approximate Sandy Beach Length in 2015 (miles)
Short Sands Beach, Ellis Park	York	0.24
Long Sands Beach	York	1.25
Harbor Beach, Hartley Mason Park	York	0.14
Gerrish Island, Delano Easement	York	0.25
	TOTAL MILES	**13.68 (28% of sandy beach shoreline)**

Table B-3. The length and proportion of shoreline within each community (from north to south) along the oceanfront shoreline of Maine south of Georgetown that was modified with hard shoreline stabilization, or armor, in 2015. Note that the length of armored shoreline with no beach is the length of shoreline where sandy beaches were absent seaward of armor in September 2015 (north of Wells) or April 2016 (south of Wells) but where evidence indicated sandy beaches would be present in the absence of the armor.

Community	Known Approximate Length of Armored Sandy Beach Shoreline (miles)	Approximate Length of Armored Shoreline with No Sandy Beach (miles)	Total Length of Armored Sandy Shoreline (miles)	Percentage of Sandy Shoreline Modified with Armor
Georgetown	0	0	0	0%
Phippsburg	0.15	0	0.15	3%
Harpswell	0	0	0	0%
Chebeague Island	0.02	0	0.02	0%
Little Chebeague Island	0	0	0	0%
Long Island	0	0	0	0%
Portland	0.37	0.169	0.53	19%
Cape Elizabeth	0.42	0	0.42	13%
Scarborough	1.16	0	1.16	25%
Old Orchard Beach	1.40	0	1.40	46%
Saco	0.62	0.333	0.96	40%
Biddeford	2.47	0.008	2.48	47%
Kennebunkport	1.69	0	1.69	64%
Kennebunk	1.39	0.204	1.60	52%
Wells	3.03	0.967	4.00	81%
Ogunquit	0.26	0	0.26	18%
York	1.78	0	1.78	83%
Kittery	0	0	0	0%
TOTAL	**14.77**	**1.681**	**16.45**	**33%**

Table B-4. The length of shoreline known to be modified by sediment placement projects in each community (from north to south) along the oceanfront shoreline of Maine south of Georgetown and the proportions of each that were in pre-existing project areas or new placement areas.

Community	Pre-existing Sediment Placement Project Areas (miles)	New Sediment Placement Project Areas 2012-2015 (miles)	Total Length of Shoreline Modified by Sediment Placement as of 2015 (miles)	Percentage of Shoreline Modified with Sediment Placement as of 2015
Georgetown	0	0	0	0
Phippsburg	0.2	0	0.2	4%
Harpswell	0	0	0	0
Chebeague Island	0	0	0	0
Little Chebeague Island	0	0	0	0
Long Island	0	0	0	0
Portland	0	0	0	0
Cape Elizabeth	0	0	0	0
Scarborough	0.8	0	0.8	17%
Old Orchard Beach	1.1	0	1.1	36%
Saco[1]	0.4	0	0.4	17%
Biddeford	> 0	0	> 0	> 0 %
Kennebunkport	0	0	0	0
Kennebunk	0.6	0	0.6	20%
Wells	1.78	0	1.78	36%
Ogunquit	1.42	0	1.42	97%
York	0	0	0	0
Kittery	0	0	0	0
TOTAL	**6.30 +**	**0**	**6.30 +**	**> 13%**

1 – In 2013 the USACE proposed a new sediment placement project on Camp Ellis Beach in Saco that would modify an additional ~1,800 ft (549 m) of sandy shoreline, 1,769 ft (539 m) of which was armored shoreline with no sandy beach present in 2015. If constructed, the total length of sandy shoreline in Saco modified by sediment placement would be ~3,340 ft (1,018 m), or 0.63 miles (1.01 km), or 27% of Saco's sandy shoreline.

Table B-5. The length and proportion of sandy beach within each community (from north to south) along the oceanfront shoreline of Maine south of Georgetown that was modified with beach scraping or grading from 2012 to 2015.

Community	Length of Sandy Beach Modified with Beach Scraping (miles)	Percentage of Shoreline Modified with Beach Scraping
Georgetown	0	0
Phippsburg	0	0
Harpswell	0	0
Chebeague Island	0	0
Little Chebeague Island	0	0
Long Island	0	0
Portland	0	0
Cape Elizabeth	0	0
Scarborough	0	0
Old Orchard Beach	0	0
Saco	0.10	5%
Biddeford	0	0
Kennebunkport	0	0
Kennebunk	0	0
Wells	0	0
Ogunquit	0	0
York	0	0
Kittery	0	0
TOTAL	**0.10**	**0.2%**

Table B-6. The length and proportion of sandy beach within each community (from north to south) along the oceanfront shoreline of Maine south of Georgetown that was modified with the installation of sand fencing from 2012 to 2015.

Community	Length of Sandy Beach Modified with Sand Fencing (miles)	Percentage of Shoreline Modified with Sand Fencing
Georgetown	0	0
Phippsburg	0	0
Harpswell	0	0
Chebeague Island	0	0
Little Chebeague Island	0	0
Long Island	0	0
Portland	0	0
Cape Elizabeth	0	0
Scarborough	0.20	4%
Old Orchard Beach	0	0
Saco	0.09	4%
Biddeford	0	0
Kennebunkport	0	0
Kennebunk	0	0
Wells	0	0
Ogunquit	0.66	45%
York	0	0
Kittery	0	0
TOTAL	**0.95**	**2%**

Appendix C – New Hampshire

Table C-1. Length of sandy beach for each community (from north to south) along the oceanfront shoreline of New Hampshire and the proportion of each that was developed and undeveloped along the immediate beachfront in April 2016.

Community	Length of Sandy Beach (miles)	Percentage of Sandy Beach Developed	Percentage of Sandy Beach Undeveloped
New Castle	0.51	70%	30%
Rye	3.51	76%	24%
North Hampton	0.90	81%	19%
Hampton	3.57	90%	10%
Seabrook	1.44	98%	2%
TOTAL	**9.93**	**84%**	**16%**

Table C-2. Sandy beaches that are in public or NGO ownership along the oceanfront shoreline of New Hampshire, the county in which each is located, and the approximate length of sandy beach within each visible in Google Earth imagery in April 2016.

Public / NGO Land	County Location	Approximate Sandy Beach Length in 2015 (miles)
Great Island Common	Rockingham	0.07
Crosby Easement	Rockingham	0.10
Odiorne Point State Park	Rockingham	0.54
Wallis Sands State Park	Rockingham	0.14
Rye Harbor State Park	Rockingham	0.03
Jenness Beach State Park	Rockingham	0.09
Sawyers Beach	Rockingham	0.19
North Hampton State Park	Rockingham	0.19
North Side Park	Rockingham	0.03
Hampton Beach State Park (North Beach)	Rockingham	1.18
Hampton Beach State Park (south of Great Boars Head)	Rockingham	1.51
Seabrook Dunes and Beach	Rockingham	1.23
TOTAL MILES		**5.31 (55% of sandy beach shoreline)**

Table C-3. The length and proportion of shoreline within each community (from north to south) along the oceanfront shoreline of New Hampshire that was modified with hard shoreline stabilization, or armor, in 2015. Note that the length of armored shoreline with no beach is the length of shoreline where sandy beaches were absent seaward of armor in April 2016 but where evidence indicated sandy beaches would be present in the absence of the armor.

Community	Known Approximate Length of Armored Sandy Beach Shoreline (miles)	Approximate Length of Armored Shoreline with No Sandy Beach (miles)	Total Length of Armored Sandy Shoreline (miles)	Percentage of Sandy Shoreline Modified with Armor
New Castle	0.15	0	0.15	29%
Rye	2.47	0.445	2.91	74%
North Hampton	0.61	0	0.61	68%
Hampton	3.22	0.388	3.61	91%
Seabrook	0.46	0	0.46	32%
TOTAL	**6.91**	**0.833**	**7.74**	**72%**

Table C-4. The length of shoreline known to be modified by sediment placement projects in each community (from north to south) along the oceanfront shoreline of New Hampshire and the proportions of each that were in pre-existing project areas or new placement areas.

Community	Pre-existing Sediment Placement Project Areas (miles)	New Sediment Placement Project Areas 2012-2015 (miles)	Total Length of Shoreline Modified by Sediment Placement as of 2015 (miles)	Percentage of Shoreline Modified with Sediment Placement as of 2015
New Castle	0	0	0	0
Rye	0.15	0	0.15	4%
North Hampton	0	0	0	0
Hampton	1.22	0	1.22	31%
Seabrook	> 0	0	> 0	> 0
TOTAL	**> 1.37**	**0**	**> 1.37**	**14%**

Table C-5. The length and proportion of sandy beach within each community (from north to south) along the oceanfront shoreline of New Hampshire that was modified with beach scraping or grading from 2012 to 2015.

Community	Length of Sandy Beach Modified with Beach Scraping (miles)	Percentage of Sandy Beach Modified with Beach Scraping
New Castle	0	0
Rye	0.18	5%
North Hampton	0	0
Hampton	0	0
Seabrook	0	0
TOTAL	**0.18**	**2%**

Table C-6. The length and proportion of sandy beach within each community (from north to south) along the oceanfront shoreline of New Hampshire that was modified with the installation of sand fencing from 2012 to 2015.

Community	Length of Sandy Beach Modified with Sand Fencing (miles)	Percentage of Sandy Beach Modified with Sand Fencing
New Castle	0	0
Rye	0	0
North Hampton	0	0
Hampton	0	0
Seabrook	0.20	14%
TOTAL	**0.20**	**2%**

Appendix D – Massachusetts

Table D-1. Length of sandy beach for each community (from north to south) along the oceanfront shoreline of Massachusetts and the proportion of each that was developed and undeveloped along the immediate beachfront in May 2015.

Community	Length of Sandy Beach (miles)	Percentage of Sandy Beach Developed	Percentage of Sandy Beach Undeveloped
Salisbury	3.55	79%	21%
Newburyport	0.32	35%	65%
Newbury	4.07	33%	67%
Rowley	1.05	0%	100%
Ipswich	7.05	0%	100%
Gloucester	1.91	72%	28%
Rockport	1.82	72%	28%
Manchester	2.09	82%	18%
Beverly	3.01	78%	22%
Salem	0.13	46%	54%
Marblehead	1.66	80%	20%
Swampscott	1.66	81%	19%
Lynn	0.43	74%	26%
Nahant	2.85	24%	76%
Revere	3.86	64%	36%
Winthrop	3.87	81%	19%
Boston	15.38	15%	85%
Quincy	6.02	63%	37%
Weymouth	2.26	39%	61%
Hingham	0.34	0%	100%
Hull	4.47	91%	9%
Cohasset	1.10	73%	27%
Scituate	8.37	62%	38%
Marshfield	4.03	90%	10%
Duxbury	6.35	32%	68%
Kingston	0.73	63%	37%
Plymouth	16.89	62%	38%
Sandwich	8.19	59%	41%
Barnstable	19.44	31%	69%
Yarmouth	6.03	39%	61%
Dennis	10.60	56%	44%
Brewster	5.89	60%	40%
Orleans	6.77	23%	77%
Eastham	10.47	45%	55%
Wellfleet	21.11	18%	82%

Community	Length of Sandy Beach (miles)	Percentage of Sandy Beach Developed	Percentage of Sandy Beach Undeveloped
Truro	20.14	36%	64%
Provincetown	16.75	19%	81%
Chatham	25.41	5%	95%
Harwich	4.02	75%	25%
Mashpee	4.78	41%	59%
Falmouth	15.18	55%	45%
Bourne	10.12	45%	55%
Wareham	9.60	49%	51%
Marion	3.62	49%	51%
Mattapoisett	5.32	51%	49%
Fairhaven	8.44	38%	62%
New Bedford	1.16	78%	22%
Dartmouth	9.16	28%	72%
Westport	7.89	13%	87%
Gosnold	12.00	3%	97%
Oak Bluffs	4.22	30%	70%
Edgartown	21.38	12%	88%
West Tisbury	6.96	27%	73%
Chilmark	11.05	19%	81%
Aquinnah	6.99	13%	87%
Tisbury	4.69	71%	29%
Nantucket	55.73	25%	75%
TOTAL	**458.40**	**35%**	**65%**

Table D-2. Sandy beaches that are in public or NGO ownership along the oceanfront shoreline of Massachusetts, the county in which each is located, and the approximate length of sandy beach within each visible in Google Earth imagery in May 2015.

Public / NGO Land	County Location	Approximate Sandy Beach Length in 2015 (miles)
Salisbury Beach State Reservation	Essex	3.55
Plum Island Beach (The Point)	Essex	0.33
Parker River NWR	Essex	6.16
Sandy Point State Reservation	Essex	0.70
Crane Estate	Essex	3.87
Wingaersheek Beach	Essex	0.54
Cape Hedge Beach	Essex	0.42
Good Harbor Beach	Essex	0.45
White Beach	Essex	0.14
West Beach	Essex	0.15
Dane Street Beach	Essex	0.23
Independence Park	Essex	0.12
Winter Island (Waikiki) Beach	Essex	0.11
Devereux Beach	Essex	0.21
Phillips Beach	Essex	0.26
Eisman's Beach	Essex	0.06
Fisherman's Beach	Essex	0.16
Lynn Shore and Nahant Beach Reservations (King's Beach)	Essex	2.19
Short Beach	Essex	0.52
Black Rock Beach	Essex	0.26
Revere Beach Reservation	Suffolk	2.71
Short Beach, Winthrop Shores Reservation	Suffolk	0.27
Winthrop Beach, Winthrop Shores Reservation	Suffolk	1.05
Thompson Island, Boston Harbors NRA	Suffolk	2.94
Spectacle Island, Boston Harbors NRA	Suffolk	0.59
Long Island, Boston Harbors NRA	Suffolk	2.41
Rainsford Island, Boston Harbors NRA	Suffolk	0.68
Gallops Island, Boston Harbors NRA	Suffolk	0.35
Peddocks Island, Boston Harbors NRA	Suffolk	4.26
Grape Island, Boston Harbors NRA	Suffolk	0.94
Bumpkin Island, Boston Harbors NRA	Suffolk	0.17
Webb Memorial State Park	Norfolk	1.23
Hingham Town Beach	Plymouth	0.34

Public / NGO Land	County Location	Approximate Sandy Beach Length in 2015 (miles)
Nantasket Beach Reservation	Plymouth	1.26
Sandy Beach	Norfolk	0.20
Sandy Cove Beach	Norfolk	0.16
Bassing Beach	Plymouth	0.52
Egypt Beach	Plymouth	0.22
Conservation Park	Plymouth	0.68
Rexhame Beach	Plymouth	0.35
Duxbury Beach	Plymouth	3.86
Plymouth Long Beach	Plymouth	2.48
White Horse Beach	Plymouth	0.15
Manomet Beach	Plymouth	0.16
Ellisville Harbor State Park	Plymouth	0.38
Shifting Lots Preserve	Plymouth	0.18
Scusset Beach State Reservation	Barnstable	0.44
Town Neck (Horizons) Beach	Barnstable	0.28
Town Neck (Boardwalk) Beach	Barnstable	0.44
Torrey Beach Community Association Beach	Barnstable	0.79
Sandy Neck	Barnstable	7.17
Chapin 4x4 Beach	Barnstable	0.66
Chapin Memorial Beach	Barnstable	0.41
Mayflower Beach	Barnstable	0.26
Corporation Beach	Barnstable	0.18
Cold Storage Beach	Barnstable	0.17
Crowes Beach	Barnstable	0.64
Wing Island Beach	Barnstable	0.52
Paines Creek Beach	Barnstable	0.34
Breakwater Landing Beach	Barnstable	0.06
Ellis Landing Beach	Barnstable	0.04
Cape Cod Sea Camps Bay Beach	Barnstable	0.22
Spruce Hill Beach	Barnstable	0.12
Linnell Landing	Barnstable	0.08
Nickerson State Park	Barnstable	0.69
Skacket Beach	Barnstable	0.16
Rock Harbor Beach	Barnstable	0.09
Dyer Prince Beach	Barnstable	0.18
Boat Meadow Beach	Barnstable	0.17

Public / NGO Land	County Location	Approximate Sandy Beach Length in 2015 (miles)
First Encounter Beach	Barnstable	0.54
Saltworks Association & Sunken Meadow Beaches	Barnstable	0.14
Wellfleet Bay Wildlife Sanctuary	Barnstable	1.25
Wharf Point Conservation Area	Barnstable	0.12
Old Wharf Point	Barnstable	0.09
Fox Island WMA	Barnstable	0.28
Indian Neck Beach	Barnstable	0.24
Mayo (Kendrick) Beach	Barnstable	0.22
Cape Cod National Seashore[1]	Barnstable	58.16
Corn Hill Beach	Barnstable	0.13
South Beach / Chatham Inlet islets[2]	Barnstable	3.52
Monomoy NWR	Barnstable	11.10
Hardings Beach East	Barnstable	0.10
Stage Harbor Dike (Morris Island)	Barnstable	0.23
Hardings Beach	Barnstable	1.17
Ridgevale Beach	Barnstable	0.27
Forest Beach	Barnstable	0.49
Pleasant Street Beach	Barnstable	0.05
Red River Beach	Barnstable	0.09
Red River Beach	Barnstable	0.50
Merkel Beach (Snow Inn Road)	Barnstable	0.26
Allen Harbor Beach	Barnstable	0.16
Pleasant Road Beach	Barnstable	0.09
Sea Street Beach	Barnstable	0.10
Glendon Road Beach	Barnstable	0.08
Haigis Beach	Barnstable	0.06
Davis Beach	Barnstable	0.13
West Dennis Beach	Barnstable	1.20
Bass River Beach	Barnstable	0.15
South Middle Beach	Barnstable	0.05
Parkers River Beach	Barnstable	0.10
Seaview Beach	Barnstable	0.05
Thachers Beach	Barnstable	0.04
Seagull Beach	Barnstable	0.44
Great Island (Yarmouth)	Barnstable	1.55
Point Gammon	Barnstable	0.13

Public / NGO Land	County Location	Approximate Sandy Beach Length in 2015 (miles)
Kalmas Beach Park	Barnstable	0.50
Keyes Beach	Barnstable	0.37
East (Town) Beach	Barnstable	0.13
Covell's Beach	Barnstable	0.12
Craigville Beach	Barnstable	0.23
Dowses Beach	Barnstable	0.46
Dead Neck Island	Barnstable	1.36
Sampson Island	Barnstable	0.48
Loops Beach	Barnstable	0.04
Meadow Point Conservation Area	Barnstable	0.11
Popponesset Beach	Barnstable	0.49
Popponesset Beach	Barnstable	0.33
Popponesset Beach Access	Barnstable	0.08
Waquoit Bay NERR (South Cape Beach State Park)	Barnstable	1.49
South Cape Beach Town Park	Barnstable	0.25
Waquoit Bay NERR (Washburn Island)	Barnstable	1.14
Menauhant Yacht Club Beach	Barnstable	0.10
Menauhant Beach	Barnstable	0.30
Haddad Beach	Barnstable	0.11
Acapesket Improvement Association Beach	Barnstable	0.20
Bristol 1 Beach	Barnstable	0.24
Bristol 2 Beach	Barnstable	0.12
Falmouth Heights Beach	Barnstable	0.37
Surf Drive Beach	Barnstable	0.53
Shining Sea Bikeway	Barnstable	0.61
Nobska Beach Association Beach	Barnstable	0.19
Stoney Beach	Barnstable	0.05
The Knob	Barnstable	0.14
Wood Neck Beach	Barnstable	0.20
Great Sippewissett Marsh	Barnstable	0.18
Great Sippewissett Marsh (Black Beach)	Barnstable	0.30
Chapoquoit Beach	Barnstable	0.05
Little Island Beach Preserve	Barnstable	0.13
Old Silver 2 Beach	Barnstable	0.27
Megansett Beach	Barnstable	0.11
Lawrence Island	Barnstable	0.49

Public / NGO Land	County Location	Approximate Sandy Beach Length in 2015 (miles)
Bassetts Island Landing	Barnstable	0.51
Tahanto Beach	Barnstable	0.25
Monks Marine Park	Barnstable	0.17
Tobys Island	Barnstable	0.32
Monument Beach	Barnstable	0.20
Mashnee Island Dike	Barnstable	1.74
Onset Beach	Plymouth	0.93
Stony Point Dike	Plymouth	0.83
Little Harbor Beach	Plymouth	0.44
Gray Easement	Plymouth	0.08
Swift's Beach	Plymouth	0.33
Gleason Cromesett Preserve	Plymouth	0.23
Planting Island Beach	Plymouth	0.25
Silver Shell Beach	Plymouth	0.14
Aucot Cove Conservation Area	Plymouth	0.12
Aucot Road Town Beach	Plymouth	0.11
Avenue B Beach	Plymouth	0.10
Bay Road Beach	Plymouth	0.07
Mattapoisett Town Beach	Plymouth	0.07
Land Trust Reservation Beach	Plymouth	0.13
Mattapoisett Harbor Public Beach	Plymouth	0.26
YMCA Beach	Plymouth	0.28
Antasawomak Beach	Plymouth	0.14
West Island State Reservation	Bristol	1.14
West Island Town Beach	Bristol	0.99
Winseganett Beaches	Bristol	0.66
Manhattan Avenue Beach	Bristol	0.08
Fort Phoneix State Reservation	Bristol	0.31
O'Tools Extension, O'Tools, Tower 1-4 Beaches	Bristol	0.38
Tabor Beaches	Bristol	0.23
Jones Town Beach	Bristol	0.10
Nonquitt Marsh	Bristol	0.28
Round Hill Beach	Bristol	0.51
Salter's Point South Beach	Bristol	0.42
Demarest Lloyd State Park	Bristol	0.85
Clagett Easement	Bristol	0.25

Public / NGO Land	County Location	Approximate Sandy Beach Length in 2015 (miles)
Slocums Neck Easement	Bristol	1.02
Allens Pond Wildlife Sanctuary	Bristol	0.86
East Beach	Bristol	0.27
Horseneck Beach State Reservation	Bristol	3.42
Baker's Beach	Bristol	0.93
Westport Harbor Lighthouse	Bristol	0.04
Beach Avenue Beach	Bristol	0.07
Elephant Beach	Bristol	0.34
Nashawena Island	Dukes	1.77
Pekinese Island Sanctuary	Dukes	0.16
Cuttyhunk Island Easement	Dukes	0.48
Eastville Point Beach	Dukes	0.17
East Chop Beach	Dukes	0.12
Marinelli Beach	Dukes	0.07
Oak Bluffs Town Beach	Dukes	0.12
Seaview (Pay & Inkwell) Beach	Dukes	0.38
Joseph Sylvia State Beach	Dukes	2.11
Ox Pond Meadow and Little Beach Preserve	Dukes	0.49
Lighthouse Beach	Dukes	0.41
Chappy Point Beach	Dukes	0.14
Chappaquiddick Road Preserve	Dukes	0.10
North Neck Road Tract	Dukes	0.04
North Neck Highlands Preserve	Dukes	0.14
Cape Poge Wildlife Refuge (East Beach)	Dukes	5.52
Cape Poge Light	Dukes	0.08
Wasque Point WMA (Leland Beach)	Dukes	1.47
Wasque Point	Dukes	-
Norton Point Beach	Dukes	2.32
South (Katama) Beach State Park	Dukes	0.99
Herring Creek Farm Conservation Area	Dukes	0.38
Edgartown Great Pond Beach	Dukes	0.12
Mashacket Beach	Dukes	0.10
Schley Easement	Dukes	0.11
Long Point Wildlife Refuge	Dukes	0.99
Tisbury Great Pond Beach	Dukes	0.11
Quansoo Beach Preserve	Dukes	0.04

Public / NGO Land	County Location	Approximate Sandy Beach Length in 2015 (miles)
Lucy Vincent Beach	Dukes	0.45
Squibnocket Beach	Dukes	0.43
Squibnocket Pond	Dukes	0.93
Moshup Trail Conservation Area	Dukes	0.15
Indian Lands Preserve	Dukes	0.05
Moshup Beach	Dukes	1.84
Lobsterville Beach	Dukes	0.17
Dogfish Bar Beach Access	Dukes	0.03
Lobsterville Beach	Dukes	1.57
Menemsha Beach	Dukes	0.26
Menemsha Hills Reservation	Dukes	0.26
Seven Gates Easements	Dukes	1.17
Cedar Tree Neck Sanctuary	Dukes	0.60
Lambert's Cove Beach	Dukes	0.22
Pilot Hill Farm Conservation Area	Dukes	0.09
Emmet Easement	Dukes	0.11
Herring Creek Beach	Dukes	-
Wilfrids Pond Preserve	Dukes	0.13
West Chop Lighthouse	Dukes	0.06
West Chop Scenic Vista	Dukes	0.07
Owen Little Way Beach	Dukes	0.06
Owen Park Beach	Dukes	0.03
Gosnold WMA (Cuttyhunk Island)	Dukes	0
Noman's Land Island NWR	Dukes	1.04
Coatue Preserve	Nantucket	3.62
Coskata - Coatue Wildlife Refuge	Nantucket	8.77
Nantucket NWR	Nantucket	0.56
The Haulover	Nantucket	0.40
Conover Easements	Nantucket	0.20
Squam Pond	Nantucket	0.06
Sesechacha Heathlands Wildlife Sanctuary	Nantucket	0.35
Sankaty Beach	Nantucket	0.30
Low Beach	Nantucket	0.65
USCG LORAN Station	Nantucket	0.53
Tom Nevers Beach	Nantucket	0.48
Wanoma Way Beach	Nantucket	0.37

Public / NGO Land	County Location	Approximate Sandy Beach Length in 2015 (miles)
Tom Nevers Road beach (aka Navy Base)	Nantucket	0.20
South Shore beach tract	Nantucket	0.09
Madequecham & Tom Nevers Preserve	Nantucket	1.28
Surfside Beach	Nantucket	0.14
Surfside 2 Beach	Nantucket	0.36
Surfside Beach	Nantucket	0.04
Surfside Beach	Nantucket	0.07
Miacomet & Sewerbeds Beach	Nantucket	1.17
Smooth Hummocks Coastal Preserve	Nantucket	0.43
Miacoment Heath WMA	Nantucket	0.11
Reedy Pond beach tracts	Nantucket	0.36
Cisco Beach	Nantucket	0.50
Ram Pasture	Nantucket	0.39
Head of the Plains	Nantucket	1.30
Madaket Wildlife Sanctuary	Nantucket	0.02
Smith Point / Esther Island	Nantucket	2.03
Little Neck tract	Nantucket	0.12
Warren's Landing tract	Nantucket	0.12
Warren's Landing Beach	Nantucket	0.19
Eel Point Preserve	Nantucket	1.19
40th Pole 1 Beach / Fishers Landing	Nantucket	0.22
Dionis Beach	Nantucket	0.22
Capaum Pond Conservation Area	Nantucket	0.18
Washing Pond Beach	Nantucket	0.05
Tupancy Links	Nantucket	0.08
Reed Pond Easement	Nantucket	0.17
Jetties Beach Recreation Area	Nantucket	0.36
Brant Point Lighthouse	Nantucket	0.10
Muskeget Island	Nantucket	2.60
Taylor Easement, Tuckernuck Island	Nantucket	0.10
Tuckernuck Island	Nantucket	0.09
Salt Box Easement, Tuckernuck Island	Nantucket	0.27
North Head & Howard/Harper Easements, Tuckernuck Island	Nantucket	0.59
Phinney / Stevens Easement, Tuckernuck Island	Nantucket	0.19
Hussey & Stone Easements, Tuckernuck Island	Nantucket	0.08

Public / NGO Land	County Location	Approximate Sandy Beach Length in 2015 (miles)
Tristam, Carlisle & Lafarge Tuckernuck Trust Easements, Tuckernuck Island	Nantucket	0.96
Lafarge Tuckernuck Trust Easement, Tuckernuck Island	Nantucket	0.54
Stone East End Easement, Tuckernuck Island	Nantucket	0.05
Howard & Hopkins Easements, Tuckernuck Island	Nantucket	0.09
	TOTAL MILES	**241.50 (53% of sandy beach shoreline)**

1 – Cape Cod NS as listed here includes some private inholdings and segments of beach owned and managed by various towns.

2 – Chatham Inlet reopened on the Nauset barrier spit in 2013. The northernmost section of South Beach (south of Chatham Inlet) and 4 of the 5 islets present within Chatham Inlet in 2015 are owned and managed by the Town of Chatham but are within the jurisdiction of Cape Cod NS (Kate Iaquinto, USFWS, pers. communication 1/23/2017; Mark Adams, NPS, pers. communication, 1/25/2017).

Table D-3. The length and proportion of shoreline within each community (from north to south) along the oceanfront shoreline of Massachusetts that was modified with hard shoreline stabilization, or armor, in 2015. Note that the length of armored shoreline with no beach is the length of shoreline where sandy beaches were absent seaward of armor in May 2015 but where evidence indicated sandy beaches would be present in the absence of the armor.

Community	Known Approximate Length of Armored Sandy Beach Shoreline (miles)	Approximate Length of Armored Shoreline with No Sandy Beach (miles)	Total Length of Armored Sandy Shoreline (miles)	Percentage of Sandy Shoreline Modified with Armor
Salisbury	0.141	-	0.141	4%
Newburyport	0.040	-	0.040	12%
Newbury	0.675	-	0.675	17%
Rowley	-	-	-	-
Ipswich	-	-	-	-
Gloucester	0.056	-	0.056	3%
Rockport	1.218	-	1.218	67%
Manchester	1.384	0.130	1.515	68%
Beverly	2.398	0.461	2.859	82%
Salem	0.080	0.309	0.389	89%
Marblehead	0.948	0.464	1.411	67%
Swampscott	1.379	0.194	1.573	85%
Lynn	0.430	0.553	0.984	100%
Nahant	1.464	1.816	3.280	70%
Revere	3.314	0.768	4.082	88%
Winthrop	3.277	1.968	5.246	90%
Boston	3.153	4.904	8.057	40%
Quincy	4.474	5.536	10.010	87%
Weymouth	1.038	0.586	1.623	57%
Hingham	0.016	-	0.016	5%
Hull	2.599	2.683	5.282	74%
Cohasset	0.269	-	0.269	24%
Scituate	3.087	3.136	6.223	54%
Marshfield	3.021	0.698	3.719	79%
Duxbury	1.317	0.900	2.217	31%
Kingston	0.369	0.908	1.277	78%
Plymouth	8.179	1.076	9.254	51%
Sandwich	3.099	-	3.099	38%
Barnstable	4.783	0.080	4.863	25%
Yarmouth	4.102	0.782	4.884	72%
Dennis	5.706	0.098	5.804	54%
Brewster	2.349	-	2.349	40%
Orleans	-	-	-	-

Community	Known Approximate Length of Armored Sandy Beach Shoreline (miles)	Approximate Length of Armored Shoreline with No Sandy Beach (miles)	Total Length of Armored Sandy Shoreline (miles)	Percentage of Sandy Shoreline Modified with Armor
Eastham	2.037	-	2.037	19%
Wellfleet	1.918	0.853	2.771	13%
Truro	1.774	-	1.774	9%
Provincetown	2.586	0.213	2.799	17%
Chatham	1.571	0.015	1.586	6%
Harwich	2.816	0.097	2.913	71%
Mashpee	0.604	0.479	1.083	21%
Falmouth	7.460	2.779	10.239	57%
Bourne	3.321	1.323	4.644	41%
Wareham	3.200	4.286	7.486	54%
Marion	1.772	0.147	1.919	51%
Mattapoisett	1.975	2.096	4.071	55%
Fairhaven	3.471	0.963	4.433	47%
New Bedford	1.158	1.895	3.052	100%
Dartmouth	1.991	1.269	3.260	31%
Westport	0.291	0.119	0.410	5%
Gosnold	0.505	0.081	0.586	5%
Oak Bluffs	1.948	1.316	3.263	59%
Edgartown	0.892	0.171	1.063	5%
West Tisbury	0.318	0.138	0.455	6%
Chilmark	0.302	-	0.302	3%
Aquinnah	-	-	-	-
Tisbury	1.555	1.571	3.126	50%
Nantucket	1.555	-	1.555	3%
TOTAL	**109.382**	**47.860**	**157.242**	**31%**

Table D-4. The length of shoreline known to be modified by sediment placement projects in each community (from north to south) along the oceanfront shoreline of Massachusetts and the proportions of each that were in pre-existing project areas or new placement areas.

Community	Pre-existing Sediment Placement Project Areas (miles)	New Sediment Placement Project Areas 2012-2015 (miles)	Total Length of Shoreline Modified by Sediment Placement as of 2015 (miles)	Percentage of Shoreline Modified with Sediment Placement as of 2015
Salisbury	0.57	-	0.57	16%
Newburyport	0	-	0	0%
Newbury	0.82	-	0.82	20%
Rowley	0	-	0	0%
Ipswich	0	-	0	0%
Gloucester	> 0	-	> 0	> 0%
Rockport	0	-	0	0%
Manchester	0	-	0	0%
Beverly	0.14	-	0.14	4%
Salem	0	-	0	0%
Marblehead	0	-	0	0%
Swampscott	0	-	0	0%
Lynn	0.49	-	0.49	50%
Nahant	0	-	0	0%
Revere	2.93	-	2.93	63%
Winthrop	0.8	-	0.80	14%
Boston	> 0	-	> 0	> 0%
Quincy	1.61	-	1.61	14%
Weymouth	0.49	-	0.49	17%
Hingham	0	-	0	0%
Hull	1.31	-	1.31	18%
Cohasset	> 0	0.20	> 0.20	> 18%
Scituate	0.47	-	0.47	4%
Marshfield	> 0	-	> 0	> 0%
Duxbury	> 0.24	-	0.24	3%
Kingston	0	-	0	0%
Plymouth	> 0.25	-	> 0.25	> 1%
Sandwich	> 0	0.48	> 0.48	> 6%
Barnstable	> 0.45	-	> 0.45	> 2%
Yarmouth	> 0	-	> 0	> 0%
Dennis	> 0	-	> 0	> 0%
Brewster	0	0.62	0.62	11%
Orleans	0	-	0	0%
Eastham	0	-	0	0%
Wellfleet	0	-	0	0%
Truro	> 0	-	> 0	> 0%

Community	Pre-existing Sediment Placement Project Areas (miles)	New Sediment Placement Project Areas 2012-2015 (miles)	Total Length of Shoreline Modified by Sediment Placement as of 2015 (miles)	Percentage of Shoreline Modified with Sediment Placement as of 2015
Provincetown	0	-	0	0%
Chatham	> 2.58	-	> 2.58	> 10%
Harwich	> 0.08	-	> 0.08	> 2%
Mashpee	> 1.05	-	> 1.05	> 20%
Falmouth	> 0.20	-	> 0.20	> 1%
Bourne	> 0	-	> 0	> 0%
Wareham	0.81	-	0.81	6%
Marion	0	-	0	0%
Mattapoisett	0	-	0	0%
Fairhaven	0	-	0	0%
New Bedford	> 0.30	-	> 0.30	> 10%
Dartmouth	0	-	0	0%
Westport	> 0	-	> 0	> 0%
Gosnold	> 0	-	> 0	> 0%
Oak Bluffs	> 0.85	0.12	> 0.97	> 18%
Edgartown	2.77	-	2.77	13%
West Tisbury	0	-	0	0%
Chilmark	0	-	0	0%
Aquinnah	0	0.28	0.28	4%
Tisbury	> 0	-	> 0	> 0%
Nantucket	> 0	-	> 0	> 0%
TOTAL	**> 19.20†**	**1.71**	**> 20.91**	**> 4%**

† This total has been updated from the figure included in Rice (2015b) to include data from new information sources.

Table D-5. The length and proportion of sandy beach within each community (from north to south) along the oceanfront shoreline of Massachusetts that was modified with beach scraping or grading from 2012 to 2015.

Community	Length of Sandy Beach Modified with Beach Scraping (miles)	Percentage of Shoreline Modified with Beach Scraping
Salisbury	-	-
Newburyport	-	-
Newbury	0.14	4%
Rowley	-	-
Ipswich	-	-
Gloucester	-	-
Rockport	-	-
Manchester	-	-
Beverly	-	-
Salem	-	-
Marblehead	-	-
Swampscott	-	-
Lynn	-	-
Nahant	-	-
Revere	-	-
Winthrop	-	-
Boston	-	-
Quincy	-	-
Weymouth	-	-
Hingham	-	-
Hull	-	-
Cohasset	-	-
Scituate	-	-
Marshfield	-	-
Duxbury	-	-
Kingston	-	-
Plymouth	-	-
Sandwich	-	-
Barnstable	-	-
Yarmouth	-	-
Dennis	-	-
Brewster	-	-
Orleans	-	-
Eastham	-	-
Wellfleet	-	-
Truro	-	-

Community	Length of Sandy Beach Modified with Beach Scraping (miles)	Percentage of Shoreline Modified with Beach Scraping
Provincetown	-	-
Chatham	-	-
Harwich	-	-
Mashpee	-	-
Falmouth	-	-
Bourne	-	-
Wareham	-	-
Marion	-	-
Mattapoisett	-	-
Fairhaven	-	-
New Bedford	-	-
Dartmouth	-	-
Westport	-	-
Gosnold	-	-
Oak Bluffs	0.27	6%
Edgartown	-	-
West Tisbury	-	-
Chilmark	-	-
Aquinnah	-	-
Tisbury	-	-
Nantucket	-	-
TOTAL	0.41	0.1%

Table D-6. The length and proportion of sandy beach within each community (from north to south) along the oceanfront shoreline of Massachusetts that was modified with the installation of sand fencing from 2012 to 2015.

Community	Length of Sandy Beach Modified with Sand Fencing (miles)	Percentage of Shoreline Modified with Sand Fencing
Salisbury	3.24	91%
Newburyport	0.08	27%
Newbury	0.80	20%
Rowley	0	-
Ipswich	0	-
Gloucester	0.51	27%
Rockport	0	-
Manchester	0	-
Beverly	0	-
Salem	0	-
Marblehead	0	-
Swampscott	0	-
Lynn	0	-
Nahant	0.10	4%
Revere	0.12	3%
Winthrop	0.33	8%
Boston	0	-
Quincy	0	-
Weymouth	0	-
Hingham	0	-
Hull	0.03	1%
Cohasset	0	-
Scituate	0.16	2%
Marshfield	0.04	1%
Duxbury	3.30	52%
Kingston	0	-
Plymouth	1.58	9%
Sandwich	0.32	4%
Barnstable	0.36	2%
Yarmouth	0.18	3%
Dennis	0.48	5%
Brewster	0.67	11%
Orleans	0.004	0.1%
Eastham	0.74	7%
Wellfleet	0.12	1%
Truro	1.74	9%
Provincetown	0.05	0.3%
Chatham	0.10	0.4%

Community	Length of Sandy Beach Modified with Sand Fencing (miles)	Percentage of Shoreline Modified with Sand Fencing
Harwich	0.14	4%
Mashpee	0.37	8%
Falmouth	0.50	3%
Bourne	0.06	1%
Wareham	0.17	2%
Marion	0	-
Mattapoisett	0	-
Fairhaven	0	-
New Bedford	0	-
Dartmouth	0	-
Westport	0.11	1%
Gosnold	0	-
Oak Bluffs	0.01	0.1%
Edgartown	0.78	4%
West Tisbury	0	-
Chilmark	0	-
Aquinnah	0	-
Tisbury	0.02	0.4%
Nantucket	1.28	2%
TOTAL	**18.50**	**4%**

Appendix E – Rhode Island

Table E-1. Length of sandy beach for each community (from north to south) along the oceanfront shoreline of Rhode Island and the proportion of each that was developed and undeveloped along the immediate beachfront in May 2015 or April 2016.

Community	Length of Sandy Beach (miles)	Percentage of Sandy Beach Developed	Percentage of Sandy Beach Undeveloped
Little Compton	3.69	7%	93%
Portsmouth	0.11	100%	0%
Middletown	2.08	13%	87%
Newport	1.51	33%	67%
Jamestown	0.23	0%	100%
Narragansett	5.14	59%	41%
South Kingstown	5.06	35%	65%
Charlestown	5.83	19%	81%
Westerly	9.74	34%	66%
New Shoreham (Block Island)	13.08	30%	70%
TOTAL	**46.48**	**31%**	**69%**

Table E-2. Sandy beaches that are in public or NGO ownership along the oceanfront shoreline of Rhode Island, the county in which each is located, and the approximate length of sandy beach within each visible in Google Earth imagery in May 2015 or April 2016.

Public / NGO Land	County Location	Approximate Sandy Beach Length in 2015 (miles)
Goosewing Beach Preserve	Newport	0.77
Tunipus Pond / South Shore Beach	Newport	0.21
Briggs Marsh	Newport	0.10
Briggs Marsh Easement	Newport	0.37
Sakonnet Point Easement	Newport	0.55
Third Beach Easement	Newport	0.15
Navy Beach (Third Beach)	Newport	0.33
Sachuest Point NWR	Newport	0.34
Second Beach	Newport	0.88
Atlantic Beach	Newport	0.20
First Beach / Eastons Beach	Newport	0.63
Mackerel Cove Town Beach	Newport	0.23
Kelly Beach	Washington	0.04
Whale Rock	Washington	0.10
Narragansett Town Beach	Washington	0.49
Scarborough State Beach	Washington	0.89
Camp Cronin & Point Judith Lighthouse	Washington	0.35
DiMeo / Noel	Washington	0.18
Roger Wheeler State Beach	Washington	0.45
Salty Brine State Beach	Washington	0.03
East Matunuck State Beach	Washington	0.74
Deep Hole	Washington	0.06
Weeden Farm / South Kingstown Town Beach	Washington	0.26
Trustom Pond NWR	Washington	1.32
Goose Island Access	Washington	0.09
Charlestown Beach Road parcels	Washington	0.07
Charlestown Beach Road parcel	Washington	0.01
Charlestown Beach	Washington	0.07
Charlestown Beach parcels	Washington	0.10
Charlestown Breachway Campground	Washington	0.14
Charlestown Breachway Fishing Area	Washington	0.14
Arnolda Easements	Washington	0.21
Ninigret NWR	Washington	0.20
Governor Island State Park	Washington	0.70
Ninigret Conservation Area	Washington	1.60
Blue Shutters Site	Washington	0.06
Quonchontaug Easements	Washington	0.08
Quonny Beach	Washington	0.03
Quonchontaug Breachway Fishing Area	Washington	0.16
Sand Trail Beach	Washington	0.66

Public / NGO Land	County Location	Approximate Sandy Beach Length in 2015 (miles)
Wawaloam Drive Beach	Washington	0.13
Weekapaug Fishing Area / Breachway	Washington	0.01
Westerly Town Beach	Washington	0.11
Wuskenau Beach, Town of Westerly	Washington	0.06
Misquamicut State Beach	Washington	0.61
Misquamicut Beach tracts	Washington	0.15
Fort Road Beach, Watch Hill	Washington	0.07
Napatree Point Beach	Washington	1.18
Napatree Point	Washington	0.37
Sandy Point Island	Washington	1.19
Singer / Ocean View	Washington	0.23
Spring Pond	Washington	0.11
Green Hill Cove	Washington	0.03
Mohegan Bluff / Delia Easement	Washington	0.07
Southeast Lighthouse[1]	Washington	0
Phelan Tract	Washington	0.19
Mohegan Bluff	Washington	0.17
Barlow Point[1]	Washington	0
Davis & Sugden (Black Rock) Tracts	Washington	0.12
Black Rock	Washington	0.46
Lewis-Dickens Farm	Washington	0.09
Schooner Point[1]	Washington	0
Cooneymus Swamp Easement	Washington	0.02
Stevens Cove Easement	Washington	0.36
Ocean View / Cullinan Easement	Washington	0.26
Charleston Beach	Washington	0.02
Charleston Beach	Washington	0.23
Charleston Beach	Washington	0.08
Block Island NWR	Washington	0.97
Gunners Hill	Washington	0.09
West Beach	Washington	0.71
Sachem Pond	Washington	1.11
Beach Plum Hill / Logwood Cove	Washington	0.28
North Light	Washington	0.05
White Tract	Washington	0.08
Risom Tracts	Washington	0.19
Clay Head Swamp (Lapham) Easement	Washington	1.22
Mansion Beach	Washington	0.11
New Shoreham Town Beach	Washington	1.01
	TOTAL MILES	**26.13 (56% of sandy beach shoreline)**

1 – All of the shorelines within the public or NGO-owned tracts at Southeast Lighthouse, Barlow Point and Schooner Point on Block Island were composed of rocky beaches in May 2015 or April 2016.

Table E-3. The length and proportion of shoreline within each community (from north to south) along the oceanfront shoreline of Rhode Island that was modified with hard shoreline stabilization, or armor, in 2015. Note that the length of armored shoreline with no beach is the length of shoreline where sandy beaches were absent seaward of armor in May 2015 or April 2016 but where evidence indicated sandy beaches would be present in the absence of the armor.

Community	Known Approximate Length of Armored Sandy Beach Shoreline (miles)	Approximate Length of Armored Shoreline with No Sandy Beach (miles)	Total Length of Armored Sandy Shoreline (miles)	Percentage of Sandy Shoreline Modified with Armor
Little Compton	0.40	0.287	0.69	17%
Portsmouth	0.03	0	0.03	26%
Middletown	0.14	0.117	0.26	12%
Newport	0.87	0.037	0.91	59%
Jamestown	0.01	0.044	0.05	18%
Narragansett	1.38	0.106	1.48	28%
South Kingstown	0.06	0.575	0.63	11%
Charlestown	0.56	0	0.56	10%
Westerly	1.04	0.463	1.51	15%
New Shoreham (Block Island)	0.14	0.268	0.40	3%
TOTAL	**4.62**	**1.895**	**6.51**	**13%**

Table E-4. The length of shoreline known to be modified by sediment placement projects in each community (from north to south) along the oceanfront shoreline of Rhode Island and the proportions of each that were in pre-existing project areas or new placement areas. Additional beaches are known to have been previously modified by sediment placement but precise location information was not available.

Community	Pre-existing Sediment Placement Project Areas (miles)	New Sediment Placement Project Areas 2012-2015 (miles)	Total Length of Shoreline Modified by Sediment Placement as of 2015 (miles)	Percentage of Shoreline Modified with Sediment Placement as of 2015
Little Compton	0.31	0	0.31	8%
Portsmouth	0	0	0	0%
Middletown	0	0	0	0%
Newport	0.44	0	0.44	28%
Jamestown	0.13	0.08	0.21	78%
Narragansett	> 1.82	0	> 1.82	> 35%
South Kingstown	0.82	0.08	0.89	16%
Charlestown	> 0.04	0	> 0.04	> 1%
Westerly	> 2.59	0.71	> 3.30	> 32%
New Shoreham (Block Island)	> 0	0	> 0	> 0%
TOTAL	**> 6.15**	**0.87**	**> 7.02**	**> 15%**

Table E-5. The length and proportion of sandy beach within each community (from north to south) along the oceanfront shoreline of Rhode Island that was modified with beach scraping or grading from 2012 to 2015.

Community	Length of Sandy Beach Modified with Beach Scraping (miles)	Percentage of Shoreline Modified with Beach Scraping
Little Compton	0.22	6%
Portsmouth	0	0%
Middletown	0.67	32%
Newport	0.38	25%
Jamestown	0	0%
Narragansett	0.49	10%
South Kingstown	0	0%
Charlestown	0	0%
Westerly	1.22	13%
New Shoreham (Block Island)	0.13	1%
TOTAL	**3.10**	**7%**

Table E-6. The length and proportion of sandy beach within each community (from north to south) along the oceanfront shoreline of Rhode Island that was modified with the installation of sand fencing from 2012 to 2015.

Community	Length of Sandy Beach Modified with Sand Fencing (miles)	Percentage of Shoreline Modified with Sand Fencing
Little Compton	0.21	6%
Portsmouth	0	0%
Middletown	0.46	22%
Newport	0.05	3%
Jamestown	0.12	50%
Narragansett	1.16	22%
South Kingstown	1.73	34%
Charlestown	1.33	23%
Westerly	2.88	30%
New Shoreham (Block Island)	0.55	4%
TOTAL	**8.49**	**18%**

Appendix F – Connecticut

Table F-1. Length of sandy beach for each community (from north to south) along the oceanfront shoreline of Connecticut and the proportion of each that was developed and undeveloped along the immediate beachfront in September 2015 (west of Westport) or April 2016 (east of Old Saybrook).

Community	Length of Sandy Beach (miles)	Percentage of Sandy Beach Developed	Percentage of Sandy Beach Undeveloped
Stonington	1.58	46%	54%
Groton	2.94	38%	62%
New London	1.42	74%	26%
Waterford	2.88	27%	73%
East Lyme	3.04	57%	43%
Old Lyme	4.16	41%	59%
Old Saybrook	3.45	75%	25%
Westbrook	4.08	76%	24%
Clinton	3.24	58%	42%
Madison	5.91	48%	52%
Guilford	1.14	26%	74%
Branford	1.92	89%	11%
East Haven	1.93	93%	7%
New Haven	1.90	24%	76%
West Haven	3.98	3%	97%
Milford	7.25	64%	36%
Stratford	4.00	29%	71%
Bridgeport	3.57	10%	90%
Fairfield	4.47	68%	32%
Westport	7.77	46%	54%
Norwalk	9.12	20%	80%
Darien	1.22	53%	47%
Stamford	3.67	71%	29%
Greenwich[1]	3.67	22%	78%
TOTAL	**88.29**	**46%**	**54%**

1 – The length of sandy beach measured in the westernmost section of shoreline in Greenwich was measured using October 2014 imagery; no 2015 imagery was available for this area.

Table F-2. Sandy beaches that are in public or NGO ownership along the oceanfront shoreline of Connecticut, the county in which each is located, and the approximate length of sandy beach within each visible in Google Earth imagery in September 2015 (west of Westbrook) or April 2016 (east of Old Saybrook).

Public / NGO Land	County Location	Approximate Sandy Beach Length in 2015 (miles)
Sandy Point	New London	0.12
Ram Point	New London	0.16
Esker Point Beach	New London	0.10
Bluff Point State Park & Coastal Reserve	New London	1.52
Eastern Point Beach	New London	0.13
Ocean Beach Park	New London	0.37
Waterford Beach Park	New London	0.33
Harkness Memorial State Park	New London	0.35
Dr. William A. Niering Natural Area Preserve	New London	0.13
Seaside State Park	New London	0.05
Jordan Cove Water Access[1]	New London	-
Railroad Beach, Cini Memorial Park	New London	0.49
Hole-in-the-wall Beach	New London	0.12
McCook Point Park	New London	0.11
Pattagansett Marshes	New London	0.30
Rocky Neck State Park	New London	0.50
Hatchetts Point	New London	0.26
Griswold Point	New London	0.43
Great Island Marshes	New London	0.42
Lynde Point	Middlesex	0.51
Old Saybrook Town Beach	Middlesex	0.04
Harvey's Beach[1]	Middlesex	-
Westbrook Town Beach	Middlesex	0.53
Seaside Avenue Open Space	Middlesex	0.05
Menunketesuck Island	Middlesex	0.56
Duck Island Wildlife Area	Middlesex	0.12
Clinton Town Beach	Middlesex	0.41
Hammonasset Natural Area Preserve (State Park)	Middlesex & New Haven	3.08
East Wharf Beach	New Haven	0.08
West Wharf Beach	New Haven	0.21
Grass Island	New Haven	0.52
Jacob's Beach	New Haven	0.12
East Haven Town Beach	New Haven	0.16
Lighthouse Point Park	New Haven	0.28
Fort Hale Park	New Haven	0.16
East Shore Park	New Haven	0.65
Long Wharf Park	New Haven	0.31

Public / NGO Land	County Location	Approximate Sandy Beach Length in 2015 (miles)
Sandy Point Bird Sanctuary	New Haven	1.23
East Beach	New Haven	1.23
Bradley Point Park	New Haven	0.25
Seabluff & Prospect Beaches	New Haven	1.15
Gulf Beach	New Haven	0.32
Silver Sands State Park	New Haven	0.64
Walnut Beach	New Haven	0.33
Smith-Hubbell Wildlife Refuge and Bird Sanctuary	New Haven	0.55
Milford Point Unit, Stewart B. McKinney NWR	New Haven	0.46
Short Beach Park	Fairfield	0.68
Long Beach West	Fairfield	1.54
Pleasure Beach Park	Fairfield	0.91
Seaside Park	Fairfield	1.95
St. Mary's by-the-Sea	Fairfield	0.11
Jennings Beach	Fairfield	0.39
Penfield Beach	Fairfield	0.21
Sasco Beach	Fairfield	0.13
Southport Beach	Fairfield	0.21
Sasco Creek Beach	Fairfield	0.07
Burying Hill Beach & Wetlands	Fairfield	0.12
Sherwood Island State Park	Fairfield	1.02
Compo Beach & Marina	Fairfield	0.90
Cockenoe Island	Fairfield	1.66
Goose Island	Fairfield	0.20
Westport Longshore Club Park	Fairfield	0.16
Shady Beach	Fairfield	0.20
Calf Pasture Park	Fairfield	0.51
Peach Island Unit, Stewart B. McKinney NWR	Fairfield	0.20
Grassy Island	Fairfield	0.55
Chimon Island Unit, Stewart B. McKinney NWR	Fairfield	1.17
Sheffield Island Unit, Stewart B. McKinney NWR	Fairfield	1.64
Shea (Ram) Island	Fairfield	0.87
The Plains (island)	Fairfield	0.60
Bayley Beach, Neville Bayley Park	Fairfield	0.07
Pear Tree Point Beach Park	Fairfield	0.19
Weed Beach	Fairfield	0.21
Cove Island Park	Fairfield	0.37
Cummings Park	Fairfield	0.31
West Beach, Cummings Park	Fairfield	0.17
Greenwich Point Park (Tod's Point)	Fairfield	0.84
Pelican Island	Fairfield	0.21
Greenwich Island islet	Fairfield	0.16
Calf Island Unit, Stewart B. McKinney NWR	Fairfield	0.33

Public / NGO Land	County Location	Approximate Sandy Beach Length in 2015 (miles)
Byram Park	Fairfield	0.11
Shell Island	Fairfield	0.12
Great Captain Island	Fairfield	0.73
Little Captain Island (aka Island Beach)	Fairfield	0.18
	TOTAL MILES	**39.66 (44% of sandy beach shoreline)**

1 – Neither the Jordan Cove Water Access nor Harvey's Beach had at least 500 ft of sandy beach habitat present in 2015.

Table F-3. The length and proportion of shoreline within each community (from north to south) along the oceanfront shoreline of Connecticut that was modified with hard shoreline stabilization, or armor, in 2015. Note that the length of armored shoreline with no beach is the length of shoreline where sandy beaches were absent seaward of armor in September 2015 (west of Westbrook) or April 2016 (east of Old Saybrook) but where evidence indicated sandy beaches would be present in the absence of the armor.

Community	Known Approximate Length of Armored Sandy Beach Shoreline (miles)	Approximate Length of Armored Shoreline with No Sandy Beach (miles)	Total Length of Armored Sandy Shoreline (miles)	Percentage of Sandy Shoreline Modified with Armor
Stonington	0.33	0.098	0.42	25%
Groton	1.01	0.182	1.19	38%
New London	0.75	0.448	1.20	64%
Waterford	0.45	0.583	1.03	30%
East Lyme	1.44	1.670	3.11	66%
Old Lyme	1.18	0.430	1.61	35%
Old Saybrook	1.98	1.622	3.60	71%
Westbrook	2.54	0.482	3.03	66%
Clinton	1.57	0.812	2.38	59%
Madison	1.95	1.111	3.06	44%
Guilford	0.20	0.352	0.56	37%
Branford	1.11	0.154	1.26	61%
East Haven	1.02	0.351	1.37	60%
New Haven	0.58	1.418	2.00	60%
West Haven	2.19	0.142	2.33	57%
Milford	3.34	0.156	3.50	47%
Stratford	1.95	0.289	2.24	52%
Bridgeport	1.73	1.079	2.81	60%
Fairfield	2.69	0.499	3.19	64%
Westport	3.98	1.737	5.72	60%
Norwalk	2.50	2.178	4.68	41%
Darien	1.00	0.895	1.90	90%
Stamford	2.76	0.161	2.92	76%
Greenwich	1.12	1.271	2.40	48%
TOTAL	**39.38**	**18.12**	**57.50**	**54%**

Table F-4. The length of shoreline known to be modified by sediment placement projects in each community (from north to south) along the oceanfront shoreline of Connecticut and the proportions of each that were in pre-existing project areas or new placement areas.

Community	Pre-existing Sediment Placement Project Areas (miles)	New Sediment Placement Project Areas 2012-2015 (miles)	Total Length of Shoreline Modified by Sediment Placement as of 2015 (miles)	Percentage of Shoreline Modified with Sediment Placement as of 2015
Stonington	0	0	0	0%
Groton	> 0	0	> 0	0%
New London	> 0.15	0	> 0.15	8%
Waterford	> 0	0	> 0	0%
East Lyme	0	0.49	0.49	10%
Old Lyme	0.44	0.11	0.55	12%
Old Saybrook	0.30	0	0.30	6%
Westbrook	0	0	0	0%
Clinton	> 0	0	> 0	0%
Madison	1.89	0	1.89	27%
Guilford	> 0.08	0	> 0.08	5%
Branford	0†	0	0	0%
East Haven	0.48	0	0.48	21%
New Haven	0	0	0	0%
West Haven	> 1.41	0	> 1.41	34%
Milford	3.51	0	3.51	47%
Stratford	> 0.66	0	> 0.66	15%
Bridgeport	> 1.67	0	> 1.67	36%
Fairfield	2.20	0	2.20	44%
Westport	1.93	0	1.93	20%
Norwalk	0.42	0	0.42	4%
Darien	0	0.09	0.09	4%
Stamford	0.44	0	0.44	11%
Greenwich	0	0	0	0%
TOTAL	**> 15.58**	**0.69**	**> 16.27**	**15%**

† One sediment placement project modified 0.06 miles (0.10 km) of beach in Branford in 1963, but the pocket beach was less than 500 ft (152 m) in length in 2015 and was not included in this assessment.

Table F-5. The length and proportion of sandy beach within each community (from north to south) along the oceanfront shoreline of Connecticut that was modified with beach scraping or grading from 2012 to 2015.

Community	Length of Sandy Beach Modified with Beach Scraping (miles)	Percentage of Shoreline Modified with Beach Scraping
Stonington	0	0%
Groton	0.08	2.7%
New London	0	0%
Waterford	0	0%
East Lyme	0	0%
Old Lyme	0.08	1.8%
Old Saybrook	0.04	1.1%
Westbrook	0.19	4.6%
Clinton	0	0%
Madison	0.10	1.6%
Guilford	0.08	7.0%
Branford	0	0%
East Haven	0.13	6.9%
New Haven	0	0%
West Haven	0.08	1.9%
Milford	0.65	9.0%
Stratford	0.27	6.7%
Bridgeport	0	0%
Fairfield	0	0%
Westport	0.63	8.1%
Norwalk	0.17	1.9%
Darien	0.12	10.1%
Stamford	0	0%
Greenwich	0.36	9.9%
TOTAL	**2.97**	**3.4%**

Table F-6. The length and proportion of sandy beach within each community (from north to south) along the oceanfront shoreline of Connecticut that was modified with the installation of sand fencing from 2012 to 2015.

Community	Length of Sandy Beach Modified with Sand Fencing (miles)	Percentage of Shoreline Modified with Sand Fencing
Stonington	0.01	0.8%
Groton	0.04	1.3%
New London	0.40	28.2%
Waterford	0.48	16.7%
East Lyme	0.01	0.5%
Old Lyme	0.05	1.3%
Old Saybrook	0	0%
Westbrook	0.03	0.7%
Clinton	0.02	0.6%
Madison	0.44	7.5%
Guilford	0	0%
Branford	0.02	0.9%
East Haven	0.03	1.3%
New Haven	0.00	0.1%
West Haven	0.19	4.8%
Milford	0.07	0.9%
Stratford	0.11	2.9%
Bridgeport	0.03	0.7%
Fairfield	0.86	19.3%
Westport	0.21	2.7%
Norwalk	0	0%
Darien	0	0%
Stamford	0	0%
Greenwich	0.22	6.0%
TOTAL	**3.23**	**3.7%**

Appendix G – New York – Long Island Sound Shoreline

Table G-1. Length of sandy beach for each community (from east to west) along the Long Island Sound shoreline of New York and the proportion of each that was developed and undeveloped along the immediate beachfront in May 2015. In May 2015 there were 124.19 miles (200 km) of sandy beach and 13.83 miles (22.26 km) of rocky beach on New York's Long Island Sound shoreline; an additional 4.32 miles (6.95 km) of sandy shoreline was armored with no beach present seaward of the armor, for a total shoreline length of 142.35 miles (229.09 km), 62% of which was developed.

Community	Length of Sandy Beach (miles)	Percentage of Sandy Beach Developed	Percentage of Sandy Beach Undeveloped	Length of Rocky Beach (miles)
Fishers Island	9.66	72%	28%	8.59
Plum Island	3.83	10%	90%	3.33
Orient	5.19	63%	37%	0.12
East Marion	2.86	59%	41%	0.07
Greenport	2.11	67%	33%	0.62
Southold	5.44	69%	31%	0.05
Peconic	2.72	66%	34%	-
Mattituck	4.59	56%	44%	-
Jamesport	3.87	58%	42%	-
Riverhead	2.63	41%	59%	-
Baiting Hollow	3.88	78%	22%	-
Wading River	4.46	65%	35%	-
East Shoreham	1.90	47%	53%	-
Shoreham	0.65	100%	0%	-
Rocky Point	2.19	100%	0%	-
Sound Beach	1.53	83%	17%	-
Miller Place	2.20	88%	12%	-
Mt. Sinai	0.86	0%	100%	-
Port Jefferson	0.71	100%	0%	-
Belle Terre	0.83	100%	0%	-
Town of Brookhaven (unincorporated area)	1.00	0%	100%	-
Old Field	5.85	53%	47%	-
Stony Brook	1.34	21%	79%	-
Nissequogue	4.72	48%	52%	-
Fort Salonga	6.26	57%	43%	-
Asharoken	4.25	50%	50%	-
Eatons Neck	2.22	44%	56%	-
Huntington Bay	2.28	87%	13%	-
Lloyd Harbor	9.80	38%	62%	0.52
Cold Spring Harbor	0.64	18%	82%	-
Laurel Hollow	1.80	75%	25%	-
Cove Neck	2.08	84%	16%	-

Community	Length of Sandy Beach (miles)	Percentage of Sandy Beach Developed	Percentage of Sandy Beach Undeveloped	Length of Rocky Beach (miles)
Centre Island	1.90	85%	15%	-
Bayville	2.73	79%	21%	0.48
Locust Valley	0.03	0%	100%	-
Lattingtown	2.18	57%	43%	-
Glen Cove	4.04	80%	20%	0.06
Sea Cliff	0.81	100%	0%	-
Port Washington	0.93	27%	73%	-
Sands Point	7.19	81%	19%	-
TOTAL	**124.19†**	**61%**	**39%**	**13.83**

† An additional 4.32 miles (6.95 km) of sandy shoreline was armored with hard shoreline stabilization structures with no beach present seaward of the armoring in May 2015.

Table G-2. Sandy beaches that are in public or NGO ownership along the Long Island Sound shoreline of New York, the county in which each is located, and the approximate length of sandy beach within each visible in Google Earth imagery in May 2015.

Public / NGO Land	County Location	Approximate Sandy Beach Length in 2015 (miles)
Plum Island	Suffolk	3.83
Orient Point County Park	Suffolk	0.49
Gillespie / Alford Trust Easement	Suffolk	0.09
Truman's Beach	Suffolk	0.29
Ruth Oliva Preserve at Dam Pond	Suffolk	0.06
Cove Beach Easement	Suffolk	0.30
Inlet Pond County Park	Suffolk	0.39
Town Beach	Suffolk	0.19
Booth Trust Easement	Suffolk	0.05
Horton's Point Lighthouse Park	Suffolk	0.17
McCabe's Beach	Suffolk	0.06
Kenney's Beach	Suffolk	0.12
Peconic Dunes County Park / 4-H Camp	Suffolk	0.18
Sound View Dunes Park	Suffolk	0.27
Goldsmith Inlet County Park	Suffolk	0.43
Goldsmith Inlet Park	Suffolk	0.11
Schreiber Trust Easement	Suffolk	0.09
Bailie's Beach Park	Suffolk	0.36
Breakwater Park	Suffolk	0.20
Hallock State Park Preserve	Suffolk	1.08
Iron Pier Beach	Suffolk	0.16
Granttham Preserve	Suffolk	0.12
Reeve Preserve I	Suffolk	0.16
Anderegg Preserve	Suffolk	0.24
Howard M. Reeve Park	Suffolk	0.06
McQuade Preserve	Suffolk	0.11
Baiting Hollow Tidal Wetlands Area	Suffolk	0.34
Wildwood State Park	Suffolk	1.50
Wading River Beach	Suffolk	0.05
Shoreham Beach	Suffolk	0.77
unknown county park/preserve at end of Seacliff Lane in Miller Place	Suffolk	0.26
Cedar Beach	Suffolk	0.84
Village of Port Jefferson Public Beach	Suffolk	0.83
McAllister County Park	Suffolk	1.00
Whitehall Beach	Suffolk	1.27
Flax Pond Tidal Wetlands Area	Suffolk	0.48
West Meadow Beach	Suffolk	1.34
Nissequogue Preserve	Suffolk	0.48

Public / NGO Land	County Location	Approximate Sandy Beach Length in 2015 (miles)
Otto Schubert Beach	Suffolk	0.10
Long Beach Town Park	Suffolk	0.65
The David Weld Sanctuary	Suffolk	0.39
Short Beach	Suffolk	0.68
Sunken Meadow State Park	Suffolk	2.43
Callahan's Beach Park	Suffolk	0.20
Geisslers Beach Park	Suffolk	0.32
Jerome A. Ambro Memorial Wetland Preserve	Suffolk	0.17
Crab Meadow Beach Park	Suffolk	0.21
Kirschbaum Park	Suffolk	0.07
Soundview Beach	Suffolk	0.13
USCG Station Eatons Neck	Suffolk	0.87
Hobart Beach (Sand City) Park	Suffolk	1.16
Crescent Beach Town Park	Suffolk	0.07
Lloyd Neck East Beach	Suffolk	0.80
Target Rock NWR	Suffolk	0.50
Caumsett State Historic Park Preserve	Suffolk	2.94
West Neck Beach	Suffolk	0.31
Lloyd Harbor Park	Suffolk	0.20
Laurel Hollow Beach	Nassau	0.37
Oyster Bay NWR / Sagamore Hill National Historic Site	Nassau	0.21
Soundside Beach Park	Nassau	0.08
Charles E. Ransom Beach (in Bayville)	Nassau	0.21
unnamed public beach in Locust Valley	Nassau	0.03
Stehli Beach (in Lattingtown)	Nassau	0.48
Prybil Beach	Nassau	0.21
Welwyn Preserve County Park	Nassau	0.35
Morgan Memorial Park	Nassau	0.23
Garvies Point Museum & Preserve	Nassau	0.38
Sea Cliff Municipal Beach	Nassau	0.21
Harry Tappen Beach	Nassau	0.21
North Hempstead Beach Park	Nassau	0.67
Sands Point Preserve	Nassau	0.94
	TOTAL MILES	**35.55 (29% of sandy beach shoreline)**

Table G-3. The length and proportion of shoreline within each community (from east to west) along the Long Island Sound shoreline of New York that was modified with hard shoreline stabilization, or armor, in 2015. Note that the length of armored shoreline with no beach is the length of shoreline where sandy beaches were absent seaward of armor in May 2015 but where evidence indicated sandy beaches would be present in the absence of the armor.

Community	Known Approximate Length of Armored Sandy Beach Shoreline (miles)	Approximate Length of Armored Shoreline with No Sandy Beach (miles)	Total Length of Armored Sandy Shoreline (miles)	Percentage of Sandy Shoreline Modified with Armor
Fishers Island	0.69	0.80	1.49	14%
Plum Island	0.50	0.10	0.60	15%
Orient	0.55	0.02	0.57	11%
East Marion	0	0	0	0%
Greenport	0.05	0	0.05	2%
Southold	1.87	0.37	2.24	39%
Peconic	1.11	0	1.11	41%
Mattituck	0.76	0	0.76	17%
Jamesport	1.35	0	1.35	35%
Riverhead	0.20	0	0.20	8%
Baiting Hollow	0.69	0	0.69	18%
Wading River	1.36	0	1.36	31%
East Shoreham	0.31	0	0.31	16%
Shoreham	0.33	0	0.33	50%
Rocky Point	1.46	0	1.46	67%
Sound Beach	1.15	0	1.15	75%
Miller Place	0.75	0	0.75	34%
Mt. Sinai	0	0	0	0%
Port Jefferson	0.27	0.03	0.30	40%
Belle Terre	0.24	0	0.24	29%
Town of Brookhaven (unincorporated area)	0	0	0	0%
Old Field	0.38	0	0.38	6%
Stony Brook	0.39	0	0.39	29%
Nissequogue	0.84	0	0.84	18%
Fort Salonga	2.04	0.05	2.09	33%
Asharoken	1.49	0	1.49	35%
Eatons Neck	1.04	0	1.04	47%
Huntington Bay	1.76	0	1.76	77%
Lloyd Harbor	3.59	0.33	3.91	39%
Cold Spring Harbor	0.12	0	0.12	19%
Laurel Hollow	1.21	0.03	1.24	68%
Cove Neck	0.68	0.04	0.72	34%
Centre Island	1.29	0.39	1.68	73%
Bayville	1.90	0.11	2.02	71%

Community	Known Approximate Length of Armored Sandy Beach Shoreline (miles)	Approximate Length of Armored Shoreline with No Sandy Beach (miles)	Total Length of Armored Sandy Shoreline (miles)	Percentage of Sandy Shoreline Modified with Armor
Locust Valley	0	0	0	0%
Lattingtown	0.57	0.16	0.73	31%
Glen Cove	2.58	0.72	3.30	69%
Sea Cliff	0.54	0.60	1.14	81%
Port Washington	0.40	0.40	0.80	61%
Sands Point	4.49	0.19	4.68	63%
TOTAL	**38.96**	**4.32**	**43.28**	**34%**

Table G-4. The length of shoreline known to be modified by sediment placement projects in each community (from east to west) along the Long Island Sound shoreline of New York and the proportions of each that were in pre-existing project areas or new placement areas.

Community	Pre-existing Sediment Placement Project Areas (miles)	New Sediment Placement Project Areas 2012-2015 (miles)	Total Length of Shoreline Modified by Sediment Placement as of 2015 (miles)	Percentage of Shoreline Modified with Sediment Placement as of 2015
Fishers Island	0	0	0	0%
Plum Island	0	0	0	0%
Orient	0	> 0	> 0	> 0%
East Marion	0	0	0	0%
Greenport	0	0	0	0%
Southold	0.11	0.03	0.14	2%
Peconic	0	0	0	0%
Mattituck	0	0.05	0.05	1%
Jamesport	0	0.16	0.16	4%
Riverhead	0	0	0	0%
Baiting Hollow	0	0.06	0.06	2%
Wading River	0.59	0.13	0.72	16%
East Shoreham	0	0	0	0%
Shoreham	0	0.03	0.03	5%
Rocky Point	0	0.01	0.01	1%
Sound Beach	0	0.04	0.04	3%
Miller Place	0	0.03	0.03	1%
Mt. Sinai	> 0	0	> 0	> 0%
Port Jefferson	> 0	0	> 0	> 0%
Belle Terre	0	0.14	0.14	17%
Town of Brookhaven (unincorporated area)	0	0	0	0%
Old Field	0	0.07	0.07	1%
Stony Brook	> 0	0	> 0	> 0%
Nissequogue	1.25	0.10	1.35	29%
Fort Salonga	0	0.33	0.33	5%
Asharoken	1.00	1.23	2.23	53%
Eatons Neck	> 0	0	> 0	> 0%
Huntington Bay	0	0.15	0.15	7%
Lloyd Harbor	0	0.24	0.24	2%
Cold Spring Harbor	0	0	0	0%
Laurel Hollow	> 0	0	> 0	> 0%
Cove Neck	0	0	0	0%
Centre Island	0	0	0	0%
Bayville	0	0.08	0.08	2%
Locust Valley	0	0	0	0%
Lattingtown	0	0.14	0.14	6%
Glen Cove	0	0	0	0%
Sea Cliff	0	0	0	0%

Community	Pre-existing Sediment Placement Project Areas (miles)	New Sediment Placement Project Areas 2012-2015 (miles)	Total Length of Shoreline Modified by Sediment Placement as of 2015 (miles)	Percentage of Shoreline Modified with Sediment Placement as of 2015
Port Washington	0.57	0	0.57	43%
Sands Point	0	0	0	0%
TOTAL	**3.52**	**3.04**	**6.56**	**5%**

Table G-5. The length and proportion of sandy beach within each community (from east to west) along the Long Island Sound shoreline of New York that was modified with beach scraping or grading from 2012 to 2015.

Community	Length of Sandy Beach Modified with Beach Scraping (miles)	Percentage of Shoreline Modified with Beach Scraping
Fishers Island	0.13	1.4%
Plum Island	0	0
Orient	0	0
East Marion	0	0
Greenport	0	0
Southold	0	0
Peconic	0	0
Mattituck	0	0
Jamesport	0	0
Riverhead	0	0
Baiting Hollow	0	0
Wading River	0	0
East Shoreham	0	0
Shoreham	0	0
Rocky Point	0	0
Sound Beach	0	0
Miller Place	0	0
Mt. Sinai	0	0
Port Jefferson	0	0
Belle Terre	0	0
Town of Brookhaven (unincorporated area)	0	0
Old Field	0	0
Stony Brook	0	0
Nissequogue	0	0
Fort Salonga	0.83	13.3%
Asharoken	0	0
Eatons Neck	0	0
Huntington Bay	0	0
Lloyd Harbor	0	0
Cold Spring Harbor	0	0
Laurel Hollow	0	0
Cove Neck	0	0
Centre Island	0	0
Bayville	0.10	3.8%
Locust Valley	0	0
Lattingtown	0	0
Glen Cove	0	0
Sea Cliff	0	0
Port Washington	0	0

Community	Length of Sandy Beach Modified with Beach Scraping (miles)	Percentage of Shoreline Modified with Beach Scraping
Sands Point	0	0
TOTAL	**1.07**	**0.9%**

Table G-6. The length and proportion of sandy beach within each community (from east to west) along the Long Island Sound shoreline of New York that was modified with the installation of sand fencing from 2012 to 2015.

Community	Length of Sandy Beach Modified with Sand Fencing (miles)	Percentage of Shoreline Modified with Sand Fencing
Fishers Island	0	0
Plum Island	0	0
Orient	0	0
East Marion	0	0
Greenport	0	0
Southold	0	0
Peconic	0	0
Mattituck	0	0
Jamesport	0	0
Riverhead	0	0
Baiting Hollow	0	0
Wading River	0.16	4%
East Shoreham	0	0
Shoreham	0	0
Rocky Point	0	0
Sound Beach	0	0
Miller Place	0.03	1%
Mt. Sinai	0.02	3%
Port Jefferson	0	0
Belle Terre	0	0
Town of Brookhaven (unincorporated area)	0	0
Old Field	0	0
Stony Brook	0	0
Nissequogue	0	0
Fort Salonga	0	0
Asharoken	0.44	10%
Eatons Neck	0	0
Huntington Bay	0	0
Lloyd Harbor	0	0
Cold Spring Harbor	0	0
Laurel Hollow	0	0
Cove Neck	0	0
Centre Island	0	0
Bayville	0	0
Locust Valley	0	0
Lattingtown	0	0
Glen Cove	0	0
Sea Cliff	0	0
Port Washington	0	0

Community	Length of Sandy Beach Modified with Sand Fencing (miles)	Percentage of Shoreline Modified with Sand Fencing
Sands Point	0	0
TOTAL	**0.65**	**0.5%**

Appendix H – New York – Peconic Estuary Shoreline

Table H-1. Length of sandy beach for each community (clockwise) along the Peconic Estuary shoreline of New York and the proportion of each that was developed and undeveloped along the immediate beachfront in May 2015.

Community	Length of Sandy Beach (miles)	Percentage of Sandy Beach Developed	Percentage of Sandy Beach Undeveloped
Montauk	14.00	16%	84%
Napeague	3.55	52%	48%
Amagansett	1.45	58%	42%
Springs	5.01	61%	39%
Northwest Harbor	9.41	24%	76%
Sag Harbor	0.89	72%	28%
North Haven	5.73	63%	37%
Noyack	7.45	18%	82%
North Sea	6.47	45%	55%
Tuckahoe	2.18	91%	9%
Hampton Bays	4.88	52%	48%
Flanders	2.53	18%	82%
Riverhead	0.38	0%	100%
Aquebogue	1.28	62%	38%
Jamesport	2.53	73%	27%
Laurel	1.44	94%	6%
Mattituck	1.08	90%	10%
Cutchogue	6.49	59%	41%
New Suffolk	1.33	72%	28%
Robins Island	4.55	3%	97%
Peconic	1.46	63%	37%
Southold	6.98	53%	47%
Greenport West	3.06	57%	43%
Greenport	1.04	49%	51%
East Marion	1.61	77%	23%
Shelter Island	22.13	39%	61%
Orient	8.07	7%	93%
Gardiners Island	17.01	0%	100%
TOTAL	**144.03**	**35%**	**65%**

Table H-2. Sandy beaches that are in public or NGO ownership along the Peconic Estuary shoreline of New York, the county in which each is located, and the approximate length of sandy beach within each visible in Google Earth imagery in May 2015.

Public / NGO Land	County Location	Approximate Sandy Beach Length in 2015 (miles)
Montauk Point Lighthouse	Suffolk	0.14
Montauk Point State Park	Suffolk	4.72
East Lake Beach (Gin Beach)	Suffolk	0.10
West Lake Drive Beach	Suffolk	0.13
Culloden Point Beach	Suffolk	0.18
unknown public beach or park immediately south of Culloden Point along Fort Pond Bay	Suffolk	0.98
Town Beach at Navy Road	Suffolk	0.20
unknown Suffolk County parcel along Navy Road in Montauk	Suffolk	0.12
Fort Pond Bay Park / Eddie Ecker Park / Benson Point	Suffolk	0.21
Hither Woods Preserve	Suffolk	1.80
Hither Hills State Park	Suffolk	4.20
Napeague State Park	Suffolk	0.99
Cedar Bush Preserve	Suffolk	0.02
Fresh Pond Park	Suffolk	0.09
Dennistown Bell Park - Big & Little Albert's Landing Parks	Suffolk	0.47
Barnes Landing	Suffolk	0.51
Louse Point Town Beach	Suffolk	0.38
Gerard Point	Suffolk	0.22
Gerard Park	Suffolk	0.12
unknown protected parcel along Gerard Drive north of historic inlet or sluice site in Springs	Suffolk	0.17
Camp Blue Bay	Suffolk	0.29
Maidstone Park	Suffolk	0.42
Sammy's Beach	Suffolk	0.54
Cedar Point County Park	Suffolk	4.14
Grace Estate	Suffolk	0.37
Mile Hill Beach	Suffolk	0.06
Northwest Harbor Tidal Wetlands Area[1]	Suffolk	-
Northwest Harbor County Park	Suffolk	0.55
Linda Gronlund Memorial Nature Preserve	Suffolk	1.35
Haven's Beach	Suffolk	0.16
unknown passive park or protected parcel on north shoulder of Fresh Pond Inlet in North Haven	Suffolk	0.08
Tramaridge Trust Easement	Suffolk	0.19
unknown public beach or park at end of Bayview Court in North Haven	Suffolk	0.04
Foster Memorial Town Beach	Suffolk	1.42

Public / NGO Land	County Location	Approximate Sandy Beach Length in 2015 (miles)
Clam Island	Suffolk	0.53
Elizabeth A. Morton NWR	Suffolk	3.75
Cow Neck Trust Easement	Suffolk	2.30
Tern Island Easement	Suffolk	0.46
Meschutt Beach County Park	Suffolk	0.28
Shinnecock Indian Nation lands along Peconic Bay in Hampton Bays	Suffolk	0.38
East Landing Road Beach Access	Suffolk	0.23
West Landing Road Beach Access	Suffolk	0.19
Squiretown Park	Suffolk	0.52
unknown public beach or park on east side of Red Creek Pond Inlet	Suffolk	0.45
Hubbard County Park	Suffolk	1.09
unknown protected parcel at Fantasy Drive and Longneck Blvd in Flanders	Suffolk	0.19
unknown protected parcel in Flanders at mouth of Peconic River at Iron Point	Suffolk	0.23
Indian Island County Park	Suffolk	0.38
Wines / Gilbert Trust Easement	Suffolk	0.04
Miamogue Point	Suffolk	0.09
South Jamesport Park	Suffolk	0.43
Yacht Club Property Beach	Suffolk	0.08
Veteran Memorial Park	Suffolk	0.10
New Suffolk Beach	Suffolk	0.11
New Suffolk Trust Easement[2]	Suffolk	-
Paumanok Trust Easement	Suffolk	0.03
Robins Island	Suffolk	4.55
Pequash Avenue Beach	Suffolk	0.05
Meadow Beach on Horseshoe Cove peninsula in Cutchogue	Suffolk	0.38
Pia Trust Easement	Suffolk	0.15
Nassau Point Beach	Suffolk	0.33
Little Creek Inlet open space	Suffolk	0.17
Emerson Park	Suffolk	0.07
Blocker Preserve	Suffolk	0.50
Cedar Beach County Park	Suffolk	0.65
Shellfisher Preserve	Suffolk	0.04
Goose Creek Beach	Suffolk	0.16
Founder's Landing Park	Suffolk	0.10
Moores Drain Open Space	Suffolk	0.36
5th Street Beach and Park	Suffolk	0.13
Widow's Hole Preserve	Suffolk	0.14
unknown public beach or park on east side of Stirling Basin inlet	Suffolk	0.11

Public / NGO Land	County Location	Approximate Sandy Beach Length in 2015 (miles)
Norman Klipp Park (Gull Pond Beach)	Suffolk	0.16
Truman's Beach complex	Suffolk	0.36
Long Beach Bay Tidal Wetlands Area	Suffolk	0.40
Orient Beach State Park	Suffolk	5.65
Orient Point County Park	Suffolk	0.45
Mashomack Preserve, Shelter Island	Suffolk	7.42
unknown protected parcel east of end of Sea Gull Road near inlet, Shelter Island	Suffolk	0.05
Wade's Beach, Shelter Island	Suffolk	0.38
Shell Beach, Shelter Island	Suffolk	0.65
Crescent (Louis) Beach, Shelter Island	Suffolk	0.40
Sylvester Manor Educational Farm, Shelter Island	Suffolk	0.07
Menhaden Lane public access, Shelter Island	Suffolk	0.02
Dressel Preserve, Shelter Island	Suffolk	0.51
unknown Suffolk County parcel south of Dressel Preserve, Shelter Island	Suffolk	0.14
unknown preserve on Ram Island Drive causeway, Shelter Island	Suffolk	0.41
Reel Point Reserve, Shelter Island	Suffolk	0.40
TOTAL MILES		**62.53 (43% of sandy beach shoreline)**

1 – There was no *exposed* sandy beach at the Northwest Harbor TWA in May 2015 due to accretion of the Northwest Harbor County Park barrier spit from the west seaward of the tracts owned by NYS DEC and Suffolk County at Northwest Harbor TWA.

2 – The sandy beach at the New Suffolk Trust Easement was 390 ft (119 m) long in 2015, less than the 500 ft length minimum to be included in the habitat inventory.

Table H-3. The length and proportion of shoreline within each community (clockwise) along the Peconic Estuary shoreline of New York that was modified with hard shoreline stabilization, or armor, in 2015. Note that the length of armored shoreline with no beach is the length of shoreline where sandy beaches were absent seaward of armor in May 2015 but where evidence indicated sandy beaches would be present in the absence of the armor.

Community	Known Approximate Length of Armored Sandy Beach Shoreline (miles)	Approximate Length of Armored Shoreline with No Sandy Beach (miles)	Total Length of Armored Sandy Shoreline (miles)	Percentage of Sandy Shoreline Modified with Armor
Montauk	0.41	0.613	1.02	7%
Napeague	0.29	0.176	0.47	13%
Amagansett	0.19	0.048	0.24	16%
Springs	1.65	1.083	2.74	45%
Northwest Harbor	0.19	0.004	0.20	2%
Sag Harbor	0.29	0.170	0.46	43%
North Haven	2.10	0.320	2.42	40%
Noyack	1.23	0.353	1.58	20%
North Sea	2.72	0.668	3.39	47%
Tuckahoe	0.25	0.042	0.29	13%
Hampton Bays	1.83	0.040	1.87	38%
Flanders	0.09	0	0.09	3%
Riverhead	0.00	0	0.00	0%
Aquebogue	0.60	0.289	0.89	57%
Jamesport	1.37	0.145	1.52	57%
Laurel	1.33	0.462	1.80	94%
Mattituck	1.75	0.172	1.92	92%
Cutchogue	2.96	0.169	3.13	47%
New Suffolk	0.70	0.345	1.05	62%
Robins Island	0.54	0	0.54	12%
Peconic	0.57	0	0.57	39%
Southold	2.83	0.523	3.36	45%
Greenport West	1.23	0.562	1.79	49%
Greenport	0.39	0.736	1.12	63%
East Marion	1.21	0.604	1.81	82%
Shelter Island	8.25	1.117	9.37	40%
Orient	1.94	1.373	3.31	35%
Gardiners Island	0.14	0	0.14	1%
TOTAL	**37.05**	**10.016**	**47.07**	**30%**

Table H-4. The length of shoreline known to be modified by sediment placement projects in each community (clockwise) along the Peconic Estuary shoreline of New York and the proportions of each that were in pre-existing project areas or new placement areas.

Community	Pre-existing Sediment Placement Project Areas (miles)†	New Sediment Placement Project Areas 2012-2015 (miles)	Total Length of Shoreline Modified by Sediment Placement as of 2015 (miles)	Percentage of Shoreline Modified with Sediment Placement as of 2015
Montauk	> 0	0.08	0.08	0.5%
Napeague	> 0	0.30	0.30	8.1%
Amagansett	0	0.02	0.02	1.5%
Springs	> 0.61	0.33	> 0.94	> 15.5%
Northwest Harbor	> 0	0.53	0.53	5.7%
Sag Harbor	0	0.01	0.01	0.9%
North Haven	0.6	0.08	0.68	11.2%
Noyack	0	0.43	0.43	5.5%
North Sea	0	0.14	0.14	1.9%
Tuckahoe	> 0	0	> 0	> 0%
Hampton Bays	0	0.04	0.04	0.7%
Flanders	0	0	0	0%
Riverhead	0.11	0	0.11	28.7%
Aquebogue	0.23	0	0.23	14.6%
Jamesport	0.38	0.06	0.44	16.4%
Laurel	> 0	0.14	> 0.14	> 7.1%
Mattituck	> 0	0.15	> 0.15	> 12.5%
Cutchogue	> 0	0.19	> 0.19	> 2.8%
New Suffolk	> 0	0.03	> 0.03	> 1.5%
Robins Island	0	0	0	0%
Peconic	> 0	0	> 0	> 0%
Southold	> 0	1.08	> 1.08	> 14.4%
Greenport West	0	0	0	0%
Greenport	0	0.08	0.08	4.3%
East Marion	0	0.16	0.16	7.1%
Shelter Island	> 1.29	0.71	2.00	8.6%
Orient	> 0	> 0	> 0	> 0%
Gardiners Island	> 0	> 0	> 0	> 0%
TOTAL	**3.22 +**	**4.54**	**7.76 +**	**> 5%**

† The total length of sandy beach modified by sediment placement projects prior to Hurricane Sandy listed here has been revised from the figure in Rice (2015b) due to the inclusion of new information on pre-existing projects.

Table H-5. The length and proportion of sandy beach within each community (clockwise) along the Peconic Estuary shoreline of New York that was modified with beach scraping or grading from 2012 to 2015.

Community	Length of Sandy Beach Modified with Beach Scraping (miles)	Percentage of Shoreline Modified with Beach Scraping
Montauk	0	0
Napeague	0	0
Amagansett	0	0
Springs	0	0
Northwest Harbor	0	0
Sag Harbor	0	0
North Haven	0	0
Noyack	0	0
North Sea	0	0
Tuckahoe	0	0
Hampton Bays	0	0
Flanders	0	0
Riverhead	0	0
Aquebogue	0	0
Jamesport	0	0
Laurel	0	0
Mattituck	0	0
Cutchogue	0.02	0.31%
New Suffolk	0	0
Robins Island	0	0
Peconic	0	0
Southold	0	0
Greenport West	0	0
Greenport	0	0
East Marion	0	0
Shelter Island	0	0
Orient	0	0
Gardiners Island	0	0
TOTAL	**0.02**	**0.01%**

Table H-6. The length and proportion of sandy beach within each community (clockwise) along the Peconic Estuary shoreline of New York that was modified with the installation of sand fencing from 2012 to 2015.

Community	Length of Sandy Beach Modified with Sand Fencing (miles)	Percentage of Shoreline Modified with Sand Fencing
Montauk	0.178	1.3%
Napeague	0.030	0.9%
Amagansett	0	0
Springs	0.113	2.3%
Northwest Harbor	0.067	0.7%
Sag Harbor	0	0
North Haven	0	0
Noyack	0.006	0.1%
North Sea	0	0
Tuckahoe	0	0
Hampton Bays	0.233	4.8%
Flanders	0	0
Riverhead	0	0
Aquebogue	0	0
Jamesport	0.029	1.1%
Laurel	0.014	0.9%
Mattituck	0.004	0.4%
Cutchogue	0	0
New Suffolk	0.038	2.8%
Robins Island	0	0
Peconic	0.052	3.6%
Southold	0	0
Greenport West	0	0
Greenport	0	0
East Marion	0	0
Shelter Island	0.026	0.1%
Orient	0	0
Gardiners Island	0	0
TOTAL	**0.79**	**0.55%**

Appendix I – New York – Atlantic Ocean Shoreline

Table I-1. Length of sandy beach for each community (from east to west) along the Atlantic Ocean shoreline of New York and the proportion of each that was developed and undeveloped along the immediate beachfront in May 2015.

Community	Length of Sandy Beach (miles)	Percentage of Sandy Beachfront Developed	Percentage of Sandy Beachfront Undeveloped
Montauk[1]	9.93	35%	65%
Napeague	4.02	44%	56%
Amagansett	3.02	36%	64%
East Hampton Village	4.33	82%	18%
Wainscott	0.94	46%	54%
Village of Sagaponack	2.56	70%	30%
Bridgehampton	2.29	83%	17%
Water Mill	1.43	46%	54%
Village of Southampton	7.07	80%	20%
Hampton Bays & East Quogue	5.00	28%	72%
Quogue	2.68	95%	5%
Westhampton Beach	3.64	95%	5%
Town of Southampton (unincorporated areas)	2.28	38%	62%
West Hampton Dunes	1.82	93%	7%
Fire Island	31.47	22%	78%
Islip (Captree SP)	0.78	0	100%
Babylon (Oak Beach & Gilgo Beach)	7.73	7%	93%
Oyster Bay (Tobay Beach)	1.84	2%	98%
Hempstead (Jones Beach SP, Point Lookout, Lido Beach & Silver Point County Park)	9.88	29%	71%
Long Beach	3.32	89%	11%
East Atlantic Beach	0.85	100%	0%
Atlantic Beach	1.80	79%	21%
Far Rockaway	1.09	54%	46%
Arverne	1.99	28%	72%
Rockaway Park	4.00	62%	38%
Breezy Point	3.48	12%	88%
Manhattan Beach	0.35	24%	76%
Brighton Beach	0.75	100%	0%
Coney Island – West Brighton	1.80	95%	5%
Sea Gate	0.42	100%	0%
TOTAL	**122.57**	**43%**	**57%**

1 – Montauk also had 0.646 miles (1.04 km) of shoreline that were predominantly rocky and were excluded in these figures.

Table I-2. Sandy beaches that are in public or NGO ownership along the Atlantic Ocean shoreline of New York, the county in which each is located, and the approximate length of sandy beach within each visible in Google Earth imagery in May 2015. Beaches owned or managed by Towns under the Dongan Patent are excluded where private property is immediately adjacent to the beach.

Public / NGO Land	County Location	Approximate Sandy Beach Length in 2015 (miles)
Camp Hero State Park[1]	Suffolk	1.29
Rheinstein Estate Park	Suffolk	0.28
Shadmoor State Park	Suffolk	0.46
Kirk Beach Park	Suffolk	0.31
Hither Hills State Park	Suffolk	1.38
Napeague State Park	Suffolk	1.82
Atlantic Avenue Town Park	Suffolk	0.09
Amagansett NWR	Suffolk	0.27
Atlantic Double Dunes Preserve	Suffolk	0.18
Indian Wells Beach, Town of East Hampton	Suffolk	0.35
Two Mile Hollow Beach, Town of East Hampton	Suffolk	0.18
Egypt Beach, Town of East Hampton	Suffolk	0.03
Wiborg Beach, Village of East Hampton	Suffolk	0.03
East Hampton Main Beach	Suffolk	0.43
Georgica Beach, Town of East Hampton	Suffolk	0.06
Sagg Main Beach, Sagaponack	Suffolk	0.29
Mecox Beach, Town of East Hampton	Suffolk	0.07
Mecox Dunes Preserve	Suffolk	0.04
W. Scott Cameron Beach, Bridgehampton	Suffolk	0.12
Flying Point Beach, Water Mill	Suffolk	0.52
Shinnecock County Park East	Suffolk	0.42
Shinnecock County Park West & Ponquogue Beach	Suffolk	2.81
Tiana Beach Oceanside, Town of Southampton	Suffolk	0.23
Sand Bar Beach, Town of Southampton	Suffolk	0.05
Triton Beach (aka Hot Dog Beach), Town of Southampton	Suffolk	0.20
Quogue Village Beach	Suffolk	0.04
Pike’s Beach, West Hampton Dunes	Suffolk	0.06
Cupsogue Beach County Park	Suffolk	1.41
Great Gun Beach, Town of Brookhaven	Suffolk	0.90
Smith Point County Park	Suffolk	5.32
Fire Island NS (inholdings removed)	Suffolk	13.07
Davis Town Park	Suffolk	0.13
Atlantique Park	Suffolk	0.17
Robert Moses State Park	Suffolk	5.13
Captree State Park[2]	Suffolk	1.10
Town of Babylon – Oak Beach	Suffolk	0.64
Gilgo State Park	Suffolk	1.11

Public / NGO Land	County Location	Approximate Sandy Beach Length in 2015 (miles)
Town of Babylon Beaches (Gilgo, Cedar, & Overlook)	Suffolk	5.21
Tobay Beach & JFK Memorial Wildlife Sanctuary	Nassau	1.84
Jones Beach State Park	Nassau	6.50
Point Lookout Town Park	Nassau	0.56
Malibu Town Park	Nassau	0.16
Nickerson Beach Park	Nassau	0.62
Lido East Town Park	Nassau	0.38
Lido West Town Park	Nassau	0.38
Silver Point County Park	Nassau	0.22
Jamaica Bay Unit - Jacob Riis Park, Fort Tilden & Breezy Point of Gateway NRA	Queens	4.42
Manhattan Beach Park	Kings	0.26
	TOTAL MILES	**61.55 (50% of sandy beach shoreline)**

1 – The park also has 0.08 miles (0.14 km) of oceanfront shoreline that has a revetment with no beach, which is not included here.

2 – Captree State Park is included here even though its present location in Fire Island Inlet is not exposed to the Atlantic Ocean; historically the east end of Jones Beach Island was directly exposed to the ocean when the inlet was located farther east. All of Jones Beach Island was included in this assessment because the island is a barrier island.

Table I-3. The length and proportion of shoreline within each community (east to west) along the Atlantic Ocean shoreline of New York that was modified with hard shoreline stabilization, or armor, in 2015. Note that the length of armored shoreline with no beach is the length of shoreline where sandy beaches were absent seaward of armor in May 2015 but where evidence indicated sandy beaches would be present in the absence of the armor.

Community	Known Approximate Length of Armored Sandy Beach Shoreline (miles)	Approximate Length of Armored Shoreline with No Sandy Beach (miles)	Total Length of Armored Sandy Shoreline (miles)	Percentage of Shoreline Modified with Beach Armor
Montauk[1]	0.69	0.269	0.96	9%
Napeague	0.00	0	0	0%
Amagansett	0.04	0	0.04	1%
East Hampton Village	1.92	0	1.92	44%
Wainscott	0.04	0	0.04	4%
Village of Sagaponack	0.50	0	0.50	19%
Bridgehampton	0.21	0	0.21	9%
Water Mill	0.21	0	0.21	15%
Village of Southampton	1.16	0	1.16	16%
Hampton Bays & East Quogue	0.00	0	0	0%
Quogue	0.46	0	0.46	17%
Westhampton Beach	2.56	0	2.56	70%
Town of Southampton (unincorporated areas)	0.88	0	0.88	39%
West Hampton Dunes	0.03	0	0.03	2%
Fire Island	5.34	0	5.34	17%
Islip (Captree SP)	0.00	0	0	0%
Babylon (Oak Beach & Gilgo Beach)	0.35	1.788	2.13	22%
Oyster Bay (Tobay Beach)	0.00	0	0	0%
Hempstead (Jones Beach SP, Point Lookout, Lido Beach & Silver Point County Park)[2]	0.99	0	0.99	10%
Long Beach	3.33	0	3.33	100%
East Atlantic Beach	0.85	0	0.85	100%
Atlantic Beach	1.24	0	1.24	69%
Far Rockaway	0.99	0	0.99	91%
Arverne	2.00	0	2	100%
Rockaway Park	4.00	0	4.00	100%
Breezy Point	1.40	0	1.40	40%
Manhattan Beach	0.36	0.873	1.23	100%
Brighton Beach	0.75	0.038	0.79	100%
Coney Island – West Brighton	1.80	0	1.8	100%
Sea Gate	0.42	0.153	0.57	100%
TOTAL	**32.51**	**3.12**	**35.63**	**28%**

1 – Three additional projects involving hard shoreline stabilization structures were proposed in Montauk prior to the end of 2015: one private 135 ft. rock revetment at 108 Surfside Drive, one private 145 ft. coir log bulkhead at 376 Old Montauk Highway, and a federal USACE project to replace and improve the rock revetment at Montauk Point. The two private projects had not received NYS DEC permits by the end of 2015, and final project plans for the USACE project are anticipated in 2016.

2 – The USACE initiated construction of the Jones Inlet to East Rockaway Inlet (Long Beach Island) Hurricane and Storm Damage Reduction Project in Long Beach, Lido Beach and Point Lookout in early 2016; this project is construction 4 new groins in Lido Beach and modifying 17 existing groins in Long Beach. Once completed, an additional 0.51 miles (0.82 km) of Hempstead beaches will be armored.

Table I-4. The length of shoreline modified by sediment placement projects in each community (from east to west) along the Atlantic Ocean shoreline of New York and the proportions of each that were in pre-existing project areas or new placement areas.

Community	Pre-existing Sediment Placement Project Areas (miles)	New Sediment Placement Project Areas 2012-2015 (miles)	Total Length of Shoreline Modified by Sediment Placement as of 2015 (miles)	Percentage of Shoreline Modified with Sediment Placement as of 2015
Montauk	0	1.25	1.25	11%
Napeague	0	0	0	0%
Amagansett	0	0.04	0.04	1%
East Hampton Village	2.37	0.17	2.54	59%
Wainscott	0.11	0.54	0.65	69%
Village of Sagaponack	0.60	1.96	2.56	100%
Bridgehampton	0	2.29	2.29	100%
Water Mill	1.30	0.13	1.43	100%
Village of Southampton	2.26	1.62	3.88	55%
Hampton Bays & East Quogue	1.60	0.42	2.02	40%
Quogue	0.02	0.65	0.67	25%
Westhampton Beach	1.16	0	1.16	32%
Town of Southampton (unincorporated areas)	2.18	0	2.18	96%
West Hampton Dunes	1.82	0	1.82	100%
Fire Island	30.88	0	30.88	98%
Islip (Captree SP)	0	0	0	0%
Babylon (Oak Beach & Gilgo Beach)	3.41	0.68	4.09	53%
Oyster Bay (Tobay Beach)	0	0.74	0.74	40%
Hempstead (Jones Beach SP, Point Lookout, Lido Beach & Silver Point County Park)	7.93	0	7.93	80%
Long Beach	0	1.04	1.04	31%
East Atlantic Beach	0	0	0	0%
Atlantic Beach	0	0	0	0%
Far Rockaway	1.04	0	1.04	95%
Arverne	2.00	0	2.00	100%
Rockaway Park	3.49	0.51	4.00	100%
Breezy Point	0	0.14	0.14	4%
Manhattan Beach	0	0	0	0%
Brighton Beach	0.75	0	0.75	100%
Coney Island – West Brighton	1.8	0	1.80	100%
Sea Gate	0	0.38	0.38	67%
TOTAL	**65.02**	**12.26**	**77.27**	**62%**

Table I-5. The length and proportion of sandy beach within each community (from east to west) along the Atlantic Ocean shoreline of New York that was modified with beach scraping or grading from 2012 to 2015.

Community	Length of Sandy Beach Modified with Beach Scraping (miles)	Percentage of Shoreline Modified with Beach Scraping
Montauk	0.587	6%
Napeague	0	0%
Amagansett	0	0%
East Hampton Village	0.507	12%
Wainscott	0.028	3%
Village of Sagaponack	1.251	49%
Bridgehampton	0.455	20%
Water Mill	0.510	36%
Village of Southampton	1.306	18%
Hampton Bays & East Quogue	0.278	6%
Quogue[1]	2.675	100%
Westhampton Beach	0	0%
Town of Southampton (unincorporated areas)[2]	Unknown	> 0 %
West Hampton Dunes	0.236	13%
Fire Island[3]	6.613	21%
Islip (Captree SP)	0	0%
Babylon (Oak Beach & Gilgo Beach)	0.441	5%
Oyster Bay (Tobay Beach)	0	0%
Hempstead (Jones Beach SP, Point Lookout, Lido Beach & Silver Point County Park)	0.188	2%
Long Beach[4]	0.742	22%
East Atlantic Beach	0.072	8%
Atlantic Beach[4]	0	0%
Far Rockaway	0.285	26%
Arverne	1.101	55%
Rockaway Park	3.204	80%
Breezy Point	1.002	29%
Manhattan Beach	0	0%
Brighton Beach	0.241	31%
Coney Island – West Brighton	0.751	42%
Sea Gate	0	0%
TOTAL	**22.475**	**18%**

1 – Quogue has a NYS DEC permit allowing community-wide beach scraping for 10 years.

2 – The unincorporated areas of the Town of Southampton include an area between Westhampton Beach and West Hampton Dunes, plus Cupsogue County Park. Beach scraping has occurred at Cupsogue County Park, but a length of beach modified was not available.

3 – 15 of the 17 developed communities on Fire Island have NYS DEC permits allowing community-wide beach scraping for 10 years.

4 – Hurricane Sandy overwash sediment also was scraped off of paved and developed areas along streets oriented perpendicular to the beach, but it could not be determined if the sediment was subsequently placed on the beach.

Table I-6. The length and proportion of sandy beach within each community (from east to west) along the Atlantic Ocean shoreline of New York that was modified with the installation of sand fencing from 2012 to 2015.

Community	Length of Sandy Beach Modified with Sand Fencing (miles)	Percentage of Shoreline Modified with Sand Fencing
Montauk	1.67	16%
Napeague	0.90	22%
Amagansett	0.96	32%
East Hampton Village	1.96	45%
Wainscott	0.88	94%
Village of Sagaponack	1.85	72%
Bridgehampton	1.86	81%
Water Mill	1.19	83%
Village of Southampton	4.91	69%
Hampton Bays & East Quogue	1.99	40%
Quogue	2.37	88%
Westhampton Beach	0.96	26%
Town of Southampton (unincorporated areas)	1.82	80%
West Hampton Dunes	1.82	100%
Fire Island	13.65	43%
Islip (Captree SP)	0	0%
Babylon (Oak Beach & Gilgo Beach)	4.00	42%
Oyster Bay (Tobay Beach)	0.65	35%
Hempstead (Jones Beach SP, Point Lookout, Lido Beach & Silver Point County Park)	7.54	76%
Long Beach	0.72	22%
East Atlantic Beach	0.66	78%
Atlantic Beach	0.66	37%
Far Rockaway	0.47	43%
Arverne	1.24	62%
Rockaway Park	2.22	56%
Breezy Point	0.20	6%
Manhattan Beach	0.11	9%
Brighton Beach	0.10	12%
Coney Island – West Brighton	0.49	28%
Sea Gate	0	0%
TOTAL	**57.85**	**46%**

Appendix J – New Jersey

Table J-1. Length of sandy beach for each community (from north to south) along the Atlantic Ocean shoreline of New Jersey and the proportion of each that was developed and undeveloped along the immediate beachfront in 2015.

Community	Length of Sandy Beach (miles)	Percentage of Sandy Beachfront Developed	Percentage of Sandy Beachfront Undeveloped
Middletown Township (Sandy Hook)	6.14	0%	100%
Sea Bright	3.70	88%	12%
Monmouth Beach	1.64	100%	0%
Long Branch	3.61	81%	19%
Deal	1.32	93%	7%
Allenhurst	0.30	100%	0%
Loch Arbour	0.19	100%	0%
Asbury Park	0.88	88%	12%
Ocean Grove	0.62	95%	5%
Bradley Beach	0.93	93%	7%
Avon-by-the-Sea	0.52	95%	5%
Belmar	1.45	90%	10%
Spring Lake	2.03	89%	11%
Sea Girt	1.46	73%	27%
Manasquan	1.00	100%	0%
Point Pleasant Beach	1.80	100%	0%
Bay Head	1.21	100%	0%
Mantoloking	2.22	76%	24%
Brick (Normandy Beach)	1.79	96%	4%
Dover Beaches North	1.48	97%	3%
Lavallette	1.46	100%	0%
Ortley Beach	0.79	68%	32%
Seaside Heights	0.67	94%	6%
Seaside Park	1.70	95%	5%
Berkeley Township	10.22	5%	95%
Barnegat Light	1.72	34%	66%
Long Beach Township (Loveladies)	2.08	100%	0%
Harvey Cedars	1.98	100%	0%
Long Beach Township (North Beach)	1.26	100%	0%
Surf City	1.43	100%	0%
Ship Bottom	1.36	100%	0%

Community	Length of Sandy Beach (miles)	Percentage of Sandy Beachfront Developed	Percentage of Sandy Beachfront Undeveloped
Beach Haven	1.90	98%	2%
Long Beach Township	9.81	66%	34%
Galloway Township (Little Beach Island)	3.63	0%	100%
Brigantine	7.37	33%	67%
Atlantic City	3.26	90%	10%
Ventnor City	1.66	96%	4%
Margate City	1.67	100%	0%
Longport	1.38	100%	0%
Ocean City	8.50	86%	14%
Strathmere	1.81	53%	47%
Sea Isle City	5.02	74%	26%
Avalon	3.65	62%	38%
Stone Harbor	3.80	56%	44%
North Wildwood	2.05	36%	64%
Wildwood	1.35	100%	0%
Wildwood Crest (with Diamond Beach)	2.18	62%	38%
Lower Township	2.64	0%	100%
Cape May	3.63	70%	30%
Cape May Point	1.06	100%	0%
TOTAL	**125.33**	**64%**	**36%**

Table J-2. Sandy beaches that are in public or NGO ownership along the oceanfront shoreline of Delaware, the county in which each is located, and the approximate length of sandy beach within each visible in Google Earth imagery in May 2015.

Public / NGO Land	County Location	Approximate Sandy Beach Length in 2015 (miles)
Sandy Hook Unit, Gateway NRA	Monmouth	6.13
Seven Presidents Oceanfront Park	Monmouth	0.46
Island Beach State Park	Ocean	9.67
Holgate Unit, Edwin B. Forsythe NWR	Ocean	3.28
Little Beach Island, Edwin B. Forsythe NWR	Atlantic	3.62
North Brigantine Natural Area	Atlantic	2.93
Corson's Inlet State Park	Cape May	0.99
Strathmere Natural Area	Cape May	0.09
Stone Harbor - The Point Conservation Management Area	Cape May	1.52
Two Mile Beach Unit, Cape May NWR	Cape May	0.70
USCG LORAN Station	Cape May	0.52
USCG Cape May Training Center	Cape May	1.10
Lower Cape May Meadows: TNC South Cape May Meadows Preserve & Cape May State Park	Cape May	1.41
	TOTAL MILES	**32.43 (29% of sandy beach shoreline)**

Table J-3. The length and proportion of shoreline within each community (north to south) along the oceanfront shoreline of New Jersey that was modified with hard shoreline stabilization, or armor, in 2015. Note that the length of armored shoreline with no beach is the length of shoreline where sandy beaches were absent seaward of armor in late 2015 or early 2016 but where evidence indicated sandy beaches would be present in the absence of the armor.

Community	Known Approximate Length of Armored Sandy Beach Shoreline (miles)	Approximate Length of Armored Shoreline with No Sandy Beach (miles)	Total Length of Armored Sandy Shoreline (miles)	Percentage of Sandy Shoreline Modified with Beach Armor
Middletown Township (Sandy Hook)	2.16	0	2.16	35%
Sea Bright	3.70	0	3.70	100%
Monmouth Beach	1.65	0	1.65	100%
Long Branch	3.15	0.718	3.87	89%
Deal	1.32	0.305	1.62	100%
Allenhurst	0.30	0	0.30	100%
Loch Arbour	0.19	0	0.19	100%
Asbury Park	0.88	0.080	0.96	100%
Ocean Grove	0.62	0	0.62	100%
Bradley Beach	0.93	0	0.93	100%
Avon-by-the-Sea	0.52	0	0.52	100%
Belmar	1.45	0	1.45	100%
Spring Lake	2.00	0	2.00	98%
Sea Girt	1.46	0	1.46	100%
Manasquan	0.99	0	0.99	99%
Point Pleasant Beach	0	0	0	0%
Bay Head	1.20	0	1.20	99%
Mantoloking	1.99	0	1.99	90%
Brick (Normandy Beach)	1.79	0	1.79	100%
Dover Beaches North	0.04	0	0.04	3%
Lavallette	1.25	0	1.25	86%
Ortley Beach	0.02	0	0.02	3%
Seaside Heights	0	0.050[†]	0.05	7%
Seaside Park	0.37	0	0.37	22%
Berkeley Township	0	0	0	0%
Barnegat Light	0.2	0	0.20	12%
Long Beach Township (Loveladies)	2	0	2.00	96%
Harvey Cedars	1.98	0	1.98	100%
Long Beach Township (North Beach)	1.26	0	1.26	100%
Surf City	1.41	0	1.41	99%
Ship Bottom	1.35	0	1.35	100%
Beach Haven	1.9	0	1.90	100%
Long Beach Township	6.79	0	6.79	69%

Community	Known Approximate Length of Armored Sandy Beach Shoreline (miles)	Approximate Length of Armored Shoreline with No Sandy Beach (miles)	Total Length of Armored Sandy Shoreline (miles)	Percentage of Sandy Shoreline Modified with Beach Armor
Galloway Township (Little Beach Island)	0	0	0	0%
Brigantine	0.93	0	0.93	13%
Atlantic City	3.26	0.134	3.39	100%
Ventnor City	1.66	0	1.66	100%
Margate City	1.67	0	1.67	100%
Longport	1.38	0	1.38	100%
Ocean City	7.18	0	7.18	84%
Strathmere	1.78	0	1.78	98%
Sea Isle City	4.12	0	4.12	82%
Avalon	0.27	0.223	0.49	13%
Stone Harbor	2.52	0	2.52	66%
North Wildwood	1.87	0.784	2.65	94%
Wildwood	0	0	0	0%
Wildwood Crest (with Diamond Beach)	1.29	0	1.29	59%
Lower Township	0.6	0	0.60	23%
Cape May	2.76	0	2.76	76%
Cape May Point	1.06	0	1.06	100%
TOTAL	**77.24**	**2.29**	**79.53**	**62%**

† The absence of sandy beach habitat in Seaside Heights is at the pier, which is technically not armor but has precluded the presence of sandy beach habitat within the footprint of the structure.

Table J-4. The length of shoreline modified by sediment placement projects in each community (from north to south) along the Atlantic Ocean shoreline of New Jersey and the proportions of each that were in pre-existing project areas or new placement areas.

Community	Pre-existing Sediment Placement Project Areas (miles)	New Sediment Placement Project Areas 2012-2015 (miles)	Total Length of Shoreline Modified by Sediment Placement as of 2015 (miles)	Percentage of Shoreline Modified with Sediment Placement as of 2015
Middletown Township (Sandy Hook)	1.16	0	1.16	19%
Sea Bright	3.70	0	3.70	100%
Monmouth Beach	1.65	0	1.65	100%
Long Branch	4.33	0	4.33	100%
Deal	0	1.62	1.62	100%
Allenhurst	0	0.30	0.30	100%
Loch Arbour	0	0.19	0.19	100%
Asbury Park	0.96	0	0.96	100%
Ocean Grove	0.62	0	0.62	100%
Bradley Beach	0.93	0	0.93	100%
Avon-by-the-Sea	0.52	0	0.52	100%
Belmar	1.45	0	1.45	100%
Spring Lake	2.03	0	2.03	100%
Sea Girt	1.46	0	1.46	100%
Manasquan	1.00	0	1.00	100%
Point Pleasant Beach	0	0	0	0%[†]
Bay Head	0.68	0	0.68	56%[†]
Mantoloking	0	0	0	0%[†]
Brick (Normandy Beach)	0	0	0	0%[†]
Dover Beaches North	0	0	0	0%[†]
Lavallette	0.96	0.31	1.27	87%[†]
Ortley Beach	0	0.23	0.23	29%[†]
Seaside Heights	0.38	0	0.38	53%[†]
Seaside Park	0.31	0	0.31	18%[†]
Berkeley Township	0.47	0	0.47	5%
Barnegat Light	1.61	0	1.61	93%
Long Beach Township (Loveladies)	0.80	1.28	2.08	100%
Harvey Cedars	1.98	0	1.98	100%
Long Beach Township (North Beach)	0.70	0.56	1.26	100%
Surf City	1.43	0	1.43	100%
Ship Bottom	0.12	1.24	1.36	100%
Beach Haven	1.90	0	1.90	100%
Long Beach Township	2.14	5.87	8.01	82%

Community	Pre-existing Sediment Placement Project Areas (miles)	New Sediment Placement Project Areas 2012-2015 (miles)	Total Length of Shoreline Modified by Sediment Placement as of 2015 (miles)	Percentage of Shoreline Modified with Sediment Placement as of 2015
Galloway Township (Little Beach Island)	0	0	0	0%
Brigantine	3.77	0	3.77	51%
Atlantic City	3.41	0	3.41	100%
Ventnor City	1.66	0	1.66	100%
Margate City	0	0	0	0%†
Longport	> 0	0	> 0	> 0%†
Ocean City	4.70	2.5	7.20	85%
Strathmere	1.47	0.34	1.81	100%
Sea Isle City	1.62	3.24	4.86	97%
Avalon	2.38	0	2.38	61%
Stone Harbor	2.30	0.54	2.84	75%
North Wildwood	1.43	0	1.43	50%
Wildwood	> 0	0	> 0	> 0%†
Wildwood Crest (with Diamond Beach)	0	0	0	0%†
Lower Township	1.35	0	1.35	51%
Cape May	3.61	0	3.61	100%
Cape May Point	1.05	0	1.10	100%
TOTAL	**62.04**	**18.27**	**80.31**	**63%**

† Proposed sediment placement projects would increase this percentage to 100% if constructed as currently designed.

Table J-5. The length and proportion of sandy beach within each community (from north to south) along the Atlantic Ocean shoreline of New Jersey that was modified with beach scraping or grading from 2012 to 2015.

Community	Length of Sandy Beach Modified with Beach Scraping (miles)	Percentage of Shoreline Modified with Beach Scraping
Middletown Township (Sandy Hook)	0.069	1%
Sea Bright	1.049	28%
Monmouth Beach	0.171	10%
Long Branch	1.897	44%
Deal	0.544	33%
Allenhurst	0.069	23%
Loch Arbour	0.073	38%
Asbury Park	0.669	70%
Ocean Grove	0.268	44%
Bradley Beach	0.377	41%
Avon-by-the-Sea	0.013	3%
Belmar	0.723	50%
Spring Lake	0.758	37%
Sea Girt	0.714	49%
Manasquan	0.589	59%
Point Pleasant Beach	0.655	36%
Bay Head	0.772	64%
Mantoloking	2.219	100%
Brick (Normandy Beach)	1.790	100%
Dover Beaches North	0.235	16%
Lavallette	0.165	11%
Ortley Beach	0.495	63%
Seaside Heights	0.159	22%
Seaside Park	0.034	2%
Berkeley Township	0	0%
Barnegat Light	0	0%
Long Beach Township (Loveladies)	1.050	50%
Harvey Cedars	0.913	46%
Long Beach Township (North Beach)	1.257	100%
Surf City	0.197	14%
Ship Bottom	0.030	2%
Beach Haven	1.003	53%
Long Beach Township	4.765	49%
Galloway Township (Little Beach Island)	0	0%
Brigantine	0.086	1%

Community	Length of Sandy Beach Modified with Beach Scraping (miles)	Percentage of Shoreline Modified with Beach Scraping
Atlantic City	0	0%
Ventnor City	0.149	9%
Margate City	0.247	15%
Longport	0	0%
Ocean City	0.907	11%
Strathmere	0.039	2%
Sea Isle City	0.059	1%
Avalon	0	0%
Stone Harbor	0	0%
North Wildwood	0	0%
Wildwood	0	0%
Wildwood Crest (with Diamond Beach)	0	0%
Lower Township	0.072	3%
Cape May	0.036	1%
Cape May Point	0	0%
TOTAL	**25.315**	**20%**

Table J-6. The length and proportion of sandy beach within each community (from north to south) along the Atlantic Ocean shoreline of New Jersey that was modified with the installation of sand fencing from 2012 to 2015.

Community	Length of Sandy Beach Modified with Sand Fencing (miles)	Percentage of Shoreline Modified with Sand Fencing
Middletown Township (Sandy Hook)	0.97	16%
Sea Bright	2.07	56%
Monmouth Beach	0.72	44%
Long Branch	0.59	14%
Deal	0.03	2%
Allenhurst	0	0%
Loch Arbour	0.01	5%
Asbury Park	0.44	46%
Ocean Grove	0.38	61%
Bradley Beach	0.80	86%
Avon-by-the-Sea	0.04	7%
Belmar	0.89	61%
Spring Lake	0.10	5%
Sea Girt	0.12	8%
Manasquan	0.42	42%
Point Pleasant Beach	1.29	71%
Bay Head	0.24	20%
Mantoloking	1.31	59%
Brick (Normandy Beach)	1.04	58%
Dover Beaches North	1.24	84%
Lavallette	1.27	87%
Ortley Beach	0.19	24%
Seaside Heights	0	0%
Seaside Park	1.69	100%
Berkeley Township	4.55	45%
Barnegat Light	0.63	37%
Long Beach Township (Loveladies)	2.07	99%
Harvey Cedars	0.96	48%
Long Beach Township (North Beach)	1.24	99%
Surf City	1.24	87%
Ship Bottom	1.36	100%
Beach Haven	0.93	49%
Long Beach Township	5.34	54%
Galloway Township (Little Beach Island)	0	0%
Brigantine	0.33	5%
Atlantic City	2.96	87%
Ventnor City	1.25	75%

Community	Length of Sandy Beach Modified with Sand Fencing (miles)	Percentage of Shoreline Modified with Sand Fencing
Margate City	0.29	17%
Longport	0.04	3%
Ocean City	6.04	71%
Strathmere	1.57	87%
Sea Isle City	1.83	36%
Avalon	3.56	92%
Stone Harbor	2.41	63%
North Wildwood	1.23	44%
Wildwood	0.23	17%
Wildwood Crest (with Diamond Beach)	1.76	81%
Lower Township	0.36	14%
Cape May	2.09	57%
Cape May Point	0.16	15%
TOTAL	**60.26**	**47%**

Appendix K – Delaware

Table K-1. Length of sandy beach for each community (from north to south) along the oceanfront shoreline of Delaware and the proportion of each that was developed and undeveloped along the immediate beachfront in May 2015.

Community	Length of Sandy Beach (miles)	Percentage of Sandy Beach Developed	Percentage of Sandy Beach Undeveloped
Cape Henlopen[1]	4.85	2%	98%
Rehoboth Beach	2.16	77%	23%
Dewey Beach	1.79	97%	3%
Delaware Seashore SP[1]	6.35	8%	92%
Bethany Beach	4.71	100%	0%
South Bethany	0.82	100%	0%
Fenwick Island[2]	3.97	42%	58%
TOTAL	**24.65**	**45%**	**55%**

1 – Both Cape Henlopen SP and Delaware Seashore SP are within an unincorporated area of Sussex County called the Lewes Census County Division (CCD). CCDs are delineated for census purposes only and have no legal or government function.

2 – Fenwick Island SP is within an unincorporated area of Sussex County called Selbyville-Frankford CCD but is grouped with the Town of Fenwick Island for the purposes of this assessment.

Table K-2. Sandy beaches that are in public or NGO ownership along the oceanfront shoreline of Delaware, the county in which each is located, and the approximate length of sandy beach within each visible in Google Earth imagery in May 2015.

Public / NGO Land	County Location	Approximate Sandy Beach Length in 2015 (miles)
Cape Henlopen State Park	Sussex	4.85
Deauville Beach	Sussex	0.37
City of Rehoboth Beach Public Beach[1]	Sussex	0.12
Delaware Seashore State Park	Sussex	6.34
Fenwick Island State Park	Sussex	2.60
	TOTAL MILES	**14.28 (58% of sandy beach shoreline)**

1 – The City of Rehoboth Beach owns the entire beach from Deauville Beach to Dewey Beach, but only the northernmost portion that is undeveloped is included here; private development is directly adjacent to the remaining portion of the public beach and is not counted here.

Table K-3. The length and proportion of shoreline within each community (from north to south) along the oceanfront shoreline of Delaware that was modified with hard shoreline stabilization, or armor, in 2015. Note that the length of armored shoreline with no beach is the length of shoreline where sandy beaches were absent seaward of armor in May 2015 but where evidence indicated sandy beaches would be present in the absence of the armor; there were none of these areas in Delaware in 2015.

Community	Known Approximate Length of Armored Sandy Beach Shoreline (miles)	Approximate Length of Armored Shoreline with No Sandy Beach (miles)	Total Length of Armored Sandy Shoreline (miles)	Percentage of Sandy Shoreline Modified with Armor
Cape Henlopen	0.42	0	0.42	9%
Rehoboth Beach	2.16	0	2.16	100%
Dewey Beach	0.27	0	0.27	15%
Delaware Seashore SP[1]	0	0	0	0%
Bethany Beach	0.82	0	0.82	17%
South Bethany	0	0	0	0%
Fenwick Island	0	0	0	0%
TOTAL	**3.67**	**0**	**3.67**	**15%**

1 – Indian River Inlet within Delaware Seashore SP is armored with dual jetties and revetments/seawalls on the inlet shorelines. The jetties influence the adjacent shorelines for an unknown length north and south of the inlet.

Table K-4. The length of shoreline known to be modified by sediment placement projects in each community (from north to south) along the oceanfront shoreline of Delaware and the proportions of each that were in pre-existing project areas or new placement areas.

Community	Pre-existing Sediment Placement Project Areas (miles)	New Sediment Placement Project Areas 2012-2015 (miles)	Total Length of Shoreline Modified by Sediment Placement as of 2015 (miles)	Percentage of Shoreline Modified with Sediment Placement as of 2015
Cape Henlopen	0	0	0	0
Rehoboth Beach	0.76	0	0.76	35%
Dewey Beach	1.79	0	1.79	100%
Delaware Seashore SP	1.59	0.38	1.97	31%
Bethany Beach	4.63	0	4.63	98%
South Bethany	0.82	0	0.82	100%
Fenwick Island	2.08	0	2.08	52%
TOTAL	**11.67**	**0.38**	**12.05**	**49%**

Table K-5. The length and proportion of sandy beach within each community (from north to south) along the oceanfront shoreline of Delaware that was modified with beach scraping or grading from 2012 to 2015.

Community	Length of Sandy Beach Modified with Beach Scraping (miles)	Percentage of Shoreline Modified with Beach Scraping
Cape Henlopen	0	0
Rehoboth Beach	0	0
Dewey Beach	0	0
Delaware Seashore SP	1.44	23%
Bethany Beach	0	0
South Bethany	0	0
Fenwick Island	0.03	0.8%
TOTAL	**1.47**	**6%**

Table K-6. The length and proportion of sandy beach within each community (from north to south) along the oceanfront shoreline of Delaware that was modified with the installation of sand fencing from 2012 to 2015.

Community	Length of Sandy Beach Modified with Sand Fencing (miles)	Percentage of Shoreline Modified with Sand Fencing
Cape Henlopen	1.41	29%
Rehoboth Beach	2.15	99%
Dewey Beach	1.77	99%
Delaware Seashore SP	2.22	35%
Bethany Beach	4.17	88%
South Bethany	0.82	100%
Fenwick Island	2.33	59%
TOTAL	**14.85**	**60%**

Appendix L – Maryland

Table L-1. Length of sandy beach for each community (from north to south) along the oceanfront shoreline of Maryland and the proportion of each that was developed and undeveloped along the immediate beachfront in May 2015.

Community	Length of Sandy Beach (miles)	Percentage of Sandy Beach Developed	Percentage of Sandy Beach Undeveloped
Ocean City	9.00	100%	0%
Assateague Island	22.10	0%	100%
TOTAL	**31.10**	**29%**	**71%**

Table L-2. Sandy oceanfront beaches that are in public or NGO ownership in Maryland, the county in which each is located, and approximate shoreline length of each (Sources: Schupp et al. 2013, Schupp and Coburn 2015, and the Maryland DNR website).

Public / NGO Land	County Location	Approximate Sandy Beach Length in 2015 (miles)
Assateague State Park	Worcester	2.00
Assateague Island National Seashore	Worcester	20.10
	TOTAL MILES	**22.10 (71% of sandy beach shoreline)**

Table L-3. The length and proportion of shoreline within each community (from north to south) along the oceanfront shoreline of Maryland that was modified with hard shoreline stabilization, or armor, visible on aerial imagery between April 1989 and October 2015 and/or identified in Schupp and Coburn (2015). Note that the length of armored shoreline with no beach is the length of shoreline where sandy beaches were absent seaward of armor in May 2015 but where evidence indicated sandy beaches would be present in the absence of the armor; there were none of these areas in Maryland in 2015.

Community	Known Approximate Length of Armored Sandy Beach Shoreline (miles)	Approximate Length of Armored Shoreline with No Sandy Beach (miles)	Total Length of Armored Sandy Shoreline (miles)	Percentage of Shoreline Armored
Ocean City	1.52	0	1.52	17%
Assateague Island	0.10	0	0.10	0.5%
TOTAL	**1.62**	**0**	**1.62**	**5%**

Table L-4. The length of shoreline known to be modified by sediment placement projects in each community (from north to south) along the oceanfront shoreline of Maryland and the proportions of each that were in pre-existing project areas or new placement areas.

Community	Pre-existing Sediment Placement Project Areas (miles)	New Sediment Placement Project Areas 2012-2015 (miles)	Total Length of Shoreline Modified by Sediment Placement as of 2015 (miles)	Percentage of Shoreline Modified with Sediment Placement as of 2015
Ocean City	9.00	0	9.00	100%
Assateague Island	22.10	0	22.10	100%
TOTAL	**31.10**	**0**	**31.10**	**100%**

Table L-5. The length and proportion of sandy beach within each community (from north to south) along the oceanfront shoreline of Maryland that was modified with beach scraping or grading from 2012 to 2015.

Community	Length of Sandy Beach Modified with Beach Scraping (miles)	Percentage of Shoreline Modified with Beach Scraping
Ocean City	1.79	20%
Assateague Island	2.00	9%
TOTAL	**3.79**	**12%**

Table L-6. The length and proportion of sandy beach within each community (from north to south) along the oceanfront shoreline of Maryland that was modified with the installation of sand fencing from 2012 to 2015.

Community	Length of Sandy Beach Modified with Sand Fencing (miles)	Percentage of Shoreline Modified with Sand Fencing
Ocean City	6.78	75%
Assateague Island	3.27	15%
TOTAL	**10.05**	**32%**

Appendix M – Virginia

Table M-1. Length of sandy beach for each community (from north to south) along the oceanfront shoreline of Virginia and the proportion of each that was developed and undeveloped along the immediate beachfront in 2015.

Community	Length of Sandy Beach (miles)	Percentage of Sandy Beach Developed	Percentage of Sandy Beach Undeveloped
Chincoteague Island	16.55	0%	100%
Wallops-Assawoman Island	9.14	21%	79%
Metompkin Island	6.33	0%	100%
Cedar Island	7.24	0%	100%
Parramore Island	8.15	0%	100%
Hog Island	8.16	0%	100%
Cobb Island[1]	2.30	0%	100%
Wreck Island	3.27	0%	100%
Ship Shoal Island	2.84	0%	100%
Mink Island	0.44	0%	100%
Myrtle Island	1.88	0%	100%
Smith Island	7.37	0%	100%
Firshermans Island[2]	3.89	0%	100%
Virginia Beach	27.55	51%	49%
TOTAL	**105.12**	**15%**	**85%**

1 – Cobb Island has an additional 1.79 miles (2.88 km) of shoreline dominated by peat, marsh or forest that lacked a sandy beach in 2015.

2 – Additional sandy beach habitat is present on Fishermans Island but was not included due to the orientation of the island; only sandy beach habitat with direct exposure to the Atlantic Ocean was included.

Table M-2. Sandy oceanfront beaches that are in public or NGO ownership in Virginia, the county in which each is located, and approximate length of sandy beach present within each in 2015.

Public / NGO Land	County Location	Approximate Sandy Beach Length in 2015 (miles)
Chincoteague NWR	Accomack	16.55
Wallops Island NASA Flight Facility	Accomack	6.02
Assawoman Island Unit, Chincoteague NWR	Accomack	3.12
unnamed islet in Gargathy Inlet	Accomack	0.09
Metompkin Island - Chincoteague NWR & TNC	Accomack	6.24
Cedar Island Unit, Chincoteague NWR[1]	Accomack	7.24
Dawson Shoals (islet in Wachapreague Inlet)	Accomack	0.67
Parramore Island Natural Area Preserve	Accomack	7.48
Hog Island, Virginia Coast Reserve	Northampton	8.16
Cobb Island, Virginia Coast Reserve[2]	Northampton	2.30
Wreck Island Natural Area Preserve	Northampton	3.27
Ship Shoal Island, Virginia Coast Reserve	Northampton	2.84
Mink Island, Virginia Coast Reserve	Northampton	0.44
Myrtle Island, Virginia Coast Reserve	Northampton	1.88
Smith Island, Virginia Coast Reserve	Northampton	7.37
Fishermans Island NWR	Northampton	3.89
JEB Little Creek / Fort Story	Virginia Beach	1.53
31st Street Park	Virginia Beach	0.04
24th Street Park	Virginia Beach	0.05
Grommet Island Park	Virginia Beach	0.06
Croatan Beach Park	Virginia Beach	0.08
Croatan Lot	Virginia Beach	0.09
Naval Air Station Oceana Dam Neck Annex	Virginia Beach	4.00
Little Island Park	Virginia Beach	0.54
Back Bay NWR	Virginia Beach	4.30
False Cape State Park	Virginia Beach	5.66
	TOTAL MILES	**93.91 (89% of sandy beach shoreline)**

1 - An unknown portion of Cedar Island is privately owned but undeveloped. The Chincoteague NWR owns a number of island parcels. The total island length is included here.

2 – An additional 1.79 miles (2.88 km) of shoreline on Cobb Island was dominated by peat, marsh or forest and lacked sandy beach in 2015.

Table M-3. Approximate oceanfront shoreline length (in miles) within each community of Virginia that were armored with hard stabilization structures visible on aerial imagery between March 1989 and October 2015. Note that the length of armored shoreline with no beach is the length of shoreline where sandy beaches were absent seaward of armor in 2015 but where evidence indicated sandy beaches would be present in the absence of the armor; there were none of these areas in Virginia in 2015.

Community	Known Approximate Length of Armored Sandy Beach Shoreline (miles)	Approximate Length of Armored Shoreline with No Sandy Beach (miles)	Total Length of Armored Sandy Shoreline (miles)	Percentage of Sandy Shoreline Modified with Armor
Chincoteague Island	0	0	0	0
Wallops-Assawoman Island	4.08	0	4.08	45%
Metompkin Island	0	0	0	0
Cedar Island	0	0	0	0
Parramore Island	0	0	0	0
Hog Island	0	0	0	0
Cobb Island	0	0	0	0
Wreck Island	0	0	0	0
Ship Shoal Island	0	0	0	0
Mink Island	0	0	0	0
Myrtle Island	0	0	0	0
Smith Island	0	0	0	0
Firshermans Island	0	0	0	0
Virginia Beach	7.28	0	7.28	26%
TOTAL	**11.36**	**0**	**11.36**	**11%**

Table M-4. The length of shoreline known to be modified by sediment placement projects in each community (from north to south) along the oceanfront shoreline of Virginia and the proportions of each that were in pre-existing project areas or new placement areas.

Community	Pre-existing Sediment Placement Project Areas (miles)	New Sediment Placement Project Areas 2012-2015 (miles)	Total Length of Shoreline Modified by Sediment Placement as of 2015 (miles)	Percentage of Shoreline Modified with Sediment Placement as of 2015
Chincoteague Island	14.30	0	14.30	86%
Wallops-Assawoman Island	3.73	0	3.73	41%
Metompkin Island	0	0	0	0%
Cedar Island	0	0	0	0%
Parramore Island	0	0	0	0%
Hog Island	0	0	0	0%
Cobb Island	0	0	0	0%
Wreck Island	0	0	0	0%
Ship Shoal Island	0	0	0	0%
Mink Island	0	0	0	0%
Myrtle Island	0	0	0	0%
Smith Island	0	0	0	0%
Firshermans Island	0	0	0	0%
Virginia Beach	12.73	0.15	12.88	47%
TOTAL	**30.76**	**0.15**	**30.91**	**29%**

Table M-5. The length and proportion of sandy beach within each community (from north to south) along the oceanfront shoreline of Virginia that was modified with beach scraping or grading from 2012 to 2015.

Community	Length of Sandy Beach Modified with Beach Scraping (miles)	Percentage of Shoreline Modified with Beach Scraping
Chincoteague Island	0	0
Wallops-Assawoman Island	0	0
Metompkin Island	0	0
Cedar Island	0	0
Parramore Island	0	0
Hog Island	0	0
Cobb Island	0	0
Wreck Island	0	0
Ship Shoal Island	0	0
Mink Island	0	0
Myrtle Island	0	0
Smith Island	0	0
Firshermans Island	0	0
Virginia Beach	2.89	10%
TOTAL	**2.89**	**3%**

Table M-6. The length and proportion of sandy beach within each community (from north to south) along the oceanfront shoreline of Virginia that was modified with the installation of sand fencing from 2012 to 2015.

Community	Length of Sandy Beach Modified with Sand Fencing (miles)	Percentage of Shoreline Modified with Sand Fencing
Chincoteague Island	0	0%
Wallops-Assawoman Island	3.38	37%
Metompkin Island	0	0%
Cedar Island	0	0%
Parramore Island	0	0%
Hog Island	0	0%
Cobb Island	0	0%
Wreck Island	0	0%
Ship Shoal Island	0	0%
Mink Island	0	0%
Myrtle Island	0	0%
Smith Island	0	0%
Firshermans Island	0	0%
Virginia Beach	4.77	17%
TOTAL	**8.15**	**8%**

Appendix N – North Carolina

Table N-1. Length of sandy beach for each community (from north to south) along the oceanfront shoreline of North Carolina and the proportion of each that was developed and undeveloped along the immediate beachfront in late 2015 or early 2016.

Community	Length of Sandy Beach (miles)	Percentage of Sandy Beach Developed	Percentage of Sandy Beach Undeveloped
Corolla	22.82	65%	35%
Duck	5.77	90%	10%
Southern Shores	3.72	96%	4%
Kitty Hawk	3.55	59%	41%
Kill Devil Hills	4.71	96%	4%
Nags Head	16.56	69%	31%
Rodanthe[1]	14.66	15%	85%
Salvo	11.55	22%	78%
Avon	5.88	59%	41%
Buxton	13.35	5%	95%
Frisco	1.09	80%	20%
Hatteras	5.89	29%	71%
Ocracoke	17.67	0%	100%
Cape Lookout NS (Portsmouth Island to Shackleford Banks)	57.07	0%	100%
Atlantic Beach[2]	6.30	74%	26%
Pine Knoll Shores	4.86	89%	11%
Indian Beach	1.77	92%	8%
Salter Path	0.76	100%	0%
Emerald Isle	11.28	96%	4%
Swansboro Township (Hammocks Beach SP)	4.08	0%	100%
Camp Lejeune	11.49	3%	97%
North Topsail Beach	10.97	74%	26%
Surf City	6.01	81%	19%
Topsail Beach	5.56	73%	27%
Topsail Township (Lea-Hutaff Island)	4.05	0%	100%
Figure 8 Island	5.28	74%	26%
Wrightsville Beach	4.77	83%	17%
Masonboro Island	7.75	0%	100%
Carolina Beach	4.55	68%	32%
Kure Beach	2.92	88%	12%
Federal Point Township[3]	3.09	1%	99%
Bald Head Island[4]	11.07	41%	59%
Caswell Beach[5]	3.65	45%	55%
Oak Island	9.53	80%	20%
Holden Beach	8.64	84%	16%

Community	Length of Sandy Beach (miles)	Percentage of Sandy Beach Developed	Percentage of Sandy Beach Undeveloped
Ocean Isle Beach	5.89	81%	19%
Sunset Beach[6]	3.70	26%	74%
TOTAL	**322.26**	**41%**	**59%**

1 – For the purposes of this assessment, Pea Island NWR is included within the community of Rodanthe.

2 – For the purposes of this assessment, Fort Macon SP is included within the community of Atlantic Beach.

3 – Federal Point Township includes the Fort Fisher State Recreation Area and Zeke's Island Reserve.

4 – For the purposes of this assessment, the Bald Head Island State Natural Area is included within the community of Bald Head Island.

5 – For the purposes of this assessment, Fort Caswell is included within the community of Caswell Beach.

6 – For the purposes of this assessment, the Bird Island portion of Shallotte Township is included within the community of Sunset Beach. Note that the southernmost portion of Bird Island is located within the state of South Carolina and is not included in this assessment for North Carolina; in late 2015 / early 2016, approximately 1,000 ft (305 m) of sandy beach habitat was present along the South Carolina portion of Bird Island.

Table N-2. Sandy beaches that are in public or NGO ownership along the oceanfront shoreline of North Carolina, the county in which each is located, and the approximate length of sandy beach within each visible in Google Earth imagery in late 2015 or early 2016.

Public / NGO Land	County Location	Approximate Sandy Beach Length in 2015 (miles)
Swan Island Unit, Currituck NWR	Currituck	1.80
Monkey Island Unit, Currituck NWR	Currituck	1.00
Monkey Island Tract	Currituck	0.65
Lighthouse Keeper House Parcel	Currituck	0.08
Duck Field Research Facility	Dare	0.64
Wilkins St Tract	Dare	0.09
Starfish Ln to Lillian St Tracts	Dare	0.24
Kitty Hawk Rd to Perry St	Dare	0.09
Kill Devil Hills Beach Access Points	Dare	0.17
Nags Head Beach Access points	Dare	0.41
Jenette's Pier	Dare	0.09
Bodie Island, Cape Hatteras NS	Dare	5.37
Pea Island NWR	Dare	12.18
Chicamacomico Life-Saving Station & Museum	Dare	0.03
Rodanthe Beach Access	Dare	0.03
Sea Haven Dr Parcels	Dare	0.07
Hatteras Island, Cape Hatteras NS	Dare	38.09
Oceacoke Island, Cape Hatteras NS	Dare	17.21
Cape Lookout NS	Carteret	57.01
Fort Macon State Park	Carteret	1.68
The Circle Beach Access	Carteret	0.16
Morgan Hammer Park	Carteret	0.02
Dogwood Circle Park	Carteret	0.06
Iron Steamer Regional Access	Carteret	0.02
Salter Path Regional Access	Carteret	0.52
Town of Emerald Isle Beach Access Points	Carteret	0.10
Hammocks Beach State Park (Bear Island)	Onslow	4.07
Brown's Island, Camp Lejeune	Onslow	3.55
Onslow Beach, Camp Lejeune	Onslow	7.92
New River Inlet Rd Parcels	Onslow	0.27
North Topsail Beach Beach Access Points	Onslow	0.26
Surf City Beach Access Points	Pender	0.13
Topsail Beach Beach Access Points	Pender	0.21
Lea-Hutaff Island	Pender	4.04
Mason Inlet Waterbird Management Area	New Hanover	0.69
Wrightsville Beach Beach Access Points	New Hanover	0.17
Masonboro Island NERR and Masonboro Island State Natural Area	New Hanover	7.74
Freeman Park	New Hanover	1.47
Carolina Beach Beach Access Points	New Hanover	0.08

Public / NGO Land	County Location	Approximate Sandy Beach Length in 2015 (miles)
Kure Beach Ocean Front Park	New Hanover	0.36
Kure Beach Beach Access Points	New Hanover	0.08
Fort Fisher State Recreation Area	New Hanover	2.41
Zeke's Island Reserve	New Hanover and Brunswick	1.27
Bald Head Island State Natural Area	Brunswick and New Hanover	4.14
Cape Fear Point, Bald Head Island State Natural Area	Brunswick	0.24
Oak Island Lighthouse Tract	Brunswick	0.12
Commissioner's Observatory Park	Brunswick	0.07
Oak Island Fishing Pier	Brunswick	0.04
Yaupon Park	Brunswick	0.02
Oak Island Beach Access Points	Brunswick	0.22
The Point (Oak Island)	Brunswick	0.64
Holden Beach Beach Access Points	Brunswick	0.10
NC Agricultural Foundation Preserve (Holden Beach)	Brunswick	0.30
Ocean Isle Beach Beach Access Points	Brunswick	0.08
Sunset Blvd Beach Access	Brunswick	0.02
Bird Island Coastal Reserve	Brunswick	0.92
	TOTAL MILES	**179.47 (56% of sandy beach shoreline)**

Table N-3. The length and proportion of shoreline within each community (from north to south) along the oceanfront shoreline of North Carolina that was modified with hard shoreline stabilization, or armor, in 2015. Note that the length of armored shoreline with no beach is the length of shoreline where sandy beaches were absent seaward of armor in late 2015 / early 2016 but where evidence indicated sandy beaches would be present in the absence of the armor.

Community	Known Approximate Length of Armored Sandy Beach Shoreline (miles)	Approximate Length of Armored Shoreline with No Sandy Beach (miles)	Total Length of Armored Sandy Shoreline (miles)	Percentage of Sandy Shoreline Modified with Armor
Corolla	0.038	0	0.038	0.2%
Duck	0	0	0	0%
Southern Shores	0	0	0	0%
Kitty Hawk	0.640	0	0.640	18.0%
Kill Devil Hills	0.368	0	0.368	7.8%
Nags Head	0.303	0	0.303	1.8%
Rodanthe	0.813	0	0.813	5.5%
Salvo	0	0	0	0%
Avon	0	0	0	0%
Buxton	0.329	0	0.329	2.5%
Frisco	0	0	0	0%
Hatteras	0	0	0	0%
Ocracoke	0	0	0	0%
Cape Lookout NS (Portsmouth Island to Shackleford Banks)	0.915	0	0.915	1.6%
Atlantic Beach	0.177	0	0.177	2.8%
Pine Knoll Shores	0.174	0	0.174	3.6%
Indian Beach	0	0	0	0%
Salter Path	0	0	0	0%
Emerald Isle	0.176	0	0.176	1.6%
Swansboro Township (Hammocks Beach SP)	0	0	0	0%
Camp Lejeune	0	0	0	0%
North Topsail Beach	0.286	0.388	0.673	5.9%
Surf City	0.181	0	0.181	3.0%
Topsail Beach	0.340	0	0.340	6.1%
Topsail Township (Lea-Hutaff Island)	0	0	0	0%
Figure 8 Island	0.312	0	0.312	5.9%
Wrightsville Beach	0	0	0	0%
Masonboro Island	0.166	0	0.166	2.1%
Carolina Beach	0.194	0.153	0.347	7.4%
Kure Beach	0.321	0	0.321	11.0%
Federal Point Township	0	0.203	0.203	6.2%
Bald Head Island	1.439	0	1.439	13.0%
Caswell Beach	0.039	0	0.039	1.1%

Community	Known Approximate Length of Armored Sandy Beach Shoreline (miles)	Approximate Length of Armored Shoreline with No Sandy Beach (miles)	Total Length of Armored Sandy Shoreline (miles)	Percentage of Sandy Shoreline Modified with Armor
Oak Island	0.217	0	0.217	2.3%
Holden Beach	0.284	0	0.284	3.3%
Ocean Isle Beach	0.594	0	0.594	10.1%
Sunset Beach	0	0	0	0%
TOTAL	**8.304**	**0.743**	**9.047**	**3%**

Table N-4. The length of shoreline known to be modified by sediment placement projects in each community (from north to south) along the oceanfront shoreline of North Carolina and the proportions of sandy beach habitat within each that have been modified.

Community	Total Length of Shoreline Modified by Sediment Placement as of 2015 (miles)	Percentage of Shoreline Modified with Sediment Placement as of 2015
Corolla	0	0%
Duck[1]	0	0%
Southern Shores[2]	0	0%
Kitty Hawk[3]	> 0	> 0%
Kill Devil Hills[4]	> 0	> 0%
Nags Head	10.00	60%
Rodanthe	5.47	37%
Salvo	0	0%
Avon	3.10	53%
Buxton[5]	3.33	25%
Frisco	1.09	100%
Hatteras	3.23	55%
Ocracoke	0.95	5%
Cape Lookout NS (Portsmouth Island to Shackleford Banks)	1.42	2%
Atlantic Beach	3.79	60%
Pine Knoll Shores	4.86	100%
Indian Beach	1.77	100%
Salter Path	0.76	100%
Emerald Isle	10.58	94%
Swansboro Township (Hammocks Beach SP)	0	0%
Camp Lejeune	1.00	9%
North Topsail Beach	4.96	45%
Surf City	0.09	2%
Topsail Beach	4.77	86%
Topsail Township (Lea-Hutaff Island)	0	0%
Figure 8 Island	3.69	70%
Wrightsville Beach	3.60	75%
Masonboro Island	2.99	39%
Carolina Beach	3.30	73%
Kure Beach	2.52	86%
Federal Point Township	0	0%
Bald Head Island	3.74	34%
Caswell Beach	2.80	77%
Oak Island	8.85	93%
Holden Beach	4.83	56%
Ocean Isle Beach	3.47	59%
Sunset Beach	0	0%

Community	Total Length of Shoreline Modified by Sediment Placement as of 2015 (miles)	Percentage of Shoreline Modified with Sediment Placement as of 2015
TOTAL	**100.97**	**31%**

1 – The Town of Duck is scheduled to receive sediment placement along 1.70 miles of beach in 2017; after the project is constructed, the proportion of sandy beach habitat within the town that has been modified by sediment placement will increase to 29%.

2 – The Town of Kitty Hawk's sediment placement project scheduled for 2017 will extend 1,000 ft into Southern Shores; after the project is constructed, 5% of the sandy beach habitat within the town will have been modified by sediment placement. In early 2017, the Town of Southern Shores proposed to extend the Kitty Hawk sediment placement area an additional 1,500 ft in Southern Shores, for a total of 2,500 ft. If constructed, the length of sandy beach habitat modified by sediment placement in Southern Shores would increase to 2,500 ft, or 13% of the community's sandy beach habitat.

3 – The Town of Kitty Hawk is scheduled to receive sediment placement along 3.55 miles of beach in 2017; after the project is constructed, the proportion of sandy beach habitat within the town that has been modified by sediment placement will increase to 100%.

4 – The Town of Kill Devil Hills is scheduled to receive sediment placement along 2.57 miles of beach in 2017; after the project is constructed, the proportion of sandy beach habitat within the town that has been modified by sediment placement will increase to 55%.

5 – Buxton is scheduled to receive sediment placement along 2.93 miles of beach in 2017; after the project is constructed, the proportion of sandy beach habitat within the town that has been modified by sediment placement will increase to 33%.

Table N-5. The length and proportion of sandy beach within each community (from north to south) along the oceanfront shoreline of North Carolina that was modified with beach scraping or grading from 2012 to 2015.

Community	Length of Sandy Beach Modified with Beach Scraping (miles)	Percentage of Shoreline Modified with Beach Scraping
Corolla	2.18	10%
Duck	0.02	0%
Southern Shores	0.42	11%
Kitty Hawk	0.37	10%
Kill Devil Hills	0.01	0%
Nags Head	0	0%
Rodanthe	0.07	0%
Salvo	0	0%
Avon	0	0%
Buxton	0	0%
Frisco	0	0%
Hatteras	0	0%
Ocracoke	0	0%
Cape Lookout NS (Portsmouth Island to Shackleford Banks)	0.00	0%
Atlantic Beach	0.07	1%
Pine Knoll Shores	0	0%
Indian Beach	0	0%
Salter Path	0	0%
Emerald Isle	0	0%
Swansboro Township (Hammocks Beach SP)	0	0%
Camp Lejeune	0	0%
North Topsail Beach	0.56	5%
Surf City	0.28	5%
Topsail Beach	0	0%
Topsail Township (Lea-Hutaff Island)	0	0%
Figure 8 Island	> 0.32	> 6%
Wrightsville Beach	0	0%
Masonboro Island	0	0%
Carolina Beach	0	0%
Kure Beach	0.54	18%
Federal Point Township[3]	0	0%
Bald Head Island	0	0%
Caswell Beach	0	0%
Oak Island	0	0%
Holden Beach	0	0%
Ocean Isle Beach	0	0%
Sunset Beach	0	0%
TOTAL	**> 4.84**	**> 2%**

Table N-6. The length and proportion of sandy beach within each community (from north to south) along the oceanfront shoreline of North Carolina that was modified with the installation of sand fencing from 2012 to 2015.

Community	Length of Sandy Beach Modified with Sand Fencing (miles)	Percentage of Shoreline Modified with Sand Fencing
Corolla	12.14	53%
Duck	2.49	43%
Southern Shores	2.36	63%
Kitty Hawk	1.52	43%
Kill Devil Hills	3.14	67%
Nags Head	8.80	53%
Rodanthe	0.80	5%
Salvo	0	0%
Avon	1.21	21%
Buxton	0.14	1%
Frisco	0.35	32%
Hatteras	0.54	9%
Ocracoke	0	0%
Cape Lookout NS (Portsmouth Island to Shackleford Banks)	0	0%
Atlantic Beach	4.00	64%
Pine Knoll Shores	4.71	97%
Indian Beach	0.57	32%
Salter Path	0.15	20%
Emerald Isle	3.56	32%
Swansboro Township (Hammocks Beach SP)	0	0%
Camp Lejeune	1.23	11%
North Topsail Beach	2.60	24%
Surf City	0.10	2%
Topsail Beach	0.36	6%
Topsail Township (Lea-Hutaff Island)	0	0%
Figure 8 Island	1.97	37%
Wrightsville Beach	1.12	24%
Masonboro Island	0	0%
Carolina Beach	0.28	6%
Kure Beach	0.72	25%
Federal Point Township	0	0%
Bald Head Island	0.44	4%
Caswell Beach	0.05	1%
Oak Island	2.08	22%
Holden Beach	3.55	41%
Ocean Isle Beach	1.73	29%
Sunset Beach	0	0%
TOTAL	**62.69**	**19%**