Inventory of Habitat Modifications to Sandy Beaches in the U.S. Atlantic Coast Breeding Range of the Piping Plover (*Charadrius melodus*) prior to Hurricane Sandy: Maine to the North Shore and Peconic Estuary of New York[1]

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Recovery Task 1.2 of the U.S. Fish and Wildlife Service (USFWS) Recovery Plan for the piping plover (*Charadrius melodus*) 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). This assessment fills a data need to identify such habitat modifications that have altered natural coastal processes and the resulting abundance, distribution, and condition of currently existing habitat in the breeding range. Four previous studies provided these data for the United States (U.S.) continental migration and overwintering range of the piping plover (Rice 2012a, 2012b) and the southern portion of the U.S. Atlantic Coast breeding range (Rice 2014, 2015a). This assessment provides these data for one habitat type – namely sandy beaches within the northern portion of the breeding range along the Atlantic coast of the U.S. prior to Hurricane Sandy. A separate report assessed tidal inlet habitat in the same geographic range prior to Hurricane Sandy (Rice 2015b). Separate reports will assess the status of these two habitats in the northern and southern portions of the U.S. Atlantic coast breeding range immediately following and 3 years after Hurricane Sandy.

Sandy beaches are a valuable habitat for piping plovers, other shorebirds and waterbirds for nesting, foraging, loafing, and roosting. The North Atlantic Landscape Conservation Cooperative 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, least terns, black skimmers, seabeach amaranth and migrating shorebirds (http://www.fws.gov/northeast/science/pdf/nalcc_terrestrial_rep_species_table.pdf). Sandy beaches and/or dunes are designated as a key habitat in the state Wildlife Action Plans for all of the states in this survey area – Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut and New York; the piping plover is listed as a species in greatest conservation need by each of those states as well (CTDEP 2005, MDIFW 2005, NYDEC 2005, RDFW 2005, MDFW 2006, NHFG 2006). 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).

Although some information is available for the number of beaches stabilized with seawalls, groins, revetments, and other hard armoring structures, these data have not been combined with other information that is available for sand placement projects and beachfront development. Altogether this information can

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provide an assessment of the cumulative impacts of habitat modifications on sandy beaches for piping plovers and other birds, including the rufa red knot (*Calidris canutus rufa*), which was added to the species protected under the Endangered Species Act in January 2015. This assessment does **not**, however, include habitat disturbances at sandy beaches such as off-road vehicle (ORV) usage, pet and human disturbance, or disturbance to dunes or vegetation.

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).

In New England and Long Island, the coast has been sculpted by glaciers, and rocky shorelines and those composed of glacial materials (e.g., sand, gravel and boulders) are common. Barrier islands are limited in New England, with one stretch of barrier islands from Great Boars Head, in Hampton, New Hampshire (NH), to the (northern) Annisquam River Inlet near Cape Ann, Massachusetts (MA), and another on the outer arm of Cape Cod stretching from Coast Guard Beach just north of Nauset Inlet in Eastham south to Monomoy Island, MA (FitzGerald 1993). Plum Island is New England's largest barrier island and is a part of the northern Massachusetts barrier island chain (Buynevich and FitzGerald 2000). One barrier island historically existed in Maine (ME) at Pine Point Beach, but the island joined the Old Orchard Beach peninsula / spit after Little River Inlet closed in the 1870s and Pine Point ceased to be an island (FitzGerald et al. 1989). Sandy Point that straddles the border between Rhode Island and Connecticut is the only other true barrier island in New England (since 1938 when the barrier spit was cut by a new inlet), although a number of barrier spits or baymouth bars occasionally will be breached and become sandy islands for short periods of time. Although barrier islands may be uncommon in New England, baymouth and bayhead barrier beaches and barrier spits are present along much of the coast and provide similar ecosystem functions, including piping plover habitat (Leatherman 1988, FitzGerald 1993 and 1996).

METHODS

Several methods were used to evaluate the status of exposed sandy beaches within the northern portion of the U.S. Atlantic Coast breeding range of the piping plover, namely those within the states of Maine (from Georgetown south, where nearly all of the state's sandy beaches are located), New Hampshire, Massachusetts, Rhode Island (RI), Connecticut (CT), and New York (the Long Island Sound shoreline from Plum Point to Fishers Island and the Peconic Estuary shoreline). The status of exposed sandy beaches was evaluated through an estimation of the length and proportions of shoreline that were developed, undeveloped, in public or non-governmental organization (NGO) ownership, armored with hard stabilization structures, and modified with sediment placement projects. Sandy beaches within harbors and inner bays were not included.

Due to a lack of published data for every state except Massachusetts, the shoreline was assessed by using Google Earth to calculate the lengths of exposed sandy beaches in each geographic area as well as to distinguish the lengths that were developed versus undeveloped. A minimum beach length of 500 ft (152.4 meters [m]) was used since much of the New England coast contains pocket beaches. No measurements were made of beach width, although some beaches were very narrow on the dates of the aerial imagery viewed and may have been too narrow to support successful piping plover nesting (at those times). Where sandy beaches were located seaward of seawalls, bulkheads or revetments, the beaches could be very narrow but were included unless evidence indicated there was no beach at any tide level. In

those cases, the length of stabilized shoreline with no beach (but where evidence indicated a sandy beach would be present in the absence of the hard stabilization structures) was measured as habitat loss as of that particular imagery date. A Microsoft Excel database of all data was created, with the data organized by geographic area. Data were compiled on a county-by-county or community/municipal basis to facilitate updates and comparison of the data over time.

Where Google Earth was utilized to calculate 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 500 ft (152.4 m) in 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. Length measurements were made in miles using the "ruler" or "path" tool of Google Earth. 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 above ground level.

The shoreline lengths used in this report are approximations for several reasons. First is the dynamic nature of the habitat. Sandy 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 exactly the same lengths that would be measured on earlier or later imagery. Second, only the ocean- or sound-facing segments of the inlet shorelines were included, and the demarcation lines were based on professional judgment. Due to the glacial history of the coast, some beaches may be composed of more gravel or cobbles than sand; sections of beach with mixed substrates (i.e., intermixed patches of sand, pebbles, gravel and/or small cobbles) were included wherever the resolution of Google Earth imagery was sufficient to make a professional judgment on the dominant sediment size(s) on the beach. Piping plovers can nest on mixed substrate beaches with varying amounts of gravel or cobble sediment (Flemming et al. 1992, Maslo et al. 2011, Boyne et al. 2014). Beaches that were composed entirely of large cobbles or boulders were excluded, but some of the excluded areas may accumulate sufficient sand during the nesting season to provide habitat. Finally, the measurements are approximations due to mathematical rounding to the nearest hundredth of a mile.

The amount of exposed sandy beach in public and/or NGO ownership (and thus protected to some degree from development) provides an approximation of how much of this 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 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 beaches that are not public or NGO-owned (i.e., private) were assumed to be developable and could provide opportunities for future conservation.

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 beaches that have been protected by non-governmental conservation organizations, such as The Nature Conservancy (TNC) preserves, were also included. Data on the name, location, approximate length of sandy beach, and type of public or NGO

land (e.g., wildlife refuge, park) were added to the Excel database. Lands in public or NGO ownership were identified using existing data found in the sources listed in Table 1. Lengths of sandy beach were obtained from published sources or websites of the individual lands wherever possible, and from Google Earth using the aforementioned methodology for measuring developed versus undeveloped areas. Public and NGO lands that were included may have diminished habitat value due to areas of development or disturbance from recreational and other activities that can occur in parks, seashores, recreation areas, military bases, etc.

Table 1. Data sources used to identify and describe sandy beaches in public and/or NGO ownership, in addition to Google Earth and Google Maps. The parks, recreation and public beach websites of numerous individual towns within each state were also consulted.

Coastline	Source(s)
Maine	ME DACF (2015) data layer for Google Earth: Conservation Lands in Maine
New Hampshire	NH GRANIT Online Mapping Tool data layer: Conservation Lands (www.grainitviewii.unh.edu)
Massachusetts	Coast Guide Online for Google Earth (MA CZM 2015a) MORIS data layers: Public Beaches, NPS Boundaries, National Wildlife Refuge System Boundaries, Tax Assessor's Parcels (MA CZM 2015b) Nantucket County GIS parcel map (Nantucket County 2015) Dukes County GIS parcel map (Dukes County 2015a) Nantucket Conservation Foundation Property Map (NCF 2015) Individual organization websites such as The Trustees of Reservations, TNC and Mass Audubon
Rhode Island	RIGIS Data layers: State Conservation Lands, Municipal & Non-Governmental Organization Conservation Lands, Public Access, and Fishing & Boating Access (RIGIS 2015)
Connecticut	CT ECO Data layers: Municipal_Private_Open_Space, Federal_Open_Space and DEP_Property (CT ECO 2015) Connecticut's Critical Habitats and Open Space Interactive Mapper (www.cteco.maps.arcgis.com) Connecticut Coastal Access Guide (www.lisrc.uconn.edu/coastalaccess/)
New York – Long Island Sound	NY GIS Clearinghouse data layer: NY Department of Environmental Conservation (NYDEC) Lands (http://gis.ny.gov/gisdata/index.cfm) Suffolk County GIS Viewer (http://gis2.suffolkcountyny.gov/GISViewer/) Nassau County Land Records Viewer (http://lrv.nassaucountyny.gov/map/?s=30&b=++B&l=1090) Peconic Land Trust Conservation Map (http://www.peconiclandtrust.org/mapsalive.html)
New York – Peconic Estuary	NY GIS Clearinghouse data layer: NY Department of Environmental Conservation (NYDEC) Lands (http://gis.ny.gov/gisdata/index.cfm) Suffolk County GIS Viewer (http://gis2.suffolkcountyny.gov/GISViewer/) Peconic Land Trust Conservation Map (http://www.peconiclandtrust.org/mapsalive.html)

Where readily available information existed or was visible in Google Earth imagery, notations about habitat modifications within individual public and NGO lands were noted in the 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;
- sand fencing;
- the presence of private inholdings or retained rights agreements that preclude some management options; and
- the presence of historic sites or structures (e.g., lighthouses).

An assessment to estimate the length of each state's exposed sandy beach that has been armored with hard structures was measured by identifying and digitizing structures visible in Google Earth imagery in historic aerial photography for every state except Massachusetts. Because armoring structures can be buried by sediment and not readily visible in aerial imagery, imagery taken from multiple dates were used to identify structures that were buried or hidden by vegetation in the most recent imagery prior to Hurricane Sandy. In Massachusetts, existing inventories of public (MA DCR 2009) and privately owned (Fontenault et al. 2013) shoreline stabilization structures, as incorporated into the recent MA Coastal Erosion Commission reports (MA CEC 2015a and 2015b) were used. Armoring structures include shore-parallel seawalls, bulkheads, revetments, riprap, geotubes and sandbags, groins, offshore breakwaters, and jetties.

With the exception of Massachusetts, the length of sandy beach shoreline modified by armoring was measured using the methodology of Coburn et al. (2010), Dallas et al (2013) and Schupp et al. (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. All armoring structures were included, even if some are periodically buried, failing, in disrepair or remnant structures. 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 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. 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.

An estimate of the length of exposed sandy 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. This information serves two purposes: 1) a basis for cumulative effects to sandy oceanfront beaches resulting from soft stabilization and dredge disposal activities, 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, published sources were used to compile the lengths of shoreline affected by beach nourishment and dredge disposal placement activities in each state (e.g., Suffolk County 1985; Haddad and Pilkey 1998; Town of East Hampton 1999; Barnstable County 2009, 2010, 2011, 2012; USACE 2013c). Where readily available published sources were absent for a geographic area, the beach nourishment database of the Program for the Study of Developed Shorelines (PSDS) was consulted (at http://beachnourishment.wcu.edu) along with the project websites for the New York and New England Districts of the U.S. Army Corps of Engineers (USACE), and an inventory of projects in that region was added to the Excel database.

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The database can be updated by contacting the author via email at tracymrice@yahoo.com to report any modifications to the current status or new habitat modifications to sandy beaches contained within the geographic area covered in this assessment. This report and data will be posted on-line at the North Atlantic LCC Hurricane Sandy Science Coastal Resiliency Projects website (http://northatlanticlcc.org/projects).

RESULTS

Prior to Hurricane Sandy in October 2012, approximately 1,175.76 miles (1,892.20 kilometers [km]) of exposed sandy beach were present between Georgetown, ME, and the Long Island Sound (LIS) and Peconic Estuary shorelines of New York (Table 2), of which 34% was in public or NGO ownership (Table 3). There was an additional 43.43 miles (69.89 km) of shoreline without sandy beaches due to hard stabilization habitat loss (Table 4). The total length of exposed sandy beach shoreline in Massachusetts is 1.6 times the length of sandy beach found in all the other states combined (Table 2). The New Hampshire (87%), Maine (68%) and North Shore of Long Island (61%) coasts had the highest proportion of sandy beaches that were developed. The sandy beaches of Rhode Island (29%) and the Peconic Estuary (33%) were the least developed. Altogether, 510.63 of 1,175.76 miles (811.78 of 1,892.20 km; 47%) of exposed sandy beaches from southern Maine through the North Shore and Peconic Estuary of Long Island were developed prior to Hurricane Sandy (Table 2). Slightly more than one-third of the total sandy beaches (394.80 miles or 635.37 km, 34%) were in public or NGO ownership, with Rhode Island (55%) and New Hampshire (53%) having the highest proportions (Table 3).

For every state, the length of sandy beach shoreline that has been armored with hard erosion control structures was measured (Table 4). The total length of shoreline between southern Maine and the Long

Island Sound and Peconic Estuary shorelines of New York that was armored prior to Hurricane Sandy was at least 275.92 miles (444.05 km; 23% of the total sandy beach length). An additional minimum of 43.43 miles (69.89 km) of sandy beach habitat has been lost to shoreline hardening, with no sandy beaches longer than 500 ft (152.4 m) present in front of hard stabilization structures on the most recent imagery dates prior to Hurricane Sandy[2]. This assessment is a minimum number because some structures remain buried and are not visible in aerial imagery and because groin fields in Massachusetts are not included (see the Massachusetts section below for a full discussion); in addition, historical records or inventories of hard stabilization structures may be incomplete or unavailable to indicate where buried structures may exist.

The sandy beaches of the New Hampshire coast had the greatest proportion of shoreline armoring by far, with 72%. The Rhode Island sandy coast is the least armored, with only 9% of its exposed sandy beach shoreline having hard stabilization structures prior to Hurricane Sandy.

Table 2. The lengths and proportions of sandy beach in each state that were developed and undeveloped prior to Hurricane Sandy in October 2012.

State	Approximate length of sandy beach (miles)	Approximate Miles of Beach Developed (percent of total beach length)	Approximate Miles of Beach Undeveloped (percent of total beach length)[1]
Maine[2]	48.88	33.11 (68%)	15.77 (32%)
New Hampshire	9.58	8.35 (87%)	1.23 (13%)
Massachusetts	729.94	300.26 (41%)	429.68 (59%)
Rhode Island[3]	49.56	14.62 (29%)	34.94 (71%)
Connecticut	82.16	35.96 (44%)	46.20 (56%)
New York – Long Island Sound[4]	120.66	73.28 (61%)	46.96 (39%)
New York – Peconic Estuary	134.98	45.06 (33%)	89.92 (67%)
TOTAL[5]	**1,175.76**	**510.63 (47%)**	**664.71 (53%)**

1 – Beaches classified as "undeveloped" occasionally include a few scattered structures.
2 – The area of Maine shoreline included in this assessment is from Georgetown south.
3 – Upper Narragansett Bay is not included; see the Rhode Island section below for precise details.
4 – The westernmost boundary of the Long Island Sound shoreline included was Plum Point in the town of Sands Point on Manhasset Bay.
5 – Totals may differ due to rounding.

[2] Note that some of these sections of armored shoreline with no sandy beaches periodically may receive sediment from beach nourishment, storm damage reduction, or dredge disposal projects that at least temporarily create a sandy beach seaward of the hard stabilization structures; the figures presented here represent the length of armored shoreline with no sandy beach as of one particular point in time, prior to Hurricane Sandy in October 2012.

Table 3. The approximate sandy beach shoreline lengths that are in public or NGO ownership in each state. 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.

State	Length of Sandy Beach Shoreline in Public / NGO Ownership (miles)	Percentage of Sandy Beach Shoreline in Public / NGO Ownership
Maine	13.90	28 %
New Hampshire	5.11	53 %
Massachusetts	217.49	30 %
Rhode Island	27.27	55 %
Connecticut	35.09	43 %
New York – Long Island Sound	34.96	29 %
New York – Peconic Estuary	60.99	45 %
TOTAL	**394.80**	**34 %**

The Peconic Estuary and Connecticut sandy shorelines have the highest number of hard stabilization structures (Table 5). The exposed sandy beaches of the Peconic Estuary had at least 668 groins, 306 contiguous sections of seawalls, revetments and/or bulkheads, 12 breakwaters and 49 jetties. An additional 392 groins, 2 breakwaters and 1 jetty are on sections of shoreline where the sandy beach has been lost and did not exist immediately prior to Hurricane Sandy. Connecticut had at least 653 groins, 275 contiguous sections of seawalls, bulkheads and/or revetments, 18 breakwaters and 24 jetties along existing sandy beaches prior to Hurricane Sandy; another 202 groins and 88 contiguous sections of seawalls, bulkheads and/or revetments were on sections of shoreline where sandy beaches have been lost. In total there are at least 1,858 groins, 115 jetties, 1,057 contiguous sections of seawalls / bulkheads / revetments, and 37 breakwaters on existing sandy beaches from Georgetown, ME, to the North Shore and Peconic Estuary shorelines of New York prior to Hurricane Sandy, excluding Massachusetts[3].

Data on sediment placement projects from Maine to the North Shore and Peconic Estuary of Long Island are sparse. There were no large-scale federal shore protection projects involving beach fill prior to Hurricane Sandy, as is common in the Mid-Atlantic and Southeastern U.S. Most of the federal shore protection projects constructed in this region took place in the 1950s and 1960s and did not involve periodic maintenance, or renourishment, events. The most common sediment placement activities in the northern portion of the piping plover's U.S. Atlantic breeding range are dredge spoil placements with material dredged from nearby inlets. The vast majority of these projects are constructed by county and/or local governments. Both Barnstable County in MA and Suffolk County in NY own and operate their own dredges, maintaining a number of inlets and channels annually with placement of dredged material on nearby sandy beaches. Sediment volumes tend to be small when compared to other regions.

[3] If hard stabilization structures present on sections of shoreline where no sandy beaches at least 500 ft (152.4 m) were present shortly before Hurricane Sandy are included, a total of 2,518 groins, 1,155 contiguous sections of walls, 39 breakwaters and 116 jetties were identified, not including Massachusetts.

Table 4. Approximate shoreline miles that have been modified by armoring with hard erosion control structures for each state from Georgetown, ME, to the Long Island Sound and Peconic Estuary shorelines of New York prior to Hurricane Sandy in 2012. 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.

State	Known Approximate Length of Armored Sandy Beach Shoreline (miles)	Percentage of Armored Sandy Beach Shoreline	Approximate Length of Armored Shoreline with No Sandy Beach (Habitat Loss in miles)
Maine	14.51	30 %	0.48
New Hampshire	6.91	72 %	0.19
Massachusetts[1]	180.24 +	> 25 %	Unknown
Rhode Island	4.21	9 %	1.42
Connecticut	36.91	45 %	18.03
New York – Long Island Sound	6.08	29 %	6.07
New York – Peconic Estuary	27.05	20 %	17.24
TOTAL	**275.92**	**23 %**	**43.43**

1 – The figures presented for Massachusetts' shoreline armoring are for shore-parallel structures (i.e., bulkheads, seawalls, revetments) only and do not include groin fields as the other states do.

Table 5. Approximate number of each type of armoring on the exposed sandy beaches in each state visible on Google Earth imagery between 1991 and August 2012 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 4 above.

State	Number of Groins	Number of Jetties	Number of Seawalls, Bulkheads and/or Revetments	Number of Breakwaters
Maine	0	8	118	0
New Hampshire	14	2	45	2
Massachusetts[1]	unknown	unknown	unknown	unknown
Rhode Island	12	11	58	1
Connecticut	653	24	275	18
New York – Long Island Sound	511	21	255	4
New York – Peconic Estuary	668	49	306	12
TOTAL	**1,858 +**	**115 +**	**1,057 +**	**37 +**

1 – MA DCR (2009) and Fontenault et al. (2013) provide inventories of public and private shoreline stabilization structures for the entire Commonwealth of Massachusetts but do not provide data on how many of the structures are on sandy beaches versus rocky shorelines.

Haddad and Pilkey (1998) reviewed beach nourishment activities in New England, excluding New York. They found that between 1935 and 1996, "Most nourishment episodes in New England are small (<100,000 cubic yards) and state/locally funded. The total number and volume of nourishment episodes completed annually in the region is declining, and the cumulative volume of nourishment sand in the region has plateaued over time. Total known volume of sand emplaced is 12,550,881 cubic yards with 105 of 173 episodes included in this sum" (Haddad and Pilkey 1998, p. 1395). It should be noted that sediment placement projects in Maine are generally the placement of dredged material from navigation channels on sandy beaches with limited to no state funding (Beach Stakeholders Group 2006).

With the limited data available, this assessment found a minimum of 46.90 miles (75.48 km; 4%) of exposed shoreline between Georgetown, ME, and the Long Island Sound and Peconic Estuary shorelines of New York have been modified with sediment placement (Table 6). A total of 296 documented sandy beaches have been modified with sediment placement, but project lengths were only found for 174 (59%) of them.

Table 6. The approximate lengths of known constructed (existing) sediment placement projects and those proposed prior to Hurricane Sandy in October 2012 for each state; sediment placement projects include beach nourishment, artificial dune construction, inlet closure, and dredge disposal placement projects.

State	Length of Shoreline Previously Modified with Sediment Placement (miles)	Percentage of Shoreline Modified with Sediment Placement
Maine	6.30	13 %
New Hampshire	1.37 +	> 14 %
Massachusetts	14.79 +	> 2 %
Rhode Island	6.00 +	> 12 %
Connecticut	15.32 +	> 19 %
New York – Long Island Sound[1]	1.68 +	> 1.4 %
New York – Peconic Estuary	1.44 +	> 1 %
TOTAL	**46.90 +**	**> 4 %**

1 – One additional federal shoreline protection project has been proposed for up to 2.5 miles (4.0 km) of beach along the North Shore of Long Island, but formal project designs and construction were not completed prior to Hurricane Sandy.

State-specific Results

Maine

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). Sagadahoc County includes the coastal communities of Georgetown and Phippsburg. Cumberland County includes the coastal communities (from north to south) of Harpswell, Chebeague Island, Long Island, Portland, Cape Elizabeth, and Scarborough. York County includes the coastal communities (from north to south) of Old Orchard Beach, Saco, Biddeford, Kennebunkport, Kennebunk, Wells, Ogunquit, York and Kittery. 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.

Altogether there were approximately 49 miles (79 km) of sandy beaches within these communities as of May 2012 prior to Hurricane Sandy (Table 7)[4]. The sandy beaches were divided into 104 separate pocket or barrier beach segments of at least 500 ft (152.4 m) in length. Sagadahoc County had 17 pocket or barrier beach segments, Cumberland County had 46 and York County had 41 along their exposed shorelines. The longest stretch of sandy beach in Maine is in Saco Bay between Prouts Neck and the Scarborough River at the north and Fletcher Neck and the Saco River at the south, with nearly 8 miles (13 km) of sandy beach separated only by inlets at the Scarborough River and Goosefare Brook; the northern section of this shoreline at Pine Point historically was Maine's only barrier island until the Little River Inlet was closed in the late 19th century (FitzGerald et al. 1989, Rice 2015b).

Approximately 33.11 miles (53.29 km; 68%) of Maine's sandy beach are developed and 15.77 miles (25.38 km; 32%) are undeveloped (Table 7). Development of the sandy beachfront increases to the south, with York County the most developed (80%) and Sagahadoc County the least developed (32%).

Nearly 14 miles (22.5 km) of sandy beach are in public and/or NGO ownership (Table 8). In Maine, beaches are private property to the low water or tide line. Kelley et al. (1989) found that the Maine coast is the most privately owned and least accessible in the country. In addition to the public and/or NGO-owned beaches listed in Table 8, an additional 8 public beaches own the beach itself but not the adjacent

Table 7. The approximate lengths of sandy oceanfront beach within each county of Maine south of Georgetown and the proportions that are developed and undeveloped.

County	Approximate length of sandy beach (miles)	Developed shoreline miles (% of total)	Undeveloped shoreline miles (% of total)
Sagadahoc	6.83	2.21 (32%)	4.62 (68%)
Cumberland	17.18	11.06 (64%)	6.12 (36%)
York	24.87	19.83 (80%)	5.04 (20%)
TOTAL	**48.88**	**33.11 (68%)**	**15.77 (32%)**

[4] 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, MGS, pers. communication, May 15, 2015). The inclusion of some mixed substrate beaches, as described in the Methods section above, is the most likely reason why this inventory identified a greater length of sandy beaches in southern Maine than these sources.

property: Old Orchard Beach; Fortune Rocks Beach in Biddeford; Goose Rocks Beach in Kennebunkport; Gooch's Beach, Kennebunk (Middle) Beach and Mother's Beach in Kennebunk; and Drake's Island Beach and Wells Beach in Wells. Popham Beach State Park, the Bates-Morse Mountain Conservation Area, Little Chebeague Island, Ogunquit Beach, and Long Sands Beach are the longest sandy beaches in public and/or NGO ownership in Maine, with each extending for more than one mile (1.6 km).

The USFWS owns several units with sandy beaches in the Rachel Carson NWR (Table 8; USFWS 2007). The state of Maine owns a number of parks, both passive (i.e., low to no development) and active, with sandy beaches. Local governments own public beaches and parks. Several local and regional land trusts also own sandy beaches in southern Maine.

The Maine Geological Survey (MGS) recently mapped approximately 16.1 miles (25.9 km) of hard stabilization structures along 37.5 miles (60.35 km) of sandy beaches from Georgetown south (Peter Slovinsky, MGS, pers. communication, May 15, 2015). This inventory identified approximately 14.51 miles (23.35 km) of hard stabilization structures using Google Earth imagery dated May 2012 along 48.88 miles (78.66 km) of sandy beach (Table 9); additional structures may be buried or covered in vegetation and not visible. A total of 1 groin, 8 jetties and 118 contiguous sections of seawalls / bulkheads / revetments were identified (Table 10). These shoreline stabilization structures are disproportionally found in York County, where 51% of the sandy beaches are armored. Sagadahoc and Cumberland Counties beaches are much less armored, with 2% and 9% of the beaches having hard stabilization structures respectively. The communities of York (84%), Wells (76%), Kennebunkport (63%), Biddeford (52%), Old Orchard Beach (46%), Kennebunk (44%) and Peaks Island in Portland (43%) have the highest proportions of their beaches lined with hard stabilization structures. 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.

Maine prohibits the construction of new hard stabilization structures that are anchored to land on sandy beaches and dunes, including seawalls and groins (Kelley et al. 1989, Beach Stakeholders Group 2006, Woods Hole Group and Aubrey Consulting 2006, USACE 2013d), but a number of structures were built prior to the prohibition that was enacted in 1983.

In addition to the 14.51 miles (23.35 km) of sandy beaches with hard shoreline stabilization structures, an additional 0.48 miles (0.77 km) of shoreline was armored with hard shoreline stabilization structures but did not have any sandy beaches longer than 500 ft (152.40 m) as of May 2012; thus approximately half a mile (three-quarters of a kilometer) of sandy beach habitat had been lost at that time. (Evidence indicated sandy beaches would be present in these locations in the absence of the hard stabilization structures.)

Table 8. Sandy oceanfront beaches of at least 500 ft (152.4 m) in length that are in public or NGO ownership in Maine from north to south, the county in which each is located, and approximate length of sandy beach in each visible in Google Earth imagery from May 2012 prior to Hurricane Sandy (Sources: See Table 1).

Public / NGO Land	County Location	Approximate Beach Length in Miles
Reid State Park	Sagadahoc	1.01
Popham Beach State Park	Sagadahoc	1.24
Bates-Morse Mountain Conservation Area	Sagadahoc	1.47
Small Point Preserve	Sagadahoc	0.09
Upper Flag Island, Petit Menan NWR	Cumberland	0.19
Rose's Point, Chebeague Island	Cumberland	0.24
Higgins Farm, Chebeague Island	Cumberland	0.11
Belvins Easement, Chebeague Island	Cumberland	0.04
Indian Point, Chebeague Island	Cumberland	0.24
Curit Property, Chebeague Island	Cumberland	0.11
Little Chebeague Island	Cumberland	1.34
Andrews Beach	Cumberland	0.16
Kettle Cove, Crescent Beach State Park	Cumberland	0.20
Crescent Beach State Park	Cumberland	0.83
Scarborough WMA	Cumberland	0.10
Scarborough Beach State Park	Cumberland	0.39
Ferry Beach	Cumberland	0.48
Pine Point Easements	Cumberland	0.35
Hurd Park, Pine Point	Cumberland	0.05
Rachel Carson NWR, Goosefare Brook Division	York	0.15
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	0.34
Colony Beach	York	0.05
Strawberry Island	York	0.02
Rachel Carson NWR, Mousam River Division (Little River Inlet)	York	0.32
Laudholm Farm, Wells NERR	York	0.40
Crescent Beach	York	0.08
Ogunquit Beach	York	1.42
Short Sands Beach, Ellis Park	York	0.23
Long Sands Beach	York	1.30
Harbor Beach, Hartley Mason Park	York	0.14
Gerrish Island, Delano Easement	York	0.24
	TOTAL MILES	**13.89 (28% of sandy beach shoreline)**

Table 9. Approximate oceanfront shoreline length (in miles) within each county of Maine that were armored with hard stabilization structures visible on Google Earth imagery between 1997 and May 2012. Hard stabilization structures include groins, jetties, seawalls, bulkheads, revetments, geotubes, sandbags and breakwaters. Structures may be periodically exposed or buried and include those that are failing, in disrepair, or remnants of old structures.

County	Approximate Length of Armoring (miles)	Percentage of Beach Length Armored
Sagadahoc	0.14	2%
Cumberland	1.58	9%
York	12.79	51%
TOTAL	**14.51**	**30%**

Table 10. Approximate number of each type of armoring visible on the oceanfront beach in each county of southern Maine visible on Google Earth imagery between 1997 and May 2012. 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 9 above.

County	Number of Groins	Number of Jetties	Number of Seawalls, Bulkheads and/or Revetments	Number of Breakwaters
Sagadahoc	0	0	4	0
Cumberland	1	1	15	0
York	0	7	99	0
TOTAL	1	8	118	0

There are 11 sandy beaches in southern Maine where sediment has been placed on the beach and/or dune, nearly always as beneficial use of material dredged during navigation channel maintenance (Table 11). Dredge spoil material from the Scarborough River has been placed at both Western Beach and Pine Point (Haddad and Pilkey 1998, USACE 2013f, PSDS 2015). Ferry Beach and Camp Ellis have received dredge spoil from the Saco River, with at least 383,719 cubic yards (cy) of material placed on the beach since 1919 (Haddad and Pilkey 1998, Slovinksy and Dickson 2003, Beach Stakeholders Group 2006, USACE 2013d, PSDS 2015). Camp Ellis Beach has been proposed for a larger beach fill project (with and without modifications to existing hard stabilization structures) to address erosion problems caused by the Saco River jetties, which were initially constructed in 1869-1890 (Slovinsky and Dickson 2003, Slovinsky 2005, Woods Hole Group and Aubrey Consulting 2006), but a formal federal project was not proposed prior to Hurricane Sandy in October 2012 (USACE 2013d). Hills Beach in Biddeford received dredge spoil material from the nearby federal navigation channel in 1989 (Haddad and Pilkey 1998, Beach Stakeholders Group 2006). Gooch's Beach in Kennebunk received federal dredge spoil material in 1985 and 2004 (Haddad and Pilkey 1998, Beach Stakeholders Group 2006, Peter Slovinsky, MGS, pers. communication, May 15, 2015). Drakes Island and/or Wells Beach in Wells have received dredged material from Wells Harbor in 1990, 1991, and 2000-01 (Dickson 2001, Beach Stakeholders Group 2006, USACE 2013c, PSDS 2015).

In addition to these dredge spoil disposal projects, two other beaches intentionally have been modified with sediment placement. Dunes were constructed with fill material along 1.1 miles (1.77 km) of Old

Orchard Beach in 1986 (Peter Slovinsky, MGS, pers. communication, May 15, 2015). The flood tidal delta of the Ogunquit River Inlet was mined in 1974 to construct dunes along Ogunquit Beach (Haddad and Pilkey 1998, PSDS 2015). Neither of those projects were federally-sponsored. There were no federal storm damage reduction projects involving beach fill prior to Hurricane Sandy in southern Maine.

Dickson (2003, p. 5) found that "The combined influence of jetty engineering, seawalls and dredging has accelerated shoreline change and the inland positions of floodplains in Maine in the last century."

Table 11. The approximate lengths of known constructed beach nourishment and dredge disposal placement projects on Maine oceanfront beaches from Georgetown south to New Hampshire (Sources: Kelley et al. 1989; Haddad and Pilkey 1998; Dickson 2001; Slovinsky and Dickson 2003; Beach Stakeholders Group 2006; Slovinsky 2006; USACE 2013c, 2013d and 2013f,; PSDS 2015; e USACE New England District website; Peter Slovinsky, MGS, pers. communication, May 15, 2015).

Location	Project Length (miles)
Popham Beach, Phippsburg[1]	0.2
Western Beach, Scarborough	0.4
Pine Point, Scarborough	0.4
Old Orchard Beach	1.1
Ferry Beach, Saco	0.2
Camp Ellis Beach, Saco	< 0.2
Hills Beach / Biddeford Pool, Biddeford	Unknown
Gooch's Beach, Kennebunk	0.6
Drakes Island, Wells[2]	1.2
Wells Beach, Wells[2]	
Ogunquit Beach, Ogunquit	2.0
TOTAL MILES	**6.3 (13% of state's sandy beaches)**

1 – A minor inlet relocation project with associated beach scraping involved sediment placement along approximately 0.2 miles of beach in 2011 (Peter Slovinsky, MGS, pers. communication, May 15, 2015).

2 – Sediment was placed along both Drakes Island and Wells Beach in 2000 along 1.2 miles of total beach (Peter Slovinsky, MGS, pers. communication, May 15, 2015).

New Hampshire

The oceanfront New Hampshire shoreline contained approximately 9.58 miles (15.41 km) of sandy beaches as of November 2011, prior to Hurricane Sandy in October 2012 (Table 12). The entire New Hampshire Atlantic coastline falls within Rockingham County, which contains the communities of (from north to south) New Castle, Rye, North Hampton, Hampton and Seabrook. There were 22 distinct pocket or barrier beach segments in November 2011 in New Hampshire, with Rye and Hampton having the most and longest totals of sandy beach. It should be noted, however, that Seabrook's beach is contiguous with sandy beach in Massachusetts since the town boundary is also the state boundary.

The majority (87%) of New Hampshire's oceanfront sandy beaches are developed, with only 13% undeveloped (Table 12). New Castle's sandy beaches are 100% developed, Seabrook's 98% developed, Hampton's 91% developed, Rye's 81% developed, and North Hampton's 72% developed.

Just over half (53%) of New Hampshire's oceanfront sandy beaches are in public and/or NGO ownership (Table 13). The longest of these are Hampton Beach State Park, which is divided into two sections north and south of Great Boars Head, and Seabrook Dunes and Beach. Two additional public beaches, Foss Beach in Rye and Bass Beach in North Hampton, are owned by local governments but are limited to the beach only with private property directly adjacent to the beach; therefore they are not included in Table 13. All but one of the sandy beaches listed in Table 13 are locally or state owned; the federal government does not own any sandy beaches in New Hampshire.

Table 12. The approximate lengths of sandy oceanfront beach within Rockingham County in New Hampshire and the proportions that are developed and undeveloped as of November 2011 according to Google Earth imagery.

County	Approximate length of sandy beach (miles)	Developed shoreline miles (% of total)	Undeveloped shoreline miles (% of total)
Rockingham	9.58	8.35 (87%)	1.23 (13%)

Table 13. Sandy oceanfront beaches that are in public or NGO ownership in New Hampshire and approximate length of sandy beach in each visible in Google Earth imagery from November 2011 prior to Hurricane Sandy (Sources: See Table 1).

Public / NGO Land	Approximate Beach Length in Miles
Great Island Common	0.07
Crosby Easement	0.09
Odiorne Point State Park	0.53
Wallis Sands State Park	0.12
Rye Harbor State Park	0.03
Jenness Beach State Park	0.09
Sawyers Beach	0.19
North Hampton State Park	0.20
North Side Park	0.03
Hampton Beach State Park (North Beach)	1.05
Hampton Beach State Park (south of Great Boars Head)	1.48
Seabrook Dunes and Beach	1.23
TOTAL MILES	**5.11 (53% of sandy beach shoreline)**

Approximately 72% (6.91 miles or 11.12 km) of New Hampshire's sandy oceanfront beaches is armored with hard stabilization structures (Table 14). There are approximately 14 groins, 2 jetties, 45 contiguous sections of seawalls / bulkheads / revetments, and 2 breakwaters (Table 15). Hampton and North Hampton's sandy beaches are the most armored with 95 and 90% respectively. Rye's sandy beaches are 73% armored with hard stabilization structures. Seabrook (30%) and New Castle (25%) were the least armored sandy beaches in New Hampshire. Hard stabilization structures can also be found on the non-sandy sections of shoreline in New Hampshire, but those structures were not included in this assessment.

In addition to the 6.91 miles (11.12 km) of sandy beaches with hard shoreline stabilization structures, an additional 0.19 miles (0.31 km) of shoreline was armored with hard shoreline stabilization structures but did not have any sandy beaches longer than 500 ft (152.40 m) as of November 2011; thus 0.19 miles (0.31 km) miles of sandy beach habitat had been lost at that time. (Evidence indicated sandy beaches would be present in these locations in the absence of the hard stabilization structures.)

At least 1.37 miles (2.20 km) of New Hampshire's sandy oceanfront beaches have been modified with sediment placement (Table 16). Wallis Sands State Park received beach fill along 800 ft (243.84 m) of shoreline along with the construction of a groin at its south end in a federal project in 1963; additional beach fill was placed on the beach in 1972 and 1983 (Haddad and Pilkey 1998, USACE New England District website). A federal shore protection project was constructed at Hampton Beach along 6,450 ft (1966 m) of shoreline in 1955; some portion of the beach previously received fill in a state project in 1935. Dredged material from Hampton Harbor and/or Hampton River Inlet are periodically placed along the Hampton Beach State Park beach as well (Haddad and Pilkey 1998, USACE 2013c, USACE New England District website). Seabrook also receives dredge spoil from Hampton Harbor along an unknown length of beach (NHFG 2006, USACE 2013c).

Table 14. Approximate oceanfront shoreline length (in miles) within each county of New Hampshire that were armored with hard stabilization structures visible on Google Earth imagery between 1992 and November 2011. Hard stabilization structures include groins, jetties, seawalls, bulkheads, revetments, geotubes, sandbags and breakwaters. Structures may be periodically exposed or buried and include those that are failing, in disrepair, or remnants of old structures.

County	Approximate Length of Armoring (miles)	Percentage of Beach Length Armored
Rockingham	6.91	72%

Table 15. Approximate number of each type of armoring visible on the oceanfront beach in each county of New Hampshire visible on Google Earth imagery between 1992 and November 2011. 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 14 above.

County	Number of Groins	Number of Jetties	Number of Seawalls, Bulkheads and/or Revetments	Number of Breakwaters
Rockingham	14	2	45	2

Table 16. The approximate lengths of known constructed beach nourishment and dredge disposal placement projects on New Hampshire oceanfront beaches from north to south. (Sources: Haddad and Pilkey 1998, NHFG 2006, USACE 2013c and the website of the USACE New England District).

Location	Project Length (miles)
Wallis Sands State Park	0.15
Hampton Beach	1.22
Seabrook Beach	Unknown
TOTAL MILES	**1.37+ (14% of sandy beach shoreline)**

Massachusetts

The Massachusetts coastline is approximately 1,500 miles (2,414 km) long, but only a portion of it is composed of sandy beaches. Some sections of the coast are rocky while others may be composed of marsh. Sandy beaches in Massachusetts come in many forms: barrier beaches[5], barrier islands, barrier spits, baymouth bars, and coastal beaches[6]. There are two major barrier island chains in Massachusetts, the northern one extending from Great Boards Head in New Hampshire to Cape Ann and the other along Cape Cod National Seashore from Coast Guard Beach to Monomoy Island along outer Cape Cod (FitzGerald 1993). These are the only two true barrier island chains in the region covered in this assessment. For the purposes of this assessment, findings on Massachusetts' sandy beaches are presented by county. Within the 8 coastal counties, there are 57 communities (see Table A-1 in Appendix A for a full list).

The Massachusetts Coastal Erosion Commission (MA CEC 2015a, 2015b) summarizes recent Commonwealth projects to inventory the location and distribution of coastal landforms (including sandy beaches), shoreline stabilization projects and developed lands along the immediate, exposed Massachusetts shoreline. The immediate, exposed shoreline typically does not include harbors and estuaries (MA CEC 2015b). Using shoreline, land use / land cover and wetlands class data that pre-date Hurricane Sandy (and thus are applicable to this assessment), the entire coastline was mapped at 50 meter (164 ft) intervals. Data from this project were used in this assessment to calculate the lengths of sandy beach, development and shoreline stabilization structures for each community (Tables 17, 18, and 20).

The Commonwealth of Massachusetts, as per Executive Order Number 181, mapped the state's barrier beaches for regulatory purposes in 1982 (MA Barrier Beach Task Force 1994). Only minor edits have been made to the mapped barrier beach units since that time (Rebecca Haney, MA Office of Coastal Zone Management, pers. Comm., February 11, 2015). The barrier beach units did not include all of the state's

[5] A "barrier beach" is defined by the Commonwealth of Massachusetts as "a narrow low-lying strip of land generally consisting of coastal beaches and coastal dunes extending roughly parallel to the trend of the coast. It is separated from the mainland by a narrow body of fresh, brackish or saline water or a marsh system. A barrier beach may be joined to the mainland at one or both ends" (MA Barrier Beach Task Force 1994, p. 39; 310 Code of Mass. Regulations 10.29(2)).

[6] A "coastal beach" is defined by the Commonwealth of Massachusetts as "unconsolidated sediment subject to wave, tidal and coastal storm action which forms the gently sloping shore of a body of salt water and includes tidal flats. Coastal beaches extend from the mean low water line landward to the dune line, coastal bankline or the seaward edge of existing man-made structures, when those structures replace one of the above lines, whichever is closest to the ocean" (MA Barrier Beach Task Force 1994, p. 40; 310 Code of Mass. Regulations 10.27(2)(b)).

sandy beaches, however; sandy beaches at the bases of bluffs and along mainland shorelines, designated as coastal beaches, were omitted (MA Barrier Beach Task Force 1994). In addition, in some areas the current locations of the state-mapped barrier beaches are outdated, particularly where inlets have opened, migrated or closed.

The Commonwealth mapped 681 barrier beaches covering approximately 222 miles (357 km) in the 1982 project (MA Barrier Beach Task Force 1994). This assessment included areas designated as coastal beaches along with barrier beaches and identified a total of approximately 730 miles (1,175 km) of sandy beaches along the 1,028 mile (1,654 km) immediate, exposed shoreline using data from MA CEC (2015a and 2015b). The lengths of sandy beach found in each county are listed in Table 17. Approximately 71% of the state's immediate, exposed shoreline contains sandy beaches.

The Massachusetts Wildlife Action Plan (MDFW 2006) identified the protection of breeding and migratory habitat for piping plovers and other beach-nesting birds from degradation due to development as a conservation action. Of the 730 miles (1,175 km) of sandy beach habitat identified in this inventory, the MA Division of Fisheries and Wildlife (MA DFW) has identified approximately 350.5 miles (564.07 km) of sandy beach that has supported piping plover nesting (and foraging) in the last 25 years (Jon Regosin, MA DFW, pers. communication, May 18, 2015). Of the ~730 miles (1,175 km) of sandy beaches in Massachusetts, approximately 41% have development within 150 to 200 m (492 to 656 ft) of the beach[7] (Table 18). Norfolk and Plymouth Counties' beaches are the most developed at 67% and 64% respectively. The offshore island counties of Dukes and Nantucket are the least developed, with only 17% and 24% of their beaches lined with adjacent development respectively.

Table 17. The approximate lengths of exposed sandy beach within each county of Massachusetts as utilized in MA CEC (2015b). Note that MA CEC (2015b) incorporated the beaches identified in the MA Department of Environmental Protection (MA DEP) Wetlands GIS data layer, which was based on 1990-1993 imagery; this is the best data available for mapping all of Massachusetts' sandy beaches at this time.

County	Approximate total shoreline length in miles	Approximate length of sandy beach (miles)	Percent of Shoreline with Sandy Beaches
Essex	143.85	56.31	39%
Suffolk	36.98	28.24	76%
Norfolk	30.58	20.55	67%
Plymouth	195.15	116.24	60%
Barnstable	327.53	269.53	82%
Bristol	70.31	41.15	59%
Dukes	142.63	122.67	86%
Nantucket	80.88	75.23	93%
TOTAL	**1,027.90**	**729.94**	**71%**

[7] Because this range inland from the beach is generally wider than that used in the visual analysis using Google Earth imagery in the other states that assessed their levels of beachfront development, some sections of beach may be classified as developed in Massachusetts that would have been considered undeveloped in other states.

Roughly 217 miles (349 km) of sandy beaches in Massachusetts are in public or NGO ownership, in 221 separate tracts (for a full list see Table A-2 in Appendix A). Thirty-eight (38) of these tracts have sandy beaches that are at least 1 mile (1.6 km) in length (Table 19). The longest length of sandy beach in public or NGO ownership, one-fourth of the state's total, is the Cape Cod National Seashore owned by the National Park Service, which contained approximately 55.59 miles (89.46 km) of sandy beaches as of March 2012, prior to Hurricane Sandy. Monomoy NWR[8] contains the second-highest total length of sandy beaches with 13.59 miles (21.87 km) that were exposed to the Atlantic Ocean or Nantucket Sound; the refuge owns other sandy beaches on North Monomoy and Morris Islands that are not directly exposed to the Sound that were not counted in this assessment.

Some of Massachusetts' offshore islands have several miles of sandy beaches in public or NGO ownership. More than 34% (27.64 miles or 44.48 km) of Nantucket's sandy beaches are in public or NGO ownership or easement, with more than 34 tracts (exceeding 500 ft or 152.4 m in length) of sandy beach owned by the USFWS, Nantucket Conservation Foundation, Trustees of Reservations, Town of

Table 18. The approximate lengths of sandy beach within each county of Massachusetts and the proportions that have development (residential and non-residential) within approximately 150 to 200 m (492 to 656 ft) of the beach using data[9] from MA CEC (2015a, 2015b).

County	Approximate length of sandy beach (miles)	Developed shoreline miles (% of total)	Undeveloped shoreline miles (% of total)
Essex	56.31	29.47 (52%)	26.84 (48%)
Suffolk	28.24	12.35 (44%)	15.89 (56%)
Norfolk	20.55	13.68 (67%)	6.87 (33%)
Plymouth	116.24	74.64 (64%)	41.60 (36%)
Barnstable	269.53	108.87 (40%)	160.66 (60%)
Bristol	41.15	22.18 (54%)	18.97 (46%)
Dukes	122.67	20.96 (17%)	101.71 (83%)
Nantucket	75.23	18.11 (24%)	57.12 (76%)
TOTAL[10]	**729.94**	**300.26 (41%)**	**429.68 (59%)**

[8] Note that this assessment describes the sandy beaches of Massachusetts as of March or August 2012 Google Earth imagery; inlets that opened separating Monomoy NWR from Cape Cod NS that altered the location and lengths of sandy beaches within the refuge will be included in subsequent reports that describe the status of sandy beaches in Massachusetts following Hurricane Sandy.

[9] The land use classes "residential" and "non-residential" were used to calculate the length of sandy beaches that are developed. These land use classes did not include golf courses (MA CEC 2015a), which were considered development in the other states' analyses using Google Earth imagery.

[10] Totals may differ from adding all of the individual county numbers due to rounding.

Nantucket, Nantucket Islands Land Bank, TNC, Mass Audubon, and the Madaket Conservation Land Trust. Martha's Vineyard also has numerous tracts of sandy beach in public or NGO ownership, totaling 27.43 miles (44.14 km) of sandy beaches owned or protected with easements by the Trustees of Reservations, Dukes County, Commonwealth of Massachusetts, Wampanoag Tribe of Gay Head (Aquinnah), Vineyard Open Land Foundation, Vineyard Conservation Society, Martha's Vineyard Land Bank Commission, Sheriff's Meadow Foundation, and the Towns of Aquinnah, Edgartown, Chilmark, Oak Bluffs and West Tisbury. Noman's Land Island is entirely protected as a National Wildlife Refuge, with approximately 2.83 miles (4.55 km) of sandy beaches interspersed with rocky beaches in March 2012.

In Massachusetts, private property extends to the mean low water line on the beach as it does in Maine. Therefore the dry beach that provides nesting habitat for piping plovers and other wildlife can be privately owned. In many areas public agencies own the beach as public beaches, but not the private property immediately adjacent to the beach. Approximately 71 such public beaches were identified in this assessment, but they are not included in Tables 19 or A-2 because private property is directly adjacent to the beach. Table A-3 in Appendix A lists these public and semi-public beaches that were at least 500 ft (152.4 m) in length[11], which total an additional ~21.56 miles (34.70 km) of sandy beaches.

Table 19. Sandy beaches that are in public or NGO ownership in Massachusetts, the county in which each is located, and approximate length of sandy beach in each visible in Google Earth imagery from March 2012 prior to Hurricane Sandy. Note that only tracts that exceed 1 mile (1.6 km) in length are listed here. See Table A-2 in Appendix A for a full listing (Sources: See Table 1).

Public / NGO Land	County Location	Approximate Beach Length in Miles
Salisbury Beach State Reservation	Essex	3.49
Parker River NWR	Essex	6.17
Crane Estate	Essex	4.01
Lynn Shore and Nahant Beach Reservations (King's Beach)	Essex	2.19
Revere Beach Reservation	Suffolk	2.71
Winthrop Beach, Winthrop Shores Reservation	Suffolk	1.04
Long Island, Boston Harbors NRA	Suffolk	2.80
Nantasket Beach Reservation	Plymouth	1.26
Duxbury Beach	Plymouth	3.86
Plymouth Long Beach	Plymouth	3.09
Sandy Neck	Barnstable	6.10
Cape Cod National Seashore	Barnstable	55.59
Monomoy NWR	Barnstable	13.59
Hardings Beach	Barnstable	1.27
West Dennis Beach	Barnstable	1.22
Great Island Easement (Yarmouth)	Barnstable	1.56
Dead Neck Island	Barnstable	1.34
Waquoit Bay NERR (South Cape Beach State Park)	Barnstable	1.42

[11] There are several public beaches in the towns of Eastham, Provincetown, Harwich and Yarmouth that are less than 500 ft (152.4 m) in length that were excluded in this assessment.

Public / NGO Land	County Location	Approximate Beach Length in Miles
Mashnee Island Dike	Barnstable	1.84
West Island State Reservation	Bristol	1.57
Horseneck Beach State Reservation	Bristol	3.59
Baker's Beach	Bristol	1.10
Coatue Preserve, Nantucket	Nantucket	3.62
Coskata - Coatue Wildlife Refuge, Nantucket	Nantucket	8.72
Madequecham & Tom Nevers Preserve, Nantucket	Nantucket	1.27
Sanford Farm & Ram Pasture, Nantucket	Nantucket	1.06
Smith Point / Esther Island, Nantucket	Nantucket	1.52
Eel Point Preserve, Nantucket	Nantucket	1.19
Muskeget Island, Nantucket	Nantucket	2.58
Cape Poge Wildlife Refuge (East Beach), Martha's Vineyard	Dukes	5.47
Leland Beach, Martha's Vineyard	Dukes	1.49
Norton Point Beach, Martha's Vineyard	Dukes	2.38
Long Point Wildlife Refuge, Martha's Vineyard	Dukes	1.19
Moshup Beach, Martha's Vineyard	Dukes	1.88
Lobsterville Beach, Martha's Vineyard[1]	Dukes	1.75
Joseph Sylvia State Beach, Martha's Vineyard	Dukes	1.82
Little Beach, Martha's Vineyard	Dukes	1.00
Noman's Land Island NWR	Dukes	2.83
	TOTAL MILES	**217.49 (30% of sandy beach shoreline)**

1 – The "public beaches" data layer from MORIS includes Lobsterville public beach in the Town of Aquinnah with a sandy beach length of 3.03 miles (4.88 km). The Dukes County parcels online map of property ownership does not include this public beach, but does include two parcels along this area of shoreline that are public/NGO owned – a 0.18 mile (0.29 km) nature preserve owned by the Sheriff's Meadow Foundation and a 1.57 miles (2.53 km) public beach owned by the Wampanoag Tribe of Gay Head (Aquinnah).

Shoreline stabilization projects were identified as a threat to coastal dune, beach and small island habitat in the Massachusetts Wildlife Action Plan (MDFW 2006). The Commonwealth of Massachusetts completed an inventory of all publicly-owned shoreline stabilization structures in the state in 2009 and of privately-owned shoreline stabilization structures in 2013[12] (MA DCR 2009 and Fontenault et al. 2013 respectively). Using the data from MA CEC (2015b) that incorporated both the public and private shoreline stabilization structure inventories, approximately 180.24 miles (290.07 km), or 25%, of the sandy beaches in Massachusetts are armored with shore-parallel hard stabilization structures (i.e., bulkheads, seawalls and revetments) (Table 20). The shoreline transect methodology used in MA CEC (2015b) precluded the inclusion of shore-perpendicular structures (i.e., groin fields, jetties). Therefore the 180.24 miles (290.07 km) of armoring is a minimum. MA DCR (2009) identified 143 publicly owned groins and jetties and Fontenault et al. (2013) identified 1,969 privately owned groins and jetties along the

[12] Although the publication date for the privately-owned coastal engineered structures inventory is 2013, the imagery and data used to compile the inventory dated from 2002 to 2011 prior to Hurricane Sandy (Fontenault et al. 2013).

Table 20. Approximate length of immediate, exposed sandy beach (in miles) within each county of Massachusetts that were armored with shore-parallel hard stabilization structures as identified by MA CEC (2015b). Shore-parallel hard stabilization structures include seawalls, bulkheads, revetments, geotubes, sandbags and breakwaters. Note that because groin fields and jetties are excluded, the lengths of armored beaches provided in the table are minimum numbers – the actual lengths of sandy beach modified with hard stabilization structures would be higher if groin fields were incorporated as per the methods of Dallas et al. (2013) applied to the other states in this assessment.

County	Approximate Total Armor Length (miles)	Approximate Length of Sandy Beach (miles)	Percentage of Beach Length Armored
Essex	22.43	56.31	40%
Suffolk	17.28	28.24	61%
Norfolk	12.32	20.55	60%
Plymouth	56.03	116.24	48%
Barnstable	51.97	269.53	19%
Bristol	13.20	41.15	32%
Dukes	4.78	122.67	4%
Nantucket	2.23	75.23	3%
TOTAL	**180.24**	**729.94**	**25%**

entire Massachusetts coast, both sandy and rocky sections. The number of these groins and jetties located on just sandy beaches is not known at this time.

Sandy beaches in Suffolk and Norfolk Counties, near and including Boston, are the most armored, with 60-61% of their beaches lined with bulkheads, seawalls and/or revetments (Table 20). The offshore islands in Dukes and Nantucket Counties have the least armored beaches, with only 3-4% of their sandy beaches stabilized with bulkheads, seawalls and/or revetments.

It is not known at this time how many miles of sandy beach habitat are currently lost to hard stabilization structures, although it has occurred in numerous locations. The seawall/revetment system in the Town of Hull known as Seawall Boulevard, north of Nantasket Beach, was initially constructed in 1874 by the USACE and turned over to the Commonwealth in 1981. Erosion over the last 140 years has led to the loss of the beach in front of the seawall/revetment and increased erosion in North Nantasket and Nantasket Beaches as sediment source material for those beaches has been lost (MA DCR 2009). The MA CEC (2015a, 2015b) found that of more than 26,000 shoreline transects, 21% of them had shoreline retreat that was restricted by the presence of shoreline stabilization structures; "the shoreline has essential been fixed due to armoring" in these locations (MA CEC 2015b, p. V2-29).

Over 86% of the publicly owned hard shoreline stabilization structures were found to be more than 50 years old, the typical designed and constructed lifespan of coastal and marine structures; only 206 of 1,284 projects along the entire state coastline were built after 1958. Thus the vast majority of the structures have not had any major repairs and are susceptible to damages (MA DCR 2009). "It is feared that without the rehabilitation of these structures, another storm with intensity such as the Blizzard of '78 or Hurricane Bob [in 1991] will cause incalculable damage to the coastline of the Commonwealth" (MA DCR 2009, p. 21). MA DCR (2009, p. 22) further concludes that

Whereas, the hard coastal protection structures have changed from being navigation aids or land development aides to protecting public and private infrastructure, the possibility of removing them and allowing the area to go back to natural is nearly impossible. Prior to the 20th century, seawalls and revetments were built predominantly to stop the erosion of drumlins and coastal banks, to keep navigable channels and harbors open. Bulk-heading was used to expand landforms and were used for depositing dredged materials as was performed for the City of Boston. Since that time a big push to the water's edge was made for residential and commercial development and for public amenities to service these areas; now these structures protect these developed areas. All new considerations should strive to balance nature and the man-made protection structures.

O'Connell and Leatherman (1999, p. 27) state that "Progressive erosion [of the Massachusetts coast] over the next 60 years will put at risk a significant number of beachfront and cliff-top houses. While the use of hard shoreline stabilization is discouraged due to adverse impacts on sediment supply to downdrift beaches, this is the approach that many communities will attempt to use, especially in the wake of major coastal storm damage."

At least 81 oceanfront sandy beaches have been modified with sediment placement projects in Massachusetts but precise project locations and lengths are not known for most of them (Table 21). Haddad and Pilkey (1998) report an additional 28 sections of sandy beach that were modified with sediment placement prior to 1961(but not since then) but project details are not known (see Appendix A, Table A-4 for a list).

Sacrificial dunes at Duxbury Beach have been artificially maintained with sediment placement and vegetation plantings following storm events since 1992 (FitzGerald et al. 2001, Duxbury Beach Reservation 2012, Rosen and FitzGerald 2014), but the total length of beach and dune modified is not known; dune fill placement in 2001 extended along at least 1,250 ft (381 m) of beach near High Pines (Duxbury Beach Reservation 2012). Rosen and FitzGerald (2014, p. 14) state that "the present management plan [to maintain a dune ridge at Duxbury Beach] has virtually ended short term overwash and retreat, and is proving effective on a generational scale for managing the multiple resources that the barrier provides." Eventually, however, the barrier beach will be overtopped, breached or retreat during future storms as the long-term geologic record (the past several thousand years) indicates is the natural pattern for Duxbury Beach (Rosen and FitzGerald 2014).

Federal navigation projects that have placed dredged material on nearby beaches have occurred at Salisbury Beach, Plum Island, Sandy Beach in Cohasset, Green Harbor in Marshfield, Plymouth Harbor, the Cape Cod Canal in Sandwich, Sesuit Harbor, Chatham (Stage) Harbor, Cuttyhunk Harbor on Cuttyhunk Island, and Nantucket Harbor on Nantucket (Haddad and Pilkey 1998, USFWS 2014, PSDS 2015, USACE New England District website). The USACE constructed several shore protection projects in the 1950s and 1960s in Massachusetts, including Plum Island, Lynn – Nahant, Revere Beach, Winthrop Beach, Quincy Shore Beach (Wollaston Beach), Wessagussett Beach, North Scituate Beach, and Town Beach in Plymouth (Haddad and Pilkey 1998, PSDS 2015, USACE New England District website). There are no large-scale federal beach nourishment projects in Massachusetts like those in the Mid-Atlantic and Southeast.

Barnstable County owns and operates its own dredge (Barnstable County 2009). The County and the Town of Harwich have placed dredge spoil material on numerous beaches in Harwich, with material dredged from Saquatucket Harbor / Andrews River, Wychmere Channel and Outer Harbor, Allen Harbor, and the Herring River (Table 21). Other locations in Barnstable County that have received fill include Menauhant Beach west of Bournes Pond Inlet, the beaches east and west of Green Pond Inlet, the beach

west of Great Pond Inlet, and the beach west of Little Pond Inlet (Howes et al. 2005, Barnstable County 2009, 2010, 2011, and 2012).

Dukes County conducts dredging operations with placement of dredge spoil material on nearby beaches at numerous locations on Martha's Vineyard (USACE 2014a). Dredged material from Sengekontacket Pond and its two inlets have been placed by both the County and the Massachusetts Highway Department in the groin field at Joseph Sylvia State Beach, as well as at Pay Beach and Inkwell Beach to the north and Bend in the Road Beach and Cow Bay Beach to the south. Material dredged from Edgartown Harbor and/or Eel Pond has been placed on the private Froelich Property, the Eel Pond spit, and Lighthouse (Fuller) Beach. Cape Poge Bay dredge spoil has been placed at Cape Poge Elbow, North Gut, The Narrows[13], Nantucket Sound Beach, and the Over Sand Roads area of The Narrows. Dredge spoil from Great Pond has been placed at South Beach. And the beach east of Menemsha Creek Inlet received dredge spoil placement in 1973 (USACE 2014c).

Private sediment placement projects have also been constructed on sandy beaches in Massachusetts, although details are poorly known. One such project with known details occurs on Sampsons Island and Dead Neck, where Three Bays Preservation, Mass Audubon, and the Town of Barnstable dredge material from Cotuit Bay Inlet and/or West Bay for fill on Dead Neck / Sampsons Island (Haddad and Pilkey 1998, Howes et al. 2006b, PSDS 2015).

Table 21. The approximate lengths of known constructed beach nourishment and dredge disposal placement projects on Massachusetts sandy exposed beaches from north to south prior to Hurricane Sandy in October 2012 (Sources: Haddad and Pilkey 1998; Howes et al. 2004, 2005, 2006a, and 2006b; Barnstable County 2009, 2010, 2011, and 2012; USACE 1996, 2013b, 2013c, 2013e, 2014a, 2014b, 2014c, 2014d and 2014f; Rosen and FitzGerald 2014; USFWS 2014; MORIS 2015; PSDS 2015; Dukes County Dredging website; Town of Harwich Dredging website; USACE New England District website).

Location	Project Length (miles)
Salisbury Beach, Salisbury	0.44
Pavilion area, Salisbury Beach, Salisbury	0.11
Driftway Street, Salisbury	0.01
Broadway Road, Salisbury	0.02
Plum Island Beach, Newbury	0.76
Plum Island Boulevard access ramp, Plum Island, Newbury	0.03
Dartmouth Way access ramp, Plum Island, Newbury	0.04
Long Beach, Gloucester	Unknown
Lyons Park Beach, Beverly	0.14
Lynn - Nahant	0.49
Revere Beach, Revere	2.93
Winthrop Beach, Winthrop	0.80
Pleasure Bay Beach, Boston	Unknown
Quincy Shore Beach (Wollaston Beach), Quincy	1.61

[13] Although The Narrows beach is located on Cape Poge Bay, the beaches of the large bay were included in MA CEC (2015a & 2015b) and thus included in the total length of sandy beaches presented in Table 23. Therefore the sediment placement activities at The Narrows are included here as a modification of the sandy beaches included in this assessment.

Location	Project Length (miles)
Nantaskett Beach, Hull	1.31
Wessagussett Beach, Weymouth	0.49
Sandy Beach, Cohasset	Unknown
North Scituate Beach, Scituate	0.47
Green Harbor, Marshfield	Unknown
Duxbury Beach, Duxbury	0.24 +
Town Beach, Plymouth	0.25
Plymouth Harbor, Plymouth	Unknown
Springhill Beach, Sandwich	Unknown
Town Neck Beach, Sandwich	Unknown
Sesuit Harbor, Dennis	Unknown
Morris Island, Chatham	Unknown
Chatham Harbor, Chatham	Unknown
Hardings Beach, Chatham	1.36
Cockle Cove Beach, Chatham	0.15
Mill Creek beach, Chatham	0.08
Forest Beach, Chatham	0.22
Pleasant Street, Chatham	0.06
Saquatucket West, Harwich	Unknown
Neel Road and Mill Road beach, Harwich	Unknown
Red River Beach, Harwich	Unknown
Saquatucket Bluffs, Harwich	Unknown
Wah-Wah Taysee Road to Cottage Avenue, Harwich	Unknown
Gray Neck Road Beach, Harwich	Unknown
Earle Road Beach, Harwich	Unknown
Patricia Lane Beach, Harwich	Unknown
Brook Road Beach, Harwich	Unknown
Wahwahtaysee Road Beach, Harwich	Unknown
Wyndemere Bluffs Beach, Harwich	Unknown
Pleasant Road Beach, Harwich	Unknown
Dowses Beach, Barnstable	Unknown
Craigville Beach (East Bay / Centerville River Inlet), Barnstable	Unknown
Long Beach (East Bay / Centerville River Inlet), Barnstable	Unknown
Long Beach, Barnstable	Unknown
Dead Neck. Barnstable	Unknown
Sampsons Island, Barnstable	Unknown
New Seabury, Mashpee	Unknown
South Cape Beach, Mashpee	0.18
Menauhant Beach, Falmouth	Unknown
Pyne Trustees beach, Green Pond, Falmouth	0.10
Acapesket Association Beach, Green Pond, Falmouth	0.10
Falmouth Heights, Falmouth	Unknown
beach west of Great Pond Inlet, Falmouth	Unknown
beach west of Little Pond Inlet, Falmouth	Unknown
Point Independence Beach, Wareham	0.23

Location	Project Length (miles)
Onset Beach, Wareham	0.21
Onset Beach - West, Wareham	0.38
East Beach, Clark Point, New Bedford	Unknown
Clark Point Beach, west of Clark Point, New Bedford	0.30
Horseneck Beach State Reservation, Westport	Unknown
Barges Beach, Cuttyhunk Island	Unknown
Cuttyhunk Harbor area beaches, Cuttyhunk Island	Unknown
Oak Bluffs Town Beach / Pay Beach, Martha's Vineyard	0.23
Inkwell Beach, Martha's Vineyard	Unknown
Joseph Sylvia State Beach, Martha's Vineyard	0.53
Bend in the Road Beach, Edgartown, Martha's Vineyard	Unknown
Cow Bay Beach, Edgartown, Martha's Vineyard	Unknown
Froelich Property, Edgartown, Martha's Vineyard	Unknown
Eel Pond Spit, Edgartown, Martha's Vineyard	Unknown
Lighthouse (Fuller) Beach, Edgartown, Martha's Vineyard	Unknown
Cape Poge Elbow, Edgartown, Martha's Vineyard	Unknown
North Gut, Edgartown, Martha's Vineyard	Unknown
The Narrows, Edgartown, Martha's Vineyard	Unknown
The Narrows - Over Sand Roads & Nantucket Sound Beach	Unknown
South Beach, Edgartown, Martha's Vineyard	Unknown
beach east of Menemsha Creek inlet, Martha's Vineyard	Unknown
Nantucket Harbor, Nantucket	Unknown
TOTAL MILES	**14.79 + (> 2% of state beaches)**

Rhode Island

Rhode Island's coastline includes the South Shore (which faces Block Island Sound), Narragansett Bay, and Block Island offshore. Rhode Island's shoreline has 25 coastal ponds that are separated from Block Island Sound by barrier spits that have formed between adjacent headlands. These spits are periodically overwashed or breached during storms (some spits are also periodically breached mechanically – see Rice 2015b). The mouth of Narragansett Bay contains Aquidneck Island and Conanicut Island, which protect upper Narragansett Bay from direct exposure to Block Island Sound. Aquidneck Island includes the communities of Portsmouth, Middletown and Newport. Conanicut Island is located west of the larger Aquidneck Island and includes the community of Jamestown.

For the purposes of this assessment, only sections of coastline with direct exposure to Block Island Sound were included; upper Narragansett Bay was excluded since it is fetch-limited[14] (Hehre 2007). In Little

[14] Fetch is the length of open water over which wind or waves can travel. For a description of the beaches and other shoreline types of Narragansett Bay see Hehre (2007), which found 59 miles (95 km) of beach plain and barrier spit shoreline. Narrow sandy beaches may also be present along glacial bluffs that extend along another 21 miles (34 km) of Narragansett Bay shoreline. Hehre (2007) also found that 30% of the entire 266 mile (424 km) Narragansett Bay shoreline is armored with hard stabilization structures. The southern portion of the Hehre (2007) study area overlaps with the exposed shoreline assessed in this study.

Compton on the southeastern Rhode Island coast, this assessment included the coastline from Church Point south to Sakonnet Point and then east to the Massachusetts state boundary. In Portsmouth on the northeast side of Aquidneck Island, this assessment included the coastline from Black Point south through Middletown and Newport to Ragged Point on the southeast side of the island. Only the south-facing shoreline of Conanicut Island was included, from Bull Point to Beavertail State Park. In Narragansett on the western shoreline of Narragansett Bay, this assessment included the coastline from Bonnet Point west and then south and west to the Connecticut state boundary plus Block Island.

Therefore this study includes the south-facing shoreline of Newport and Washington Counties in Rhode Island. Newport County includes the communities, from east to west, of Little Compton, Portsmouth, Middletown, Newport and Jamestown. Washington County includes the communities of Narragansett, South Kingstown, Charlestown, Westerly, and New Shoreham (Block Island). Altogether there were 49.56 miles (79.76 km) of sandy beaches in these areas of Rhode Island as of April 2012, prior to Hurricane Sandy in October 2012 (Table 22). The majority (84%) of the sandy beaches were in Washington County, which had 41.81 miles (67.29 km) of the sandy beaches. Rhode Island's sandy beaches are mostly undeveloped, with 88% of Newport County's beaches undeveloped and 67% of Washington County's beaches undeveloped (Table 22).

Over half (55%) of Rhode Island's sandy beaches (exclusive of upper Narragansett Bay) are in public or NGO ownership (Table 23). Approximately 65% of the Newport County sandy beaches are in public or NGO ownership; approximately 53% of Washington County sandy beaches are in public or NGO ownership. On Block Island, roughly 61% of the sandy beaches are owned or have conservation

Table 22. The approximate lengths of sandy beach within each county of Rhode Island, exclusive of upper Narragansett Bay, and the proportions that are developed and undeveloped as of April 2012 according to Google Earth imagery.

County	Approximate length of sandy beach (miles)	Developed shoreline miles (% of total)	Undeveloped shoreline miles (% of total)
Newport	7.76	0.95 (12%)	6.81 (88%)
Washington	41.81	13.67 (33%)	28.13 (67%)
TOTAL	**49.56**	**14.62 (29%)**	**34.94 (71%)**

Table 23. Sandy beaches that are in public or NGO ownership in Rhode Island, the county in which each is located, and approximate length of sandy beach in each visible in Google Earth imagery from April 2012 prior to Hurricane Sandy (Sources: See Table 1).

Public / NGO Land	County Location	Approximate Beach Length in Miles
Goosewing Beach Preserve	Newport	0.77
Tunipus Pond / South Shore Beach	Newport	0.22
Briggs Marsh	Newport	0.09
Briggs Marsh Easement	Newport	0.36

Public / NGO Land	County Location	Approximate Beach Length in Miles
Sakonnet Point Easement	Newport	0.55
Third Beach Easement	Newport	0.13
Navy Beach (Third Beach)	Newport	0.33
Sachuest Point NWR	Newport	0.55
Second Beach	Newport	0.91
Atlantic Beach	Newport	0.20
First Beach / Eastons Beach	Newport	0.67
Mackerel Cove Town Beach, Town of Jamestown	Newport	0.27
Kelly Beach	Washington	0.04
Whale Rock	Washington	0.12
Narragansett Town Beach	Washington	0.49
Scarborough State Beach	Washington	0.89
Camp Cronin, state of RI	Washington	0.07
DiMeo / Noel Tract, state of RI	Washington	0.18
Roger Wheeler State Beach	Washington	0.44
Salty Brine State Beach	Washington	0.03
East Matunuck State Beach	Washington	0.25
Deep Hole, state of RI	Washington	0.07
Weeden Farm / South Kingstown Town Beach	Washington	0.26
Trustom Pond NWR	Washington	1.38
Goose Island Access	Washington	0.09
Charlestown Beach Road parcels[1]	Washington	0.05
Charlestown Beach Road parcel[1]	Washington	0.01
Charlestown Beach, Town of Charlestown	Washington	0.07
Charlestown Beach parcels[1]	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	0.07
Quonny Beach	Washington	0.03
Quonchontaug Breachway Fishing Area	Washington	0.07
Sand Trail Beach	Washington	1.10
Wawaloam Drive Beach	Washington	0.11
Weekapaug Fishing Area / Breachway	Washington	0.01
Town Beach, Town of Westerly	Washington	0.11
Armenakes / Misquamicut Easement	Washington	0.04
Misquamicut State Beach	Washington	0.61
Misquamicut Fire District parcels	Washington	0.15
Fort Road Beach, Watch Hill	Washington	0.07
Napatree Point	Washington	1.18

Public / NGO Land	County Location	Approximate Beach Length in Miles
Sandy Point Island	Washington	1.16
Singer / Ocean View, Block Island	Washington	0.23
Spring Pond, Block Island	Washington	0.11
Green Hill Cove, Block Island	Washington	0.03
Mohegan Bluff / Delia Easement, Block Island	Washington	0.11
Southeast Light, Block Island	Washington	0.08
Phelan Tract, Block Island	Washington	0.26
Mohegan Bluff, Block Island	Washington	0.20
Davis & Sugden (Black Rock) Tracts, Block Island	Washington	0.12
Black Rock, Block Island	Washington	0.71
Lewis-Dickens Farm, Block Island	Washington	0.85
Schooner Point, Block Island	Washington	0.07
Cooneymus Swamp Easement, Block Island	Washington	0.02
Stevens Cove Easement, Block Island	Washington	0.36
Ocean View / Cullinan Easement, Block Island	Washington	0.26
Charleston Beach, Block Island (Block Island Conservancy tract)	Washington	0.02
Charleston Beach, Block Island (Audubon Society of RI tract)	Washington	0.23
Charleston Beach, Block Island (Town of New Shoreham tract)	Washington	0.08
Block Island NWR, Block Island	Washington	1.19
Gunners Hill, Block Island	Washington	0.09
West Beach, Block Island	Washington	0.71
Sachem Pond, Block Island	Washington	1.11
Beach Plum Hill / Logwood Cove, Block Island	Washington	0.28
North Light, Block Island	Washington	0.05
White Tract, Block Island	Washington	0.08
Risom Tracts, Block Island	Washington	0.19
Clay Head Swamp (Lapham) Easement, Block Island	Washington	1.22
Mansion Beach, Block Island	Washington	0.11
Town Beach, Block Island	Washington	1.13
	TOTAL MILES	**27.27 (55% of sandy beach shoreline)**

1 – Several individual parcels along Charlestown Beach Road east and west of Charlestown Beach are owned by the South Kingstown Land Trust, Town of South Kingstown, South County Conservancy and Town of Charlestown.

easements by public agencies and/or NGOs. Numerous areas of sandy beach are owned by the USFWS, the state of Rhode Island, local governments, TNC, local and regional land trusts, and other non-government organizations. The longest individual public or NGO owned beaches are at Trustom Pond NWR, the state Ninigret Conservation Area, Napatree Point, Sandy Point, Block Island NWR, and Sachem Pond on Block Island. The longest contiguous stretch of sandy beaches in conservation is the 2.85 miles (4.59 km) west of the Charlestown Breachway, which includes the state Charlestown Breachway Fishing Area, the Arnolda conservation easements held by the state on 10 parcels (with 3 undeveloped inholdings), Ninigret NWR, Governor Island State Park, and the state Ninigret Conservation Area.

Approximately 4.21 miles (6.78 km) of sandy beaches identified in this assessment were armored with hard stabilization structures as of April 2012 (Table 24). The hard stabilization structures include 58 contiguous sections of seawalls / bulkheads / revetments, 12 groins, 1 breakwater and 11 jetties (Table 25). Narragansett and Westerly contained the highest number of structures, but Newport had the highest proportion (59%) of its sandy beaches armored by far. Hard stabilization structures can also be found on the non-sandy sections of shoreline in Rhode Island, but those structures were not included in this assessment. Current Rhode Island regulations prohibit the construction of new hard shoreline stabilization structures on all of the beaches included in this assessment (which are classified as Type 1 Waters by the RI CRMC) because of their adverse impacts to beaches and public access to the shoreline, but new erosion control structures may be allowed in other areas based on their Water Type Classification (RI CRMC 1999).

In addition to the 4.21 miles (6.78 km) of sandy beaches with hard shoreline stabilization structures, an additional 1.42 miles (2.29 km) of shoreline was armored with hard shoreline stabilization structures (9 additional seawalls / bulkheads / revetments) but did not have any sandy beaches longer than 500 ft (152.40 m) as of April 2012; thus 1.42 miles (2.29 km) of sandy beach habitat had been lost at that time. (Note that evidence indicated sandy beaches would be present in these locations in the absence of the hard stabilization structures.)

At least 78 sandy beaches in southern Rhode Island have been modified with sediment placement but precise location and project length data are lacking for most of the projects (Table 26). Sandy Point Island has received dredged material from the federal navigation channel in Little Narragansett Bay, with the most recent episode prior to Hurricane Sandy occurring in 1996-97 (USFWS 2014g). A federal project in 1955 placed beach fill and constructed 5 groins and a bulkhead along 1 mile (1.6 km) of Sand Hill Cove in Point Judith (Haddad and Pilkey 1998, USACE New England District website). The beaches to the east and west of Point Judith Harbor historically received dredge spoil from the inlet, but project dates, volumes and locations are unknown (Lee 1980). East Beach and Charlestown Beach in Charlestown have received dredge spoil from the Charlestown Breachway (Lee 1980, USACE 2008). A

Table 24. Approximate sandy beach length (in miles) within each county of Rhode Island that were armored with hard stabilization structures visible on Google Earth imagery between March 1995 and April 2012. Hard stabilization structures include groins, jetties, seawalls, bulkheads, revetments, geotubes, sandbags and breakwaters. Structures may be periodically exposed or buried and include those that are failing, in disrepair, or remnants of old structures.

County	Approximate Length of Armoring (miles)	Percentage of Beach Length Armored
Newport	1.37	18%
Washington	2.84	7%
TOTAL	**4.21**	**9%**

Table 25. Approximate number of each type of armoring visible on the sandy beach shoreline in each county of Rhode Island visible on Google Earth imagery between March 1995 and March 2012. 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 24 above.

County	Number of Groins	Number of Jetties	Number of Seawalls, Bulkheads and/or Revetments	Number of Breakwaters
Newport	0	0	16	0
Washington	12	11	42	1
TOTAL	**12**	**11**	**58**	**1**

Table 26. The approximate lengths of authorized constructed beach nourishment and dredge disposal placement projects on Rhode Island sandy exposed beaches from east to west (Sources: Haddad and Pilkey 1998, USACE 2014g, PSDS 2015, USACE New England District website).

Location	Project Length (miles)
Sandy Point Island	Unknown
Sand Hill Cove, Point Judith	1.00
beaches east and west of Point Judith Harbor	Unknown
East Beach, Charlestown	Unknown
Charlestown Beach, Charlestown	Unknown
Misquamicut Beach, Misquamicut	0.62
Misquamicut Club, Misquamicut	0.91
Napatree Beach, Westerly	Unknown
Town Beach, Westerly	0.08
Great Salt Pond, Block Island	Unknown
Block Island Harbor, Block Island	Unknown
Various individual projects[1]	3.40
TOTAL MILES	**6.00+ (>12% of state beaches)**

1 – The RI CRMC issued permits for 67 different private and municipal properties from 2000 through September 2012 for individual projects that involved sediment placement on beaches. See Appendix B for a full list of these properties.

federal project placed beach fill along 3,250 ft (990.6 m) of Misquamicut Beach in 1959-60 along with more than 4,000 ft (1,219.2 m) of sand fencing (Haddad and Pilkey 1998, USACE New England District website). A private beach fill project in 1992 placed sediment along 4,800 ft (1,463.04 m) of beach at the Misquamicut Club (Haddad and Pilkey 1998). Napatree Beach in Westerly received an unknown volume of sediment along an unknown length of beach prior to 1961 (Haddad and Pilkey 1998). Town Beach in Westerly has received sediment at least 4 times (1988, 1989, 1990, and 1993) in local projects along up to 400 ft (121.92 m) of beach (Haddad and Pilkey 1998, PSDS 2015). Federal dredge spoil from navigation channels in Great Salt Pond and Block Island Harbor on Block Island have both placed sediment on nearby beaches as recently as 2009 but precise locations are not known (Haddad and Pilkey 1998, PSDS 2015). Individual projects with permits from the RI CRMC that involved sediment placement activities

from 2000 through 2012 (prior to Hurricane Sandy) modified an additional 67 private and municipal properties (see Appendix B for a complete list). Many of these small, individual projects removed overwash sand and gravel from parking areas and placed the material back on the beach. Although these projects are generally very small, and may involve the addition of from 5 to 1,000 cy of new material, they cumulatively account for more than half of the known beach length modified by sediment placement projects in Rhode Island.

Connecticut

Long Island Sound has been designated an Estuary of National Significance and has been a part of the federal National Estuary Program since 1987 (LISS 1994). Managed under the Long Island Sound Study (LISS), a partnership of federal, state, and local agencies, educational institutions and private organizations collaboratively manages Long Island Sound resources with the goal of protecting and improving water quality, habitat and living resources in the estuary. Habitat degradation and loss resulting from land use and development has been identified as one of six priority threats to the ecosystem and is a priority management issue (LISS 1994). The LISS program has identified beaches and dunes as one of 12 priority habitat types in Long Island Sound (LISS 2015). The LISS has also identified the piping plover as an environmental indicator species for the health of the ecosystem (LISS 2015).

The Connecticut coastline on Long Island Sound, like its neighboring coastal states to the north, contains both rocky and sandy shorelines. Patton and Kent (1992) describe Connecticut's sandy beaches as narrow and small as compared to the beaches of the Mid-Atlantic and Cape Cod; the state's sandy beaches are found as barriers spits extending into bays, fronting salt marshes, or in front of coastal cliffs composed of glacial sediment. Dunes are small and commonly merge with adjacent salt marshes (Patton and Kent 1992).

From east to west, the coastline consists of New London, Middlesex, New Haven and Fairfield Counties. New London County includes the towns of Stonington, Groton, New London, Waterford, East Lyme, and Old Lyme. Middlesex County includes the towns of Old Saybrook, Westbrook, and Clinton. New Haven County includes the towns of Madison, Guilford, Branford, East Haven, New Haven, West Haven and Milford. Fairfield County includes the towns of Stratford, Bridgeport, Fairfield, Westport, Norwalk, Darien, Stamford and Greenwich. Altogether these communities had approximately 82.16 miles (132.22 km) of sandy beaches prior to Hurricane Sandy in October 2012 (Table 27). Patton and Kent (1992) identified 80.1 miles (128.91 km) of beaches along 250.8 miles (403.62 km) of total shoreline in Connecticut as of 1992, which is consistent with this assessment conducted 23 years later.

Slightly more than half (56%) of these sandy beaches were undeveloped, with the highest proportions of undeveloped sandy beaches in New London and Fairfield Counties (Table 27). Middlesex County's sandy beaches were the most developed (65%). Connecticut has identified the loss of coastal habitat from development as a key threat in its 2015 update to its state Wildlife Action Plan (CT DEEP 2015).

Forty-three percent (43%) of Connecticut's sandy beaches are in public or NGO ownership (Table 28). Of the 67 sandy beach tracts listed in Table 28, only 10 exceed one mile (1.6 km) in length: Bluff Point Coastal Reserve / State Park, Hammonasset State Park and Natural Area Preserve, the Sandy Point Bird Sanctuary owned by the City of West Haven, West Haven's East Beach, Stratford's Long Beach Park, Bridgeport's Seaside Park, Westport's Compo Beach, Westport's Cockenoe Island, and the Chimon Island and Sheffield Island Units of the Stewart B. McKinney NWR. Hammonasset State Park and Natural Area Preserve has the longest total length of sandy beach in conservation in Connecticut, but the park's beaches have been modified with beach fill, the artificial closure of three inlets, 1 groin, and 1

Table 27. The approximate lengths of sandy beach within each county of Connecticut (from east to west) and the proportions that are developed and undeveloped as of September 2011 for New London County and March 2012 for the remaining counties according to Google Earth imagery.

County	Approximate length of sandy beach (miles)	Developed shoreline miles (% of total)	Undeveloped shoreline miles (% of total)
New London	14.75	5.71 (39%)	9.05 (61%)
Middlesex	9.48	6.17 (65%)	3.31 (35%)
New Haven	22.27	10.29 (46%)	11.99 (54%)
Fairfield	25.65	13.80 (39%)	21.86 (61%)
TOTAL	**82.16**	**35.96 (44%)**	**46.20 (56%)**

jetty. The park's beaches are not contiguous but contain 2 inholdings on the Cedar Island spit portion of the park in Clinton and sections of marshy and rocky shoreline at and east of Hammonasset Point.

Patton and Kent (1992) state that Connecticut had 37.1 miles (59.71 km) of publicly owned beaches as of 1992, and 43.0 miles (69.20 km) in private ownership. Although their account of 37.1 miles (59.71 km) is slightly higher than the amount identified in this assessment (35.10 miles, or 56.49 km), the difference is likely due to the exclusion of public beaches that have private property directly adjacent to the beach in this assessment.

Close to half (45%) of Connecticut's sandy beaches are armored with hard stabilization structures (Table 29). The approximately 37 miles (59.55 km) of shoreline armor are found in all four coastal counties, with 60% of Middlesex County's sandy beaches lined with hard stabilization structures. New London County's sandy beaches are the least armored at 30%. There were a total of at least 275 contiguous sections of seawalls / bulkheads / revetments, 653 groins, 18 breakwaters and 24 jetties along sandy beaches in Connecticut prior to Hurricane Sandy (Table 30). Hard stabilization structures can also be found on the non-sandy sections of shoreline in Connecticut, but those structures were not included in this assessment.

In addition to the 36.91 miles (59.40 km) of sandy beaches with hard shoreline stabilization structures, an additional 18.03 miles (29.01 km) of shoreline was armored with hard shoreline stabilization structures (88 additional seawalls / bulkheads / revetments and 202 additional groins) but did not have any sandy beaches longer than 500 ft (152.40 m) as of September 2011 (New London County) or March 2012 (the other counties); thus 18.03 miles (59.40 km) of sandy beach habitat had been lost at that time. (Note that evidence indicated sandy beaches would be present in these locations in the absence of the hard stabilization structures.) Connecticut has identified the loss and degradation of coastal habitat from hard shoreline stabilization as a key threat in its 2015 update to its state Wildlife Action Plan (CT DEEP 2015).

Table 28. Sandy beaches that are in public or NGO ownership in Connecticut from east to west, the county in which each is located, and approximate length of sandy beach in each visible in Google Earth imagery from September 2011 for New London County and March 2012 for the remaining counties (Sources: See Table 1).

Public / NGO Land	County Location	Approximate Beach Length in Miles
Sandy Point	New London	0.15
Ram Point	New London	0.16
Esker Point Beach	New London	0.11
Bluff Point State Park & Coastal Reserve	New London	1.29
Eastern Point Beach	New London	0.12
Ocean Beach Park	New London	0.37
Waterford Beach Park	New London	0.33
Harkness Memorial State Park	New London	0.35
Jordan Cove Water Access	New London	0.12
McCook Point Park	New London	0.22
Pattagansett Marshes	New London	0.33
Rocky Neck State Park	New London	0.53
Hatchetts Point	New London	0.28
Griswold Point	New London	0.59
Great Island Marshes	New London	0.35
Old Saybrook Town Beach	Middlesex	0.04
Westbrook Town Beach	Middlesex	0.52
Menunketesuck Island	Middlesex	0.56
Duck Island Wildlife Area	Middlesex	0.11
Clinton Town Beach	Middlesex	0.42
Hammonasset State Park and Natural Area Preserve	Middlesex & New Haven	2.54
East Wharf Beach	New Haven	0.07
West Wharf Beach	New Haven	0.21
Grass Island	New Haven	0.53
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	0.61
Long Wharf Park	New Haven	0.42
Sandy Point Bird Sanctuary	New Haven	1.35
East Beach	New Haven	1.24
Bradley Point Park	New Haven	0.25
Silver Sands State Park	New Haven	0.62
Walnut Beach	New Haven	0.35
Smith-Hubbell Wildlife Refuge and Bird Sanctuary	New Haven	0.57
Milford Point Unit, Stewart B. McKinney NWR	New Haven	0.49
Short Beach Park	Fairfield	0.67
Lordship Point Water Access	Fairfield	0.51

Public / NGO Land	County Location	Approximate Beach Length in Miles
Long Beach Park	Fairfield	1.55
Pleasure Beach Park	Fairfield	0.91
Seaside Park	Fairfield	1.56
St. Mary's by-the-Sea	Fairfield	0.10
Jennings Beach	Fairfield	0.39
Penfield Beach	Fairfield	0.21
Sasco Beach	Fairfield	0.14
Burying Hill Beach & Wetlands	Fairfield	0.14
Sherwood Island State Park	Fairfield	0.93
Compo Beach & Marina	Fairfield	1.01
Cockenoe Island	Fairfield	1.64
Goose Island	Fairfield	0.25
Westport Longshore Club Park	Fairfield	0.10
Shady Beach	Fairfield	0.21
Calf Pasture Park	Fairfield	0.49
Peach Island Unit, Stewart B. McKinney NWR	Fairfield	0.17
Grassy Island	Fairfield	0.57
Chimon Island Unit, Stewart B. McKinney NWR	Fairfield	1.14
Sheffield Island Unit, Stewart B. McKinney NWR	Fairfield	1.56
Shea (Ram) Island	Fairfield	0.91
The Plains (island)	Fairfield	0.59
Pear Tree Point Beach Park	Fairfield	0.21
Weed Beach	Fairfield	0.21
Cummings Park	Fairfield	0.34
West Beach	Fairfield	0.17
Greenwich Point Park (Tod's Point)	Fairfield	0.90
Pelican Island	Fairfield	0.26
Greenwich Island islet	Fairfield	0.15
Calf Island Unit, Stewart B. McKinney NWR	Fairfield	0.30
	TOTAL MILES	**35.10 (43% of sandy beach shoreline)**

Table 29. Approximate sandy beach length (in miles) within each county of Connecticut that were armored with hard stabilization structures visible on Google Earth imagery between 1991 and September 2011 for New London County and March 2012 for the remaining counties prior to Hurricane Sandy. Hard stabilization structures include groins, jetties, seawalls, bulkheads, revetments, geotubes, sandbags and breakwaters. Structures may be periodically exposed or buried and include those that are failing, in disrepair, or remnants of old structures.

County	Approximate Length of Armoring (miles)	Percentage of Beach Length Armored
New London	4.48	30%
Middlesex	5.72	60%
New Haven	9.75	44%
Fairfield	16.96	48%
TOTAL	**36.91**	**45%**

Table 30. Approximate number of each type of armoring visible on the sandy beaches of each county in Connecticut visible on Google Earth imagery between April 1991 and September 2011 (New London County) or March 2012 (other counties) prior to Hurricane Sandy. 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 29 above.

County	Number of Groins	Number of Jetties	Number of Seawalls, Bulkheads and/or Revetments	Number of Breakwaters
New London	71	5	40	0
Middlesex	163	5	39	2
New Haven	115	3	90	8
Fairfield	304	11	106	8
TOTAL	**653**	**24**	**275**	**18**

At least 36 sandy beach locations in Connecticut have been modified with sediment placement, but precise project locations and lengths are not known for 10 of them (Table 31). At least 15.32 miles (24.66 km) of the state's sandy beaches have been modified with sediment placement. State-sponsored beach fill projects have been constructed at Esker Point Park (1969), Neptune Park (1964), Seaside Regional Center (1967), White Sand Beach (1957 and 1967), Chalker Beach (1961), Clinton Town Beach (1964), Branford Point Beach (1963), West Silver Sands Beach (1958), Laurel Beach (1965), Fairfield Beach (1959), and West Fairfield Beach (1964).

Federal beach fill or dredge spoil placement projects have been constructed near Clinton Harbor (2011), Guilford Point Beach (1959), Prospect Beach (1957, 1973, and 1994), Sea Bluff Beach (1990-91), Woodmont Beach (1959, 1964 and 1994), Gulf Beach (1957 and 1966), Short Beach (since 1955), Seaside Park (1958), Sasco Hill Beach (1958), Southport Beach (1958), Burial Hill Beach (1957), Sherwood Island State Park (1959 and 1983), Compo Beach (1959), Calf Pasture Beach (1958), Cove Island (1958) and Cummings Park (1960). The longest federal shore protection projects have been at Hammonasset State Park and Natural Area Preserve (1.89 miles or 3.04 km) in 1955 and the Silver to Cedar Beaches Project. The Silver to Cedar Beaches Project area is authorized for 15,600 ft (4,754.88 m)

Table 31. The approximate lengths of authorized constructed beach nourishment and dredge disposal placement projects on Connecticut's Soundfront beaches from east to west (Sources: Patton and Kent 1992, Haddad and Pilkey 1998, USACE 2013c, PSDS 2015, USACE New England District website).

Location	Project Length (miles)
Eastern Point Beach, Groton	Unknown
Esker Point Park, Groton	Unknown
Neptune Park, New London	0.15
Ocean Beach, New London	Unknown
Seaside Regional Center, Waterford	Unknown
Point O'Woods, Old Lyme	0.18
White Sand Beach, Old Lyme	0.26
Chalker Beach, Old Saybrook	0.30
Clinton Town Beach, Clinton	Unknown
Clinton Harbor area (dredge disposal**)**	Unknown
Hammonasset Beach State Park, Madison	1.89
Guilford Point Beach, Guilford	0.08
Jacob's Beach, Guilford	Unknown
Branford Point Park, Branford	0.06
West Silver Sands Beach, East Haven	0.48
Prospect Beach, West Haven	1.23
Sea Bluff Beach, West Haven	0.19
Savin Rock, West Haven	Unknown
Laurel Beach, Milford	0.53
Woodmont Beach, Milford	0.81
Gulf Beach, Milford	0.23
Silver to Cedar Beaches, Milford	1.61
Short Beach, Stratford	0.66
Long Beach, Stratford	Unknown
Seaside Park, Bridgeport	1.67
Pleasure Beach, Bridgeport	Unknown
Fairfield Beach, Fairfield	0.83
West Fairfield Beach, Fairfield	1.06
Sasco Hill Beach, Fairfield	0.17
Southport Beach, Fairfield	0.13
Burial Hill Beach, Westport	0.09
Sherwood Island State Park, Westport	1.14
Compo Beach, Westport	0.70
Calf Pasture Beach Park, Norwalk	0.42
Cove Island, Stamford	0.25
Cummings Park, Stamford	0.19
TOTAL MILES	**15.32+ miles (19% of sandy beach shoreline)**

of beaches including Silver, Meadows End, Myrtle, Walnut, Laurel and Cedar Beaches. In 1955 the Cedar Beach and western Laurel Beach segment received fill from dredging of the Housatonic River, and in 1960 parts of Silver, Meadows End and Myrtle Beaches received fill (Haddad and Pilkey 1998, PSDS 2015, USACE New England District website). The remaining portions of the federal project area had not received beach fill prior to Hurricane Sandy. Sediment placement projects at Eastern Point Beach, Ocean Beach, Jacob's Beach, and Savin Rock all took place prior to 1961 and project details are unknown (Haddad and Pilkey 1998).

Nearly all of these sediment placement projects were constructed in the 1950s and 1960s. The extent of more recent beach fill projects is not known. Patton and Kent (1992) reported that at least 6.5 million cubic yards (mcy) of sediment have been placed on Connecticut's beaches, with approximately half of that volume placed on the beaches between Milford Harbor and the Norwalk Islands.

New York – Long Island Sound Shoreline

As described in the section above for Connecticut, the Long Island Sound Study program has identified beaches and dunes as one of 12 priority habitat types in Long Island Sound and the piping plover as an environmental indicator (LISS 2015). In addition, the New York Wildlife Action Plan (NYDEC 2005) identified the collection of data on beach habitats and their use by species including the piping plover as a conservation action to identify priority areas for beach management and land protection. Another conservation action identified in the New York plan includes the mapping of all the major coastal habitat types, including beaches, to establish a baseline for future trends analyses.

The Long Island Sound shoreline of New York is composed primarily of glacial material which form bluffs or cliffs along the majority of the coast, some of which reach 150 ft (45.72 m) or more in height (Eisel 1977, Morgan et al. 2005, Town of Southold 2011). Landslides and slumps of bluff material occasionally occur onto the beaches (Eisel 1977). The beaches are derived from this glacial material, and many of them are sandy with some number of large boulders, or glacial erratics. The North Shore of Long Island has coarser sediment, steeper slopes and an absence of barrier islands when compared to the South Shore of Long Island (Morgan et al. 2005). Eisel (1977) found that the beaches along New York's Long Island Sound shoreline were wider than those along the Peconic Estuary. At the time of Eisel's study, half of New York's Long Island Sound shoreline beaches were greater than 50 ft (15.24 m) and half less than 50 ft (15.24 m) wide.

Maslo et al. (2011) identified a minimum distance of 31 ft (9.5 m) from the high tide line to the toe of the dune as necessary to support nesting piping plovers in oceanfront New Jersey, but it is not known how wide a beach backed by bluffs or hard stabilization structures must be to support beach-nesting birds along other shorelines such as those along Long Island Sound. The beaches along the Long Island Sound shoreline of New York tend to be narrower at the base of bluffs and wider near inlets where the bluffs recede or jetties trap sediment. Breakwater Beach west of Mattituck Inlet in Southold, for example, is 50 to 100 ft (15 to 30 m) wide due to impoundment by the western jetty at the federally-maintained inlet, and the barrier spit at Bailie's Beach to the east of the inlet is narrower than Breakwater Beach but is backed by primary and secondary dunes which are absent in areas with bluffs (Morgan et al. 2005). The tidal range along Long Island Sound increases to the west, with the tidal range three times as high at the western end of the Sound as the tidal range in Block Island Sound; the mean tidal range at Plum Island, for example, is 2.6 ft (0.8 m) but it increases to 7.3 ft (2.2 m) at Hempstead Harbor (Morgan et al. 2005). As a result of the increased tidal range, beaches that may be narrow at high tide may be much wider at low tide and provide valuable foraging habitat for piping plovers and chicks during the breeding season as well as during migration.

Table 32. The approximate lengths of sandy beach within each county of the Long Island Sound shoreline of New York (from east to west) and the proportions that are developed and undeveloped as of September 2011 to August 2012 according to Google Earth imagery.

County	Approximate length of sandy beach (miles)	Developed shoreline miles (% of total)	Undeveloped shoreline miles (% of total)
Suffolk	99.22	57.18 (58%)	42.03 (42%)
Nassau	21.53	16.14 (75%)	5.39 (25%)
TOTAL	**120.75**	**73.32 (61%)**	**47.43 (39%)**

From east to west, the Long Island Sound shoreline of New York falls within Suffolk and Nassau Counties. Within Suffolk County, the communities are Fisher Island, Plum Island, Orient, East Marion, Greenport, Southold, Peconic, Mattituck, Jamesport, Riverhead, Baiting Hollow, Wading River, East Shoreham, Shoreham, Rocky Point, Sound Beach, Miller Place, Port Jefferson, Belle Terre, an unincorporated area of the Town of Brookhaven, Old Field, Stony Brook, Nissequogue, Fort Salonga, an unincorporated area of the Town of Huntington, Eatons Neck, Huntington Bay, Lloyd Harbor and Cold Spring Harbor. The communities within Nassau County which were included in this assessment are Laurel Hollow, Cove Neck, Centre Island, Bayville, Locust Valley, Lattingtown, Glen Cove, Sea Cliff, Port Washington, and Sands Point. The westernmost boundary along the Long Island Sound shoreline included in this assessment was Plum Point in Sands Point on Manhasset Bay. The shoreline to the west of this point falls within the greater New York City metropolitan area and contains fewer sandy beaches. Inner bays or harbors such as Mt. Sinai or Port Jefferson Harbors were not included; only sandy beaches with direct exposure to Long Island Sound were included in this assessment.

Altogether 120.75 miles (194.33 km) of sandy beaches were identified along the Long Island Sound shoreline of New York from Plum Point to Orient Point, plus Plum and Fisher Islands (Table 32). Sixty-one percent (61%) of these beaches were developed prior to Hurricane Sandy in October 2012. The sandy beaches in Nassau County were more developed (75%) than those in Suffolk County (58%). The New York Wildlife Action Plan has identified development of beaches as a threat to this key habitat in the state that can result in habitat loss and ultimately, along with shoreline stabilization measures, threaten the viability of all coastal species that use beach habitats throughout their lifecycle (NYDEC 2005).

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 Southold, Riverhead, Brookhaven, Huntington and Smithtown. These towns have multiple incorporated villages or hamlets (e.g., Greenport, Jamesport, Nissequogue, or Asharoken) as well as unincorporated areas. 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 (Town of Southold 2011). The Dongan Patent of 1686 granted several of 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 Southold owns the sandy beach along its shoreline on Long Island Sound and manages several sections as public parks (e.g., Goldsmith Inlet Park).

Immediately adjacent to the public beaches that are not within larger parks, however, are a number of private properties.

The public and NGO owned lands listed in Table 33 do not include Town-owned beaches unless the adjacent properties are also public or NGO lands. 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.

Less than one-third (29%) of the sandy beaches along New York's Long Island Sound shoreline are in public or NGO ownership (Table 33). Although at least 71 tracts of sandy beach are in public or NGO ownership, most of these tracts are short. Plum Island, which is owned by the federal government, has the longest total length of sandy beaches at 3.81 miles (6.13 km). The only other conservation lands that exceed one mile (1.6 km) in length are the Hallock State Park Preserve, Wildwood State Park, McAllister County Park, Whitehall Beach (owned by the Village of Old Field), West Meadow Beach (owned by the Town of Brookhaven), Sunken Meadow State Park, Hobart Beach Park in Huntington and the Caumsett State Historic Park Preserve. The Peconic Land Trust owns a number of properties or conservation easements along the Long Island Sound shoreline, totaling 1.03 miles (1.66 km) of sandy beaches. The USFWS owns the Oyster Bay NWR, but the refuge is a marine refuge that owns the bay bottom and

Table 33. 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 approximate length of sandy beach in each visible in Google Earth imagery from September 2011 to August 2012 prior to Hurricane Sandy (Sources: See Table 1).

Public / NGO Land	County Location	Approximate Beach Length in Miles
Plum Island	Suffolk	3.81
Orient Point County Park	Suffolk	0.48
Gillespie / Alford Trust Easement	Suffolk	0.09
Truman's Beach	Suffolk	0.24
Ruth Oliva Preserve at Dam Pond	Suffolk	0.06
Cove Beach Easement	Suffolk	0.12
Inlet Pond County Park	Suffolk	0.42
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	0.25
Goldsmith Inlet Park	Suffolk	0.03
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

Public / NGO Land	County Location	Approximate Beach Length in Miles
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	1.49
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	0.86
McAllister County Park	Suffolk	1.01
Whitehall Beach	Suffolk	1.28
Flax Pond Tidal Wetlands Area	Suffolk	0.46
West Meadow Beach	Suffolk	1.34
Nissequogue Preserve	Suffolk	0.47
Otto Schubert Beach	Suffolk	0.10
Long Beach Town Park	Suffolk	0.65
The David Weld Sanctuary	Suffolk	0.39
Short Beach	Suffolk	0.67
Sunken Meadow State Park	Suffolk	2.56
Callahan's Beach Park	Suffolk	0.20
Geisslers Beach Park	Suffolk	0.32
Jerome A. Ambro Memorial Wetland Preserve	Suffolk	0.16
Crab Meadow Beach Park	Suffolk	0.22
Kirschbaum Park	Suffolk	0.07
Soundview Beach	Suffolk	0.13
USCG Station Eatons Neck	Suffolk	0.67
Hobart Beach (Sand City) Park	Suffolk	1.13
Crescent Beach Town Park	Suffolk	0.07
Lloyd Neck East Beach	Suffolk	0.71
Target Rock NWR	Suffolk	0.50
Caumsett State Historic Park Preserve	Suffolk	2.93
West Neck Beach	Suffolk	0.30
Lloyd Harbor Park	Suffolk	0.31
Laurel Hollow Beach	Nassau	0.36
Oyster Bay NWR / Sagamore Hill National Historic Site	Nassau	0.16
Soundside Beach Park	Nassau	0.08
Charles E. Ransom Beach (in Bayville)	Nassau	0.21

Public / NGO Land	County Location	Approximate Beach Length in Miles
unnamed public beach in Locust Valley	Nassau	0.03
Stehli Beach (in Lattingtown)	Nassau	0.47
Prybil Beach	Nassau	0.21
Welwyn Preserve County Park	Nassau	0.36
Morgan Memorial Park	Nassau	0.22
Garvies Point Museum & Preserve	Nassau	0.38
Sea Cliff Municipal Beach	Nassau	0.19
Harry Tappen Beach	Nassau	0.20
North Hempstead Beach Park	Nassau	0.62
Sands Point Preserve	Nassau	0.95
	TOTAL MILES	**34.79 (29% of sandy beach shoreline)**

adjacent shoreline only to the mean high water line (USFWS 2006) while the adjacent upland is owned by private interests except at the Sagamore Hill National Historic Site owned by the NPS and the public Stehli Beach owned by the Town of Oyster Bay.

In many places glacial boulders have been used to build groins along the beach (Town of East Hampton 1999), but these groins are piles of boulders arranged on the surface of the beach and not engineered and designed shoreline stabilization structures. Nevertheless they interfere with longshore sediment transport and access for wildlife and recreational uses, and are included in this assessment's accounting of shoreline stabilization structures. Many of the bulkheads, seawalls and revetments lining the shoreline are found at the base of the bluffs to address erosion of the bluff that could threaten private development built on top of the bluffs; these hard stabilization structures then cut off the natural sediment supply for the beaches.

Approximately 34.64 miles (55.75 km) of the Long Island Sound shoreline in New York were armored with hard stabilization structures prior to Hurricane Sandy (Table 34). These hard stabilization structures include 255 contiguous sections of seawalls / bulkheads / revetments, 511 groins, 4 breakwaters and 21 jetties (Table 35). Hard stabilization structures can also be found on the non-sandy (rocky) sections of shoreline in New York, but those structures were not included in this assessment. The New York Wildlife Action Plan has identified the construction of hard stabilization structures on beaches as a threat to this key habitat in the state that can result in habitat loss and ultimately, along with development, threaten the viability of all coastal species that use beach habitats throughout their lifecycle (NYDEC 2005).

In addition to the 34.64 miles (55.75 km) of sandy beaches with hard shoreline stabilization structures, an additional 6.08 miles (9.78 km) of shoreline was armored with hard shoreline stabilization structures (66 additional groins) but did not have any sandy beaches longer than 500 ft (152.40 m) as of September 2011 to August 2012; thus 6.08 miles (9.78 km) of sandy beach habitat had been lost at that time. (Evidence indicated sandy beaches would be present in these locations in the absence of the hard stabilization structures.)

At least 12 sandy beaches along the Long Island Sound shoreline of New York have been modified with sediment placement projects, but only 3 have known project lengths (Table 36). Suffolk County has owned and operated a dredge throughout the county since 1956. As of 1985, the county had dredged and

Table 34. Approximate shoreline length (in miles) within each county of the Long Island Sound shoreline of New York that were armored with hard stabilization structures visible on Google Earth imagery between April 1994 and September 2011 to August 2012. Hard stabilization structures include groins, jetties, seawalls, bulkheads, revetments, geotubes, sandbags and breakwaters. Structures may be periodically exposed or buried and include those that are failing, in disrepair, or remnants of old structures.

County	Approximate Length of Armoring (miles)	Percentage of Beach Length Armored
Suffolk	22.39	23%
Nassau	12.25	57%
TOTAL	**34.64**	**29%**

Table 35. Approximate number of each type of armoring visible on the Long Island Sound beaches in each county of New York visible on Google Earth imagery between April 1994 and September 2011 to August 2012. 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 34 above.

County	Number of Groins	Number of Jetties	Number of Seawalls, Bulkheads and/or Revetments	Number of Breakwaters
Suffolk	287	18	166	2
Nassau	224	3	89	2
TOTAL	**511**	**21**	**255**	**4**

placed sediment on beaches near Goldsmith Inlet, Mattituck Inlet, Mt. Sinai Harbor, Stony Brook Harbor, and the Nissequogue River (Suffolk County 1985). Google Earth imagery dated March 6, 2012, showed sediment placement activities on-going at The Creek Club golf course in Lattingtown and at Orient Point County Park. Louis C. Tiffany modified his Soundfront property in Laurel Hollow with "countless tons of sand" as beach fill plus hard stabilization structures in the early 20th century (Hornblower 1951, p. 4). O'Connor (1973) cited dredge spoil placement on beach(es) near Wading River Creek as having taken place between 1961 and 1971. Bailie's Beach east of Mattituck Inlet in Southold and Hempstead Beach in North Hempstead were the only federal navigation projects with dredge disposal on adjacent beaches prior to Hurricane Sandy (Morgan et al. 2005, PSDS 2015). Material dredged from the intake and discharge canals of the Northport Power Plant in Huntington are periodically placed along approximately 1.0 miles (1.6 km) of Asharoken Beach to the west (USACE 2013g, Steve Sinkevich, USFWS, pers. communication May 22, 2015). Additional sediment placement projects constructed by private interests are unknown but likely to have occurred on a localized basis.

In addition to the known sediment placement projects, the USACE has proposed a federal shore protection project within the Village of Asharoken that could include beach fill along up to 2.5 miles of beach, but the project was not finalized or constructed prior to Hurricane Sandy (USACE New York District website).

The area in and around Mattituck Inlet in Southold has been commercially mined for sand and gravel, as has the area in and around Flax Pond Inlet and the beach and bluff area between the two former jetties

Table 36. The approximate lengths of known constructed beach nourishment and dredge disposal placement projects on the sandy beaches of New York's Long Island Sound shoreline from east to west (Sources: O'Connor 1973, Suffolk County 1985, Morgan et al. 2005, USACE 2013g, Google Earth March 6, 2012 imagery, PSDS 2015, USACE New York District website).

Location	Project Length (miles)
Orient Point County Park	Unknown
Kenneys Road Beach, Southold	Unknown
Goldsmith Inlet Park, Southold	Unknown
Bailie's Beach, Mattituck Inlet, Southold	0.11
Wading River Creek, Riverhead	Unknown
Mt. Sinai Harbor, Brookhaven	Unknown
Stony Brook Harbor, Brookhaven	Unknown
Nissequogue River, Smithtown	Unknown
Asharoken Beach, Northport Power Plant, Huntington	1.0
Asharoken Beach, Village of Asharoken	PROPOSED
The Creek Club (golf course), Lattingtown	Unknown
Laurel Hollow Road, Laurel Hollow	Unknown
Hempstead Beach, North Hempstead	0.57
TOTAL MILES	**1.68+ (> 1.4% of state beaches)**

(northwest of Lily Pond) at Hallock State Park Preserve (Morgan et al. 2005, Abrams et al. 2008, Wines 2008, NY Office of Parks, Recreation and Historic Preservation [NY OPRHP] 2010). An estimated 260,000 to 350,000 cy of sediment were mined from material impounded by the west jetty at Breakwater Beach west of Mattituck Inlet from before 1960 (beginning probably between 1947 and 1955) to 1977 for commercial sand and gravel purposes, with undocumented reports of beach mining taking place periodically for up to 50 years (Morgan et al. 2005, Batten and Kraus 2006). In addition to dredging of the federal navigation channel at Mattituck Inlet, sand and gravel were commercially mined from the inlet from 1925 to at least 1948 under federal permit, with an estimated 250,000 to 500,000 cy of sediment mined and removed from the system (Morgan et al. 2005, Batten and Kraus 2006). The beaches adjacent to Flax Pond Inlet were mined every summer since at least 1874 for use in New York City industries; it is unknown how long the mining took place, but no mining has occurred since the state purchased Flax Pond and surrounding property in 1966. Flax Pond Inlet was mined by the McCormack Sand and Gravel Company in the 1940s for commercial sale (Abrams et al. 2008). The Levon Corporation mined sand and gravel at what later would become Hallock State Park Preserve from 1967 to 1970 under the auspices of developing a deepwater industrial seaport, but it is unknown how much sediment was permanently removed from the beach and bluff before the controversial project ended with the court-ordered removal of the two jetties and closure of the dredged port entrance in 1971 (Wines 2008, NY OPRHP 2010).

New York – Peconic Estuary

The Peconic Estuary between the north and south forks of Long Island is part of the Environmental Protection Agency's National Estuaries Program. As a part of this program, the estuary is managed by the Peconic Estuary Program (PEP), a multi-agency effort to protect and restore the ecosystem. The

protection of shoreline habitat in the estuary is a priority of the PEP Critical Lands Protection Plan (PEP 2004).

Eisel (1977, p. 1) describes the Peconic Estuary shoreline as "highly convoluted," composed of glacial sediment, and containing headland bluffs that are typically less than 20 ft (6 m) high on the north fork but up to 240 ft (73 m) high on the south fork. The sediment that supplies the beaches on the Peconic Estuary shoreline are derived from river and creek discharge within the Estuary, erosion of the bluffs, and erosion of the bay bottom, with the bluffs the major sediment source. The beaches of the Peconic Estuary are subject to short-term, seasonal variations but have a long-term trend towards erosion due to sea level rise. The highly convoluted nature of the shoreline, and the limited fetches thus created, prevent a predominant direction of longshore sediment transport (Eisel 1977).

Eisel (1977) found that the beaches along the Peconic Estuary were narrower than those on New York's Long Island Sound shoreline. Most of the Estuary's beaches (68.1%) were less than 50 ft (15.24 m) wide, as compared to half of New York's Long Island Sound shoreline beaches less than 50 ft (15.24 m) wide. The average width of a Peconic Estuary beach was approximately 40 ft (12.19 m) at the time of Eisel's study in the 1970s. Maslo et al. (2011) identified a minimum distance of 31 ft (9.5 m) from the high tide line to the toe of the dune as necessary to support nesting piping plovers in oceanfront New Jersey, but it is not known how wide a beach backed by bluffs or hard stabilization structures must be to support beach-nesting birds along other shorelines such as those along the Peconic Estuary.

The entire Peconic Estuary shoreline falls within Suffolk County. Three large islands are within the estuary's bays – Gardiners Island, Shelter Island and Robins Island. From Montauk Point clockwise to Orient Point, the communities included in this assessment include Montauk, Napeague, Amagansett, Springs, Northwest Harbor, Sag Harbor, North Haven, Noyack, North Sea, Tuckahoe, Hampton Bays, Flanders, Riverhead (at the mouth of the Peconic River), Aquebogue, Jamesport, Laurel, Mattituck, Cutchogue, New Suffolk, Peconic, Southold, Greenport West, Greenport, East Marion, Orient, plus the three islands. Inner bays or harbors such as Accabonac, Three Mile or Sag Harbors were not included; only sandy beaches with direct exposure to Flanders Bay, Great Peconic Bay, Little Peconic Bay, Noyack Bay, Sag Harbor Bay, Gardiners Bay, Napeague Bay and Block Island Sound were included in this assessment.

As of March 2012, the Peconic Estuary shoreline included approximately 134.98 miles (217.23 km) of exposed sandy beaches (Table 37). Roughly two-thirds (67%) of these sandy beaches were undeveloped prior to Hurricane Sandy. The sandy beaches on Gardiners Island and Robins Island are virtually entirely undeveloped. In contrast, the sandy beaches within the communities of Mattituck, Laurel, Aquebogue and Tuckahoe are nearly entirely developed. The New York Wildlife Action Plan has identified development of beaches as a threat to this key habitat in the state that can result in habitat loss and ultimately, along with shoreline stabilization measures, threaten the viability of all coastal species that use beach habitats throughout their lifecycle (NYDEC 2005).

Table 37. The approximate lengths of sandy beach within Suffolk County along the Peconic Estuary shoreline of New York and the proportions that are developed and undeveloped as of March 2012 according to Google Earth imagery.

County	Approximate length of sandy beach (miles)	Developed shoreline miles (% of total)	Undeveloped shoreline miles (% of total)
Suffolk	134.98	45.06 (33%)	89.92 (67%)

Nearly half (45%) of the Peconic Estuary shoreline is in public and/or NGO ownership (Table 38). Of the approximately 61 miles (98.17 km) of sandy beaches in 72 tracts of public and/or NGO ownership, the state of New York, TNC, Suffolk County, USFWS, Town of East Hampton and the Peconic Land Trust own the longest total lengths of sandy beaches. TNC's Mashomack Preserve on Shelter Island has the longest length of conserved sandy beaches (7.46 miles or 12.00 km) on the Peconic Estuary shoreline. Orient Beach State Park also has a high length of sandy beaches in conservation, with 5.73 miles (9.22 km) of sandy beaches exposed to Orient Harbor or Gardiner's Bay. Montauk Point State Park, Hither Hills State Park and Cedar Point County Park have each protected over 4 miles (6.44 km) of sandy beaches. The Robins Island Foundation has conserved Robins Island and its 3.81 miles (6.13 km) of sandy beaches. The Elizabeth A. Morton NWR owns approximately 3.66 miles (5.89 km) of sandy beaches, although some sections may be gravelly at least seasonally.

As described in the New York – Long Island Sound Shoreline section above, the public and NGO owned lands listed in Table 38 do not include Town-owned beaches unless the adjacent properties are also public

Table 38. Sandy beaches that are in public or NGO ownership along the Peconic Estuary shoreline of New York clockwise from Montauk Point to Orient Point and approximate length of sandy beach in each visible in Google Earth imagery from March 2012 prior to Hurricane Sandy. Note that the entire Peconic Estuary shoreline is within Suffolk County (Sources: See Table 1).

Public / NGO Land	Approximate Beach Length in Miles
Montauk Point Lighthouse	0.14
Montauk Point State Park	4.61
East Lake Beach (Gin Beach)	0.10
West Lake Drive Beach	0.13
Culloden Point Beach	0.19
Unknown public beach or park immediately south of Culloden Point along Fort Pond Bay[1]	0.98
Town Beach at Navy Road (East Hampton)	0.20
Unknown Suffolk County parcel along Navy Road in Montauk[1]	0.16
Fort Pond Bay Park / Eddie Ecker Park / Benson Point	0.21
Hither Woods Preserve	1.80
Hither Hills State Park	4.22
Napeague State Park	1.07
Cedar Bush Preserve	0.02
Fresh Pond Park	0.08
Dennistown Bell Park - Big & Little Albert's Landing Parks	0.42
Barnes Landing	0.51
Louse Point Town Beach	0.38
Gerard Point	0.37
Gerard Park	0.12
Unknown public beach or park along Gerard Drive north of historic inlet or sluice site in Springs[1]	0.17

Public / NGO Land	Approximate Beach Length in Miles
Camp Blue Bay	0.29
Maidstone Park	0.42
Sammy's Beach	0.54
Cedar Point County Park	4.08
Grace Estate	0.37
Mile Hill Beach	0.05
Northwest Harbor Tidal Wetlands Area	0.39
Unknown public beach or park on west shore of Northwest Harbor Inlet[1]	0.17
Linda Gronlund Memorial Nature Preserve	1.29
Haven's Beach	0.16
Unknown public beach or park on north shoulder of Fresh Pond Inlet in North Haven[1]	0.07
Tramaridge Trust Easement	0.19
Unknown public beach or park at end of Bayview Court in North Haven[1]	0.04
Foster Memorial Town Beach	1.35
Clam Island	0.53
Elizabeth A. Morton NWR	3.66
Cow Neck Trust Easement	2.18
Tern Island Easement	0.45
Meschutt Beach County Park	0.28
Shinnecock Indian Nation lands along Peconic Bay in Hampton Bays	0.38
East Landing Road Beach Access	0.23
West Landing Road Beach Access	0.18
Squiretown Park	0.52
Unknown public beach or park on east side of Red Creek Pond Inlet[1]	0.41
Hubbard County Park	0.78
Unknown protected parcel at Fantasy Drive and Longneck Boulevard in Flanders[1]	0.18
Unknown protected parcel in Flanders at mouth of Peconic River at Iron Point[1]	0.12
Indian Island County Park	0.37
Wines / Gilbert Trust Easement	0.04
Miamogue Point	0.09
South Jamesport Park	0.39
Yacht Club Property Beach	0.08
Veteran Memorial Park	0.10
New Suffolk Beach	0.10
Paumanok Trust Easement	0.03
Robins Island	3.81
Pequash Avenue Beach	0.05

Public / NGO Land	Approximate Beach Length in Miles
Meadow Beach parcels on Horseshoe Cove peninsula in Cutchogue[1]	0.37
Pia Trust Easement	0.15
Nassau Point Beach	0.33
Little Creek Inlet open space	0.17
Emerson Park	0.06
Blocker Preserve	0.49
Cedar Beach County Park	0.65
Shellfisher Preserve	0.11
Goose Creek Beach	0.15
Founder's Landing Park	0.09
Moores Drain Open Space	0.35
5th Street Beach and Park	0.13
Unknown public beach or park on east side of Stirling Basin inlet at end of Beach Street in Greenport [1]	0.10
Norman Klipp Park (Gull Pond Beach)	0.16
Truman's Beach complex	0.36
Long Beach Bay Tidal Wetlands Area	0.40
Orient Beach State Park	5.73
Orient Point County Park	0.42
Mashomack Preserve, Shelter Island	7.46
Unknown Town of Shelter Island parcel east of end of Sea Gull Road near unnamed inlet, Shelter Island[1]	0.04
Wade's Beach, Shelter Island	0.34
Shell Beach, Shelter Island	0.66
Crescent (Louis) Beach, Shelter Island	0.40
Sylvester Manor Educational Farm, Shelter Island	0.07
Menhaden Lane public access, Shelter Island	0.02
Dressel Preserve, Shelter Island	0.51
Unknown Suffolk County parcel on Ram Island Drive south of Dressel Preserve, Shelter Island[1]	0.14
Unknown TNC, Suffolk County and Town of Shelter Island parcel on Ram Island Drive causeway, Shelter Island[1]	0.49
Reel Point Reserve, Shelter Island	0.40
TOTAL MILES	**60.99 (45% of sandy beach shoreline)**

1 – A number of beach parcels are indicated on the Peconic Land Trust Conservation Map, Town open space or public access and recreation maps, and/or the Suffolk County GIS Land Viewer as being in public or NGO ownership but specific names were not found for the parcels.

or NGO lands. 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.

The PEP has identified the extent of shoreline hardening as an environmental indicator in the Peconic Estuary (Balla et al. 2005). In several places glacial boulders have been used to build groins along the estuary's beaches (Town of East Hampton 1999), but these groins are surficial and not engineered and designed shoreline stabilization structures. Nevertheless they interfere with longshore sediment transport and access for wildlife and recreational uses, and are included in this assessment's accounting of shoreline stabilization structures. Many of the bulkheads, seawalls and revetments lining the shoreline are found at the base of the bluffs to address erosion of the bluff that could threaten private development built on top of the bluffs; these hard stabilization structures then cut off the natural sediment supply for the beaches.

Approximately 27.05 miles (43.53 km), or 20%, of the Peconic Estuary shoreline in New York were armored with hard stabilization structures prior to Hurricane Sandy (Table 39). These hard stabilization structures include 306 contiguous sections of seawalls / bulkheads / revetments, 668 groins, 12 breakwaters and 49 jetties (Table 40). Hard stabilization structures can also be found on the non-sandy (rocky) sections of shoreline, but those structures were not included in this assessment. The New York Wildlife Action Plan has identified the construction of hard stabilization structures on beaches as a threat to this key habitat in the state that can result in habitat loss and ultimately, along with development, threaten the viability of all coastal species that use beach habitats throughout their lifecycle (NYDEC 2005).

In addition to the 27.05 miles (43.53 km) of sandy beaches with hard shoreline stabilization structures, an additional 17.24 miles (27.75 km) of shoreline was armored with hard shoreline stabilization structures (an additional 353 groins, 2 breakwaters and 1 jetty) but did not have any sandy beaches longer than 500 ft (152.40 m) as of March 2012; thus 17.24 miles (27.74 km) of sandy beach habitat had been lost at that time. (Note that evidence indicated sandy beaches would be present in these locations in the absence of the hard stabilization structures.) The PEP has identified the elimination or limitation of new hard shoreline stabilization structures as "an important step in preserving the habitats, and therefore the living resources, of the Peconic Estuary" (Balla et al. 2005, p. vii).

Table 39. Approximate shoreline length of sandy beaches (in miles) within Suffolk County along the Peconic Estuary shoreline of New York that were armored with hard stabilization structures visible on Google Earth imagery between April 1991 and March 2012 prior to Hurricane Sandy. Hard stabilization structures include groins, jetties, seawalls, bulkheads, revetments, geotubes, sandbags and breakwaters. Structures may be periodically exposed or buried and include those that are failing, in disrepair, or remnants of old structures.

County	Approximate Length of Armoring (miles)	Percentage of Beach Length Armored
Suffolk	27.05	20%

Table 40. Approximate number of each type of armoring within Suffolk County along the Peconic Estuary shoreline of New York prior to Hurricane Sandy (visible on Google Earth imagery between April 1991 and March 2012). Note that multiple seawalls, bulkheads or revetments are counted as one structure if they are continuous with no separations; for example, if five individual adjacent 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 39 above.

County	Number of Groins	Number of Jetties	Number of Seawalls, Bulkheads and/or Revetments	Number of Breakwaters
Suffolk	668	49	306	12

The Peconic Estuary Program reported that a 2000 analysis by the USFWS (unpublished data) found 28.6 miles (46.03 km), or 6.3% of the estuary's total shoreline (453.0 miles, or 729 km), was armored with hard stabilization structures (Balla et al. 2005, Peconic Baykeeper 2006). The unpublished USFWS data were obtained from the USFWS Long Island Ecological Services Field Office and incorporated into and updated in this assessment. The key differences in the 28.6 miles (46.03 km) identified by PEP/USFWS and the 44.29 total miles (71.28 km)[15] identified in this assessment are the inclusion of inner harbors and bays by the PEP/USFWS study and the availability of multiple dates and seasons of Google Earth aerial imagery in this assessment, which allowed for the identification of structures previously hidden by sediment or vegetation. Some structures may have been constructed between 2000 and 2012 as well. This assessment identified a greater number of individual hard stabilization structures along the exposed sandy beach shoreline of the estuary[16], despite excluding hard stabilization structures found within harbors or inner bays[17].

At least 47 beaches in the Peconic Estuary have been modified with sediment placement projects, but only 3 of those projects have known project lengths (Table 41). Suffolk County has owned and operated a dredge throughout the county since 1956. The county has dredged and placed sediment on all the beaches listed in Table 41 except for those near Devon Yacht Club, Ganet Creek, Wade's Beach, and Gardiner's Island near Gaylor Hole (Suffolk County 1985, Town of East Hampton 1999, USACE 2014e). The only federal dredge disposal project in the Peconic Estuary is at Lake Montauk, where sediment has been placed by both the USACE and Suffolk County on beaches to both the east and west periodically since 1949 (Suffolk County 1985, Town of East Hampton 1999, USACE New York District website).

Sediment placement projects constructed by private interests are unknown but likely to have occurred on a localized basis. The Town of East Hampton's Local Waterfront Revitalization Program incorporates a Town policy that does not permit the excavation, grading, mining or dredging of nearshore areas solely for the purpose of beach nourishment (Town of East Hampton 1999). The Town of East Hampton is

[15] The total length of sandy beach habitat armored with hard stabilization structures includes the 27.05 miles (43.53 km) with beaches and 17.24 miles (27.75 km) without (lost) beaches as of March 2012.

[16] The PEP / USFWS analysis in 2000 identified 1,274 hard stabilization structures along the entire Peconic Estuary shoreline (Balla et al. 2005). This assessment identified 1,391 hard stabilization structures on the exposed Peconic Estuary shoreline, excluding harbors and inner bays.

[17] The entire Peconic Estuary shoreline used by PEP / USFWS was 453.0 miles (729 km). This assessment identified 134.98 miles (217.22 km) of sandy beach shoreline as of March 2012, plus 17.24 miles (27.75 km) of sandy beach habitat lost to shoreline armoring, for a total of 152.22 miles (244.97 km) of shoreline. Therefore the PEP / USFWS analysis identified 6.3% of the entire estuary shoreline as armored and this assessment identified 20% of existing sandy beaches as hardened, or 29% of the shoreline when including areas with lost beaches.

along the southeastern shoreline of the Peconic Estuary and stretches from Montauk to Sag Harbor and includes Gardiners Island. Thus the communities within this section of Peconic Estuary shoreline are not likely to be modified by large-scale sediment placement projects except for the beneficial use of dredge spoil.

Table 41. The approximate lengths of known constructed beach nourishment and dredge disposal placement projects on the sandy beaches of New York's Peconic Estuary shoreline clockwise from from Montauk Point to Orient Point (Sources: Suffolk County 1985, Town of East Hampton 1999, USACE 2014b, USACE New York District website).

Location	Project Length (miles)
Lake Montauk, east beach, East Hampton	Unknown
Lake Montauk, west beach, East Hampton	Unknown
Goff Point (northeast of Hicks Island), East Hampton	Unknown
Hicks Island, East Hampton	Unknown
Devon Yacht Club, East Hampton	Unknown
Louse Point, East Hampton	Unknown
Gerard Road / Point, East Hampton	Unknown
Lionhead Beach, East Hampton	Unknown
Maidstone Park, East Hampton	Unknown
Sammy's Beach, East Hampton	Unknown
Cedar Point County Park, East Hampton	Unknown
Northwest Creek, east beach, East Hampton	Unknown
Northwest Creek, west beach, East Hampton	Unknown
Ganet Creek, North Haven beaches	0.60
Mill Creek, Southampton	Unknown
Noyack Creek, Southampton	Unknown
Fresh Pond, Southampton	Unknown
Wooleys Pond, Southampton	Unknown
North Sea Harbor, Southampton	Unknown
Sebonac Creek, Southampton	Unknown
Cold Spring Pond, Southampton	Unknown
Miamogue Lagoon, Riverhead	Unknown
Hawks Creek, Riverhead	Unknown
East Creek, Riverhead	Unknown
Brushes Creek east and west, Southold	Unknown
James Creek east and west, Southold	Unknown
Deep Hole Creek east and west, Southold	Unknown
Halls Creek east, Southold	Unknown
New Suffolk Town Beach, Southold	Unknown
Schoolhouse Creek, Southold	Unknown
Wickham Creek west, Southold	Unknown
Mud Creek, Southold	Unknown
Little Creek east and west, Southold	Unknown
Richmond Creek east and west, Southold	Unknown

Location	Project Length (miles)
Corey Creek, Southold	Unknown
Cedar Beach County Park, Southold	Unknown
Goose Creek, Southold	Unknown
Town Creek / Harbor west, Southold	Unknown
Gull Pond, Southold	Unknown
Orient Beach State Park	Unknown
West Neck Harbor, Shelter Island	Unknown
Smith Cove, Shelter Island	Unknown
Crab Creek, Shelter Island	Unknown
Shell Beach, Shelter Island	0.51
Wade's Beach, Shelter Island	0.32
Coecles Inlet, Shelter Island	Unknown
Gaylor Hole, Gardiner's Island	Unknown
TOTAL MILES	**1.44 + (>1% of sandy beach shoreline)**

DISCUSSION

A substantial proportion of the sandy beaches within the northern U.S. Atlantic Coast breeding range of the piping plover have been developed (47%), filled with sediment (at least 4%) and armored (at least 23%). These habitat modifications tend to occur in the same locations as each other, resulting in localized adverse cumulative effects. When combined with the habitat modifications to the tidal inlets within the same region (results of Rice 2015b), significant cumulative loss and degradation of piping plover habitat has resulted; for example on areas such New Hampshire where 100% of the inlets have been armored and/or dredged, 87% of the beachfront has been developed, 72% of the beach has been armored, and at least 14% has received sand placement. The number of beach nourishment projects is increasing in virtually every state since the 1990s, although less so in the New England area of this study than in other regions of the U.S. Atlantic and Gulf coasts (Trembanis et al. 1998, Bush et al. 2004, USFWS 2009), resulting in an increasing cumulative magnitude of habitat modification. This assessment did not include other forms of habitat modification, such as dune building and maintenance (using non-fill methods like sand fencing), vegetation plantings, beach scraping (using bulldozers to push up artificial levees or "dunes" with sediment from the beach), 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 beach habitat.

A number of beachfront communities in this assessment area have 100% development along their exposed sandy beaches. In Maine, Old Orchard Beach is completely developed. All of the sandy beaches in New Castle, NH, are developed. On New York's Long Island Sound shoreline, the beachfronts of Shoreham, Rocky Point, and Port Jefferson are 100% developed. Several other communities are nearly 100% developed in each state. Adjacent development modifies sandy beach habitat, leading to habitat loss, fragmentation and degradation, and has been identified as a threat to key beach habitat in many state Wildlife Action Plans.

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.*

Artificial dunes are often constructed to protect development along the shoreline. At Duxbury Beach, MA, an artificial dune line is maintained to protect a coastal road that is the only land-based access to development at the end of a barrier spit. 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. (Sand fencing is also utilized to trap windblown sediment and build dunes in a more natural method, but those efforts are not included in the sediment placement projects described in this assessment.)

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. Rosen and FitzGerald (2014) describe this as occurring at Duxbury Beach, MA. 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). The long-term impacts to bayside habitat are negative because "little to no deposition in the marsh/bay occurs when overwash is continually blocked, which increases back-barrier accommodation space (water depth). If the island undergoes rollover, it must transgress into comparatively deeper water that requires larger volumes of sediment to maintain island elevation relative to sea level" (Magliocca et al. 2011, p. 928).

In recent years, sediment placement projects have been constructed in front of armoring. 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) 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). 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." This assessment found at least 43.43 miles (69.89 km) of lost beach in this manner in the northeast (excluding MA).

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).

Kelley et al. (1989) and McCormick et al. (1984) describe 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."

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.

This assessment identified approximately 1,057 contiguous sections of bulkheads, seawalls and revetments from Georgetown, ME, to the LIS and Peconic Estuary shorelines of New York excluding Massachusetts. There are approximately 5,378 bulkheads, seawalls, revetments and sandbag structures along the entire coast of Massachusetts, with an unknown proportion of them found on sandy beaches. Only 14% of the publicly owned hard stabilization structures in Massachusetts are less than 50 years old (MA DCR 2009), 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 some of these walls in other regions. This not only reduces the threat of undermining of the structures but also potentially provides new sandy beach habitat (Nordstrom and Jackson 2013). Although beach fill projects in the northeast region covered in this assessment tend to be much smaller than the long-term, large-scale shore protection projects along oceanfront beaches to the south, they still generate localized impacts that can be long term. The frequent placement of dredge spoil material on beaches near inlets can perpetually modify the sandy beach habitat in those areas.

Armoring structures that are built perpendicular to the beach, namely groins and jetties, also adversely impact sandy beaches. At least 2,518 groins and 116 jetties were present on sandy beach habitat (existing and former) from Maine to the Long Island Sound and Peconic Estuary shorelines of New York, excluding Massachusetts[18], prior to Hurricane Sandy. 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[19], or removing the

[18] There are approximately 2,103 groins and jetties along the entire coast of Massachusetts, with an unknown proportion of them found on sandy beaches (MA DCR 2009, Fontenault et al. 2013).

[19] Groin notching is when a portion of the groin, typically at the mean low water mark, is lowered by removing stone, creating a notch in the elevation of the structure. The purpose of the notch is to allow a portion of the longshore sediment transport to pass through the groin via the notch when the notch is submerged at higher tide

entire groin to increase the bypassing of sand to downdrift beaches." The USACE *Coastal Engineering Manual* (USACE 2006, 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 (13.78 km) 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 and reducing downdrift erosion depending on the location and design of the notches.

Rice (2009) and USFWS (2012) provide additional best management practices and conservation measures to avoid, minimize and mitigate the adverse impacts of sediment placement and armoring projects on sandy oceanfront beaches in the migration and overwintering range of the piping plover. Many of these recommendations may also be applicable to the piping plover breeding range, but further measures may be needed to accommodate essential behaviors and habitat requirements of courtship, nesting, and rearing of precocial chicks.

Finally, nearly 400 miles (644 km) of sandy beaches between Georgetown, ME, and the North Fork and Peconic Estuary of Long Island, NY, are in public and/or NGO ownership. Massachusetts has the highest number of miles of sandy beach (~217 miles or 349 km) in public or NGO ownership, covering 30% of the state's sandy beaches. Federal and state lands have played an especially important role in limiting development of sandy beach habitat in this assessment area. For example, the Cape Cod National Seashore contributes over 55 miles (89 km) of protected sandy beaches. National Wildlife Refuges have preserved ~36 miles (~58 km) of exposed sandy beaches in the assessment area, including at Rachel Carson (ME), Parker River (MA), Monomoy (MA), Trustom Pond (RI), Stewart B. McKinney (CT) and Elizabeth A. Morton (NY) NWRs. State parks and conservation areas total ~78 miles (~126 km) of exposed sandy beaches between southern Maine and northern Long Island. 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, 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. Lands owned by county and local governments, land trusts and land banks tend to be longer and collectively make a more significant contribution to the total inventory of public and NGO-owned lands in the northeastern U.S. than they do in the southeastern or mid-Atlantic U.S. The inventory of public and NGO-owned lands provided in this assessment for southern Maine to the LIS and Peconic Estuary shorelines of New York can be used to identify geographic gaps where conservation efforts may be prioritized to maintain and increase habitat availability and quality as sea level rises and climate changes.

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levels, reducing the volume of material impounded on the updrift side of the groin and decreasing the downdrift erosion impacts of the groin.

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[20]. 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.

Most 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).

Habitat modifications resulting from development and the construction of hard structures are long-term and can be permanent. These effects are on-going, cumulative, and increasing in intensity, as hard structures continue to be built primarily by private property owners. With sea level rising and global climate change altering storm dynamics, the pressure to modify the remaining sandy beach habitat that has not been modified in the northern U.S. Atlantic Coast breeding range will only increase. Pilkey and Cooper (2014) state that 90% of the world's beaches are retreating already. Thus, the adaptation

[20] 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.

management strategies recommended by the USFWS climate change strategy (USFWS 2010), CCSP (2009), Williams and Gutierrez (2009), Pilkey and Young (2009), and many others will increasingly be difficult to implement.

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REFERENCES

Balla, R., L. Bavaro, C. deQuillfeldt, and S. Miller. 2005. Peconic Estuary Program Environmental Indicators Report. Peconic Estuary Program. Riverhead, NY. 88 p.

Barnstable County. 2009. Report from the Barnstable County Dredge. Pp. 186-188 *in* Barnstable County Annual Report – FY 2009. Barnstable, MA. Available at http://www.barnstablecounty.org/dredge/. Accessed January 13, 2015.

Barnstable County. 2010. Report from the Barnstable County Dredge. Pp. 183-185 *in* Barnstable County Annual Report – FY 2010. Barnstable, MA. Available at www.barnstable**county**.org/2011/09/16/fy**2010**-**annual**-**report**/. Accessed January 13, 2015.

Barnstable County. 2011. Report from the Barnstable County Dredge. Pp. 167-169 *in* Barnstable County Annual Report – FY 2011. Barnstable, MA. 170 p. Available at www.barnstable**county**.org/wp-content/uploads/2012/04/AR_FY11.pdf. Accessed January 13, 2015.

Barnstable County. 2012. Report from the Barnstable County Dredge. Pp. 193-196 *in* Barnstable County Annual Report – FY 2012. Barnstable, MA. 196 p. Available at www.barnstable**county**.org/wp-content/.../BC-**Annual**-**Report**-FY2012.pdf. Accessed January 13, 2015.

Beach Stakeholders Group. 2006. Protecting Maine's Beaches for the Future: A Proposal to Create an Integrated Beach Management Program. A Report of the Beach Stakeholder's Group to the Joint Standing Committee on Natural Resources, 122nd Maine Legislature, 2nd Regular Session. Augusta, ME. 86 p.

Boyne, A.W., D.L. Amirault-Langlais, and A.J. McCue. 2014. Characteristics of piping plover nesting habitat in the Canadian Maritime Provinces. *Northeastern Naturalist* 21(2):164-173.

Bush, D. M., O. H. Pilkey, Jr., and W. J. Neal. 1996. *Living by the Rules of the Sea*. Duke University Press, Durham, North Carolina. 179 pp.

Bush, D. M., W. J. Neal, N. J. Longo, K. C. Lindeman, D. F. Pilkey, L. Slomp Esteves, J. D. Congleton, and O. H. Pilkey. 2004. *Living with Florida's Atlantic beaches: Coastal hazards from Amelia Island to Key West*. Durham, NC: Duke University Press. 338 p.

Buynevich, I.V., and D.M. FitzGerald. 2000. Styles of coastal progradation revealed in subsurface records of paraglacial barriers: Duxbury, Massachusetts, USA. *Journal of Coastal Research* Special Issue 34, pp. 194-208.

CCSP (Climate Change Science Program). 2009 "Coastal Sensitivity to Sea-Level Rise: A Focus on the Mid-Atlantic Region." A report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. [James G. Titus (Coordinating Lead Author), K. Eric Anderson, Donald R. Cahoon, Dean B. Gesch, Stephen K. Gill, Benjamin T. Gutierrez, E. Robert Thieler, and S. Jeffress Williams (Lead Authors)]. U.S. Environmental Protection Agency, Washington D.C., USA. 320 pp.

Coburn, A. S., A. D. Griffith, and R. S. Young, 2010. Inventory of coastal engineering projects in coastal national parks. Natural Resource Technical Report NPS/NRPC/GRD/NRTR—2010/373. National Park Service, Fort Collins, Colorado. 160 p.

Connecticut Department of Energy and Environmental Protection (CT DEEP). 2015. Key Threats: 2015 Wildlife Action Plan Revision. Hartford, CT. 2 p. Available at http://www.ct.gov/deep/cwp/view.asp?a=2723&q=329520&deepNav_GID=1719#Revision.

Connecticut Department of Environmental Protection (CT DEP). 2005. Connecticut's Comprehensive Wildlife Conservation Strategy: Creating a Vision for the Future of Wildlife Conservation. Department of Environmental Proteciton, Bureau of Natural Resources. Various paginations + appendices.

Connecticut Environmental Conditions Online (CT ECO). 2015. Connecticut Environmental Conditions Online (CT ECO): Maps & Geospatial Data for Planning, Management, Education and Research. Connecticut Department of Energy & Environmental Protection and University of Connecticut Center for Land Use Education and Research (CLEAR). Available at http://cteco.uconn.edu/.

Cuttyhunk Historical Society. 2014. Cuttyhunk Island and the Elizabeth Islands Time Line. Gosnold, MA. 23 p. Available at http://www.cuttyhunkhistoricalsociety.org/timeline/. Accessed January 7, 2015.

Dallas, K., P. Ruggiero, and M. Berry. 2013. Inventory of coastal engineering projects in Gateway National Recreation Area. Natural Resource Technical Report NPS/NRSS/GRD/NRTR—2013/738. National Park Service, Fort Collins, Colorado.

Defeo, O., A. McLachlan, D. S. Schoeman, T. A. Schlacher, J. Dugan, A. Jones, M. Lastra, and F. Scapini. 2009. Threats to sandy beach ecosystems: A review. *Estuarine, Coastal and Shelf Science* 81:1-12.

Dickson, S.M. 2001. Laudholm and Drakes Island Beaches: Before and After Beach Nourishment. Geologic Site of the Month: October 2001. Maine Geological Survey. Augusta, ME. 16 p.

Dickson, S.M. 2003. Coastal Erosion Assessment for Maine FIRMs and Map Modernization Plan. Maine Geological Survey. Augusta, ME. 39 p.

Donohue, K.A., L.M. Bocamazo, and D. Dvorak. 2004. Experience with groin notching along the northern New Jersey coast. *Journal of Coastal Research* Special Issue No. 33, pp. 198-214.

Dukes County. 2015a. Dukes County Interactive Map – Parcels. Available at http://dukescountygis.maps.arcgis.com/home/webmap/viewer.html?webmap=86e49289ff6c4eb19768525e96bfda7.

Dukes County. 2015b. County of Dukes County Dredging. Edgartown, MA. Available at http://www.dukescounty.org/pages/dukescountyma_naturalresources/Dredging. Accessed January 7, 2015.

Duxbury Beach Reservation. 2012. Duxbury Beach Management and Habitat Conservation Plan. July 2012 Revision. Duxbury, MA. 212 p.

Eisel, M.T. 1977. Shoreline Survey: Great Peconic, Little Peconic, Gardiners, and Napeague Bays. Marine Sciences Research Center, State University of New York Special Report Series # 5. Reference 77-1. Stony Brook, NY. 45 p.

FitzGerald, D.M. 1993. Origin and stability of tidal inlets in Massachusetts. *Coastal and Estuarine Studies* 44:1-61.

FitzGerald, D.M. 1996. Geomorphic variability and morphologic and sedimentologic controls at tidal inlets. *Journal of Coastal Research*, Special Issue No. 23, pp. 47-71.

FitzGerald, D.M., J.M. Lincoln, L.K. Fink, Jr., and D.W. Caldwell. 1989. Morphodynamics of tidal inlet systems in Maine. *Studies in Maine Geology* 5(1989):67-96.

FitzGerald, D.M., I.V. Buynevich, and P.S. Rosen. 2001. Geologic evidence of former tidal inlets along a retrograding barrier: Duxbury Beach, Massachusetts, USA. *Journal of Coastal Research*, Special Issue No. 34, pp. 437-448.

Flemming, S.P., R.D. Chiasson, and P.J. Austin-Smith. 1992. Piping plover nest selection in New Brunswick and Nova Scotia. *Journal of Wildlife Management* 56(3):578-583.

Fontenault, J., N. Vinhateiro, and K. Knee. 2013. Mapping and Analysis of Privately-Owned Coastal Structures along the Massachusetts Shoreline. RPS ASA Project No. 2012-266 for the Massachusetts Office of Coastal Zone Management. South Kingstown, RI. 76 p.

Google, Inc. 2015. Google Earth (Version 7.1.2.2041) [Software]. Available from http://www.google.com/earth/index.html.

Haddad, T., and O.H. Pilkey, Jr. 1998. Summary of the New England Beach Nourishment Experience (1935-1996). *Journal of Coastal Research* 14(4):1395-1404.

Hapke, C.J., E.A. Himmelstoss, M. Kratzmann, J.H. List, and E.R. Thieler, E.R. 2010. National assessment of shoreline change: Historical shoreline change along the New England and Mid-Atlantic coasts: U.S. Geological Survey Open-File Report 2010-1118. 57 p.

Hall, M.J., and O.H. Pilkey. 1991. Effects of hard stabilization on dry beach width for New Jersey. *Journal of Coastal Research* 7(3):771-785.

Hehre, R.E. 2007. An Aerial Photographic and Spatial Analysis Survey of Shoreline Change – Narragansett Bay, Rhode Island: 1939-2002. Master of Science Thesis, Department of Geosciences, University of Rhode Island. Kingston, RI. 157 p.

Herrington, T. O. 2003. Manual for coastal hazard mitigation. New Jersey Sea Grant College Program, Publication NJSG-03-0511. 108 p. Available at http://www.state.nj.us/dep/cmp/coastal_hazard_manual.pdf.

Hornblower, D.M. 1951. History of the Incorporated Village of Laurel Hollow, Nassau County, New York. Laurel Hollow, NY. 11 p.

Howes, B., S. Kelley, J. Ramsey, R. Samimy, E. Eichner, D. Schlezinger, and J. Wood. 2004. Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Popponesset Bay, Mashpee and Barnstable, Massachusetts. Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection. Boston, MA. 150 p.

Howes, B., R. Samimy, D. Schlezinger, S. Kelley, J. Ramsey, and E. Eichner. 2003. Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Stage Harbor, Sulphur Springs, Taylors Pond, Bassing Harbor, and Muddy Creek, Chatham, Massachusetts. Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection. Boston, MA. 272 p.

Howes, B., R. Samimy, D. Schlezinger, J. Ramsey, S. Kelley, and E. Eichner. 2005. Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Great/Perch Pond, Green Pond and Bournes Pond, Falmouth, Massachusetts. Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection. Boston, MA. 221 p.

Howes, B., R. Samimy, D. Schlezinger, T. Ruthven, J. Ramsey, and E. Eichner. 2006a. Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Centerville River System, Barnstable, Massachusetts. Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection. Boston, MA. 172 p.

Howes B., S. W. Kelley, J. S. Ramsey, R. Samimy, D. Schlezinger, and E. Eichner. 2006b. Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Three Bays, Barnstable, Massachusetts. Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection. Boston, MA. 183 p.

Kelley, J.T., A.R. Kelley, and O.H. Pilkey, Sr. 1989. *Living with the Coast of Maine*. Durham, NC: Duke University Press. 174 p.

Leatherman, S.P. 1988. *Barrier Island Handbook*. College Park, Maryland: Coastal Publication Series, Laboratory for Coastal Research, The University of Maryland. 92 p.

Lee, V. 1980. An Elusive Compromise: Rhode Island Coastal Ponds and Their People. Coastal Resources Center, University of Rhode Island Marine Technical Report 73. Narragansett, RI. 91 p. Available at http://www.nsgl.gso.uri.edu/riu/riut80009.pdf.

Long Island Sound Study (LISS). 1994. The Comprehensive Conservation and Management Plan. Samford, CT. 168 p. + appendices.

LISS. 2015. Status & Trends: LISS Environmental Indicators. Available at http://longislandsoundstudy.net/?indicator_categories=marine-and-coastal-animals.

Magliocca, N.R., D.E. McNamara, and A.B. Murray. 2011. Long-term, large-scale morphodynamic effects of artificial dune construction along a barrier island coastline. *Journal of Coastal Research* 27(5):918-930.

Maine Department of Agriculture, Conservation and Forestry (ME DACF). 2015. Conservation Lands in Maine. Interactive Web Viewer and Google Earth data layer. Available at http://www.maine.gov/dacf/parks/publications_maps/conservation_lands_maine.html.

Maine Department of Inland Fisheries and Wildlife (MDIFW). 2005. Maine's Comprehensive Wildlife Conservation Strategy. Augusta, ME. Various paginations + appendices.

Maslo, B., S.N. Handel, and T. Pover. 2011. Restoring beaches for Atlantic coast piping plovers (*Charadrius melodus*): A classification and regression-tree analysis of nest-site selection. *Restoration Ecology* 19(201):194-203.

Massachusetts Barrier Beach Task Force. 1994. Guidelines for Barrier Beach Management in Massachusetts. Massachusetts Coastal Zone Management. Boston, MA. 264 p.

Massachusetts Coastal Erosion Commission (MA CEC). 2015a. Draft Volume 1 – Report and Recommendations. Massachusetts Executive Office of Energy and Environmental Affairs. Boston, MA. Various paginations + appendices. Available at http://www.mass.gov/eea/waste-mgnt-recycling/coasts-and-oceans/erosion-commission-report.html.

MA CEC. 2015b. Draft Volume 2 – Working Group Reports. Massachusetts Executive Office of Energy and Environmental Affairs. Boston, MA. 77 p. Available at http://www.mass.gov/eea/waste-mgnt-recycling/coasts-and-oceans/erosion-commission-report.html.

Massachusetts Department of Conservation and Recreation (MA DCR). 2009. Massachusetts Coastal Infrastructure Inventory and Assessment Project. MA DCR Office of Waterways, Coastal Hazard Commission. Boston, MA. 76 p.

Massachusetts Division of Fisheries and Wildlife (MDFW). 2006. Massachusetts Comprehensive Wildlife Conservation Strategy. Commonwealth of Massachusetts, Department of Fish and Game, Executive Office of Environmental Affairs. Boston, MA. 791 p.

Massachusetts Office of Coastal Zone Management (MA CZM), Executive Office of Energy and Environmental Affairs. 2015a. Coast Guide Online. Available at http://www.mass.gov/eea/agencies/czm/program-areas/public-access-and-coast-guide/coast-guide/coast-guide-online.html.

MA CZM. 2015b. Massachusetts Open Resource Information System (MORIS): CZM's Online Mapping Tool. Available at http://www.mass.gov/eea/agencies/czm/program-areas/mapping-and-data-management/moris/.

McCormick, L.R., O.H. Pilkey, Jr., W.J. Neal, and O.H. Pilkey, Sr. 1984. *Living with Long Island's South Shore*. Durham, NC: Duke University Press. 157 p.

Morgan, M. J., N. C. Kraus, and J. M. McDonald. 2005. Geomorphic analysis of Mattituck Inlet and Goldsmith Inlet, Long Island, New York, ERDC/CHL TR-05-2. U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Motavalli, J. 2012. Pleasure Beach: A Place for Birds and People. *Audubon* 114(March-April). Available at http://www.audubon.org/magazine/march-april-2012/pleasure-beach-place-birds-and-people.

Nantucket Conservation Foundation (NCF). 2015. Properties – Interactive Online Map. Available at https://www.nantucketconservation.org/property-map/.

Nantucket County. 2015. MapGeo – Town and County of Nantucket. Online Mapping Tool. Available at http://www.mapgeo.com/NantucketMA/.

New Hampshire Fish and Game Department (NHFG). 2006. New Hampshire Wildlife Action Plan. Concord, NH. Various paginations + appendices. Available at http://www.wildlife.state.nh.us/Wildlife/wildlife_plan.htm.

New Hampshire GRANIT. 2015. Online Mapping Tool - GRANIT View II v. 0. New Hampshire Statewide GIS Clearinghouse. Available at http://granitviewii.unh.edu/.

New York Department of Environmental Conservation (NYDEC). 2005. New York State Comprehensive Wildlife Conservation Strategy – A Strategy for Conserving New York's Fish and Wildlife Resources. Albany, NY. 572 p. + appendices.

New York Office of Parks, Recreation and Historic Preservation (NY OPRHP). 2010. Final Master Plan and Final Environmental Impact Statement for Hallock State Park Preserve. Albany, NY. Various paginations. Available at http://nysparks.com/inside-our-agency/master-plans.aspx.

Nordstrom, K.F., and N.L. Jackson. 2013. Removing shore protection structures to facilitate migration of landforms and habitats on the bayside of a barrier spit. *Geormorphology* 199(October 2013):179-191.

O'Connell, J.F., and S.P. Leatherman. 1999. Coastal erosion hazards and mapping along the Massachusetts Shore. *Journal of Coastal Research*, Special Issue No. 28, pp. 27-33.

O'Connor, J.S. 1973. Dredging and Spoiling on Long Island. Marine Sciences Research Center, State University of New York Technical Report Series # 19. MSRC-TR19. Stony Brook, NY. 34 p.

Patton, P.C., and J.M. Kent. 1992. *A Moveable Shore: The Fate of the Connecticut Coast*. Durham, NC: Duke University Press. 143 p.

Peconic Baykeeper. 2006. Baywatch: Long Island's Bay Health Report – 2006. Quogue, NY. 8 p.

Peconic Estuary Program (PEP). 2004. Peconic Estuary Program Critical Lands Protection Plan. Yaphank, NY. 61 p. Available at http://www.peconicestuary.org/reports.php. Accessed January 8, 2015.

Peterson, C. H., and M. J. Bishop. 2005. Assessing the environmental impacts of beach nourishment. *Bioscience* 55(10):887-896.

Peterson, C. H., D. H. M. Hickerson, and G. G. Johnson. 2000. Short-term consequences of nourishment and bulldozing on the dominant large invertebrates of the sandy beach. *Journal of Coastal Research* 16(2):368-378.

Pilkey, O.H., and J.A.G. Cooper. 2014. *The Last Beach*. Durham, NC: Duke University Press. 237 p.

Pilkey, O.H., and H.L. Wright III. 1988. Seawalls versus beaches. *Journal of Coastal Research*, Special Issue No. 4, pp. 41-64.

Pilkey, O. H., and R. Young. 2009. *The Rising Sea*. Washington, D.C.: Island Press. 203 p.

Program for the Study of Developed Shorelines (PSDS). 2015. Beach Nourishment Viewer. Available at http:// http://beachnourishment.wcu.edu. Last accessed April 13, 2015.

Rankin, K.L., M.S. Bruno, and T.O. Herrington. 2004. Nearshore currents and sediment transport measured at notched groins. *Journal of Coastal Research*, Special Issue No. 33, pp. 237-254.

Rhode Island Division of Fish and Wildlife (RDFW). 2005. Rhode Island's Comprehensive Wildlife Conservation Strategy. Rhode Island Department of Environmental Management. Wakefield, RI. 357 p.

Rhode Island Geographic Information System (RIGIS). 2015. Rhode Island Geographic Information System Geospatial Data Catalog. Available at http://www.edc.uri.edu/rigis/.

Rice, T. M. 2009. Best management practices for shoreline stabilization to avoid and minimize adverse environmental impacts. Prepared for the USFWS, Panama City Ecological Services Field Office. Terwilliger Consulting, Inc., Locustville, Virginia. 21 p.

Rice, T. M. 2012a. Inventory of habitat modifications to tidal inlets in the continental U.S. coastal migration and wintering range of the piping plover (*Charadrius melodus*). Appendix 1b *in* Comprehensive Conservation Strategy for the Piping Plover (*Charadrius melodus*) in its Coastal Migration and Wintering Range in the Continental United States, U.S. Fish and Wildlife Service, East Lansing, Michigan. 30 p.

Rice, T. M. 2012b. The Status of Sandy, Oceanfront Beach Habitat in the Continental U.S. Coastal Migration and Wintering Range of the Piping Plover (*Charadrius melodus*). Appendix 1c *in* Comprehensive Conservation Strategy for the Piping Plover (*Charadrius melodus*) in its Coastal Migration and Wintering Range in the Continental United States, U.S. Fish and Wildlife Service, East Lansing, Michigan. 36 p.

Rice, T.M. 2014. Inventory of Habitat Modifications to Tidal Inlets in the U.S. Atlantic Coast Breeding Range of the Piping Plover (*Charadrius melodus*) prior to Hurricane Sandy: South Shore of Long Island to Virginia. Report submitted to the U.S. Fish and Wildlife Service, Hadley, Massachusetts. 25 p.

Rice, T.M. 2015a. Inventory of Habitat Modifications to Sandy Oceanfront Beaches in the U.S. Atlantic Coast Breeding Range of the Piping Plover (*Charadrius melodus*) prior to Hurricane Sandy: South Shore of Long Island to Virginia. Report submitted to the U.S. Fish and Wildlife Service, Hadley, Massachusetts. 47 p.

Rice, T.M. 2015b. Inventory of Habitat Modifications to Tidal Inlets in the U.S. Atlantic Coast Breeding Range of the Piping Plover (*Charadrius melodus*) prior to Hurricane Sandy: Maine to the North Shore of Long Island. Report submitted to the U.S. Fish and Wildlife Service, Hadley, Massachusetts. 58 p.

Rosen, P.S., and D.M. FitzGerald. 2014. Morphology and coastal processes along Duxbury Beach, Duxbury, Massachusetts. 2014 Report. Report submitted to Duxbury Beach Reservation. 88 p. Available at http://www.duxburybeach.com/Techcomm.htm.

Schupp, C.A., and A. Coburn. 2015. Inventory of Coastal Engineering Projects in Assateague Island National Seashore. Natural Resources Technical Report NPS/NRPC/GRD/NRTR-2015/914. National Park Service, Fort Collins, Colorado. 56 p.

Slovinsky, P.A. 2005. Coastal Processes and Beach Erosion: The Saco Bay Shoreline. Maine Geological Survey. Augusta, ME. 44 p.

Slovinsky, P.A. 2006. Beach nourishment at Western Beach, Scarborough, Maine: Benefits for the Beaches and the Birds. Geologic Site of the Month – June 2006. Maine Geological Survey. Augusta, ME. 26 p.

Slovinsky, P.A., and S.M. Dickson. 2003. Variation of beach morphology along the Saco Bay littoral cell: An analysis of recent trends and management alternatives. Maine Geological Survey Open-File Report 03-78. Augusta, ME. 64 p.

Suffolk County Planning Department. 1985. Analysis of dredging and spoil disposal activity by Suffolk County, County of Suffolk, New York: Historical perspective and a look to the future. Suffolk County Planning Department, Hauppauge, NY. 85 p.

Tanski, J. 2012. *Long Island's Dynamic South Shore – A Primer on the Forces and Trends Shaping Our Coast*. New York Sea Grant Extension Program. 28 p.

Terchunian, A.V. 1988. Permitting coastal armoring structures: Can seawalls and beaches coexist? *Journal of Coastal Research*, Special Issue No. 4, pp. 65-75.

Town of East Hampton. 1999. Town of East Hampton Local Waterfront Revitalization Program. As adopted December 3, 1999, by the Town of East Hampton, approved by New York State Secretary of State December 20, 2007, and concurred by US Office of Ocean and Coastal Resources Management August 26, 2008. East Hampton, NY. 879 p. Available at http://docs.dos.ny.gov/communitieswaterfronts/LWRP/East%20Hampton_T/Index.html.

Town of Southold. 2011. Town of Southold Local Waterfront Revitalization Program, as amended. Southold, NY. 1,017 p. Available at http://docs.dos.ny.gov/communitieswaterfronts/LWRP/Southold_T/Index.html.

Town of Southold. 2012. Sound View Dunes Park Stewardship Management Plan. Southold, NY. 36 p.

Trembanis, A. C., H. R. Valverde, and O. H. Pilkey. 1998. Comparison of beach nourishment along the U.S. Atlantic, Great Lakes, Gulf of Mexico and New England shorelines. *Journal of Coastal Research*, Special Issue No. 26, pp. 246-251.

U.S. Army Corps of Engineers (USACE). 1996. Department of the Army Permit No. 199600817 to the Massachusetts Highway Department, Interim Shore Protection Project, Oak Bluffs / Edgartown. New England District, U.S. Army Corps of Engineers, Concord, MA. 6 p.

USACE. 2002. Coastal Engineering Manual. Manual No. EM 1110-2-1100. U.S. Army Corps of Engineers, Washington D.C. Various paginations in 6 volumes. Available at http://www.publications.usace.army.mil/USACEPublications/EngineerManuals/tabid/16439/u43544q/436F617374616C20456E67696E656572696E67204D616E75616C/Default.aspx.

USACE. 2008. Ninigret and Cross Mills Ponds Habitat Restoration Project, Charlestown, Rhode Island. Operations and Maintenance Manual. New England District, U.S. Army Corps of Engineers, Concord, MA. 32 p.

USACE. 2012. Application for dredging with ten years maintenance with beach nourishment. Dickerson Creek, Shelter Island, Suffolk County, New York. Public Notice No. NAN-2011-01446-EST. February 29, 2012. New York District, U.S. Army Corps of Engineers. 11 p.

USACE. 2013a. 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. 2013b. 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. 2013c. New England District FY 2009 – 2013 Dredging Program. New England District, Concord, MA. 9 p.

USACE. 2013d. Camp Ellis Beach, Saco, Maine, Shore Damage Mitigation Project. *Public Draft* Environmental Assessment and Clean Water Act Section 404(B)(1) Analysis. New England District, Concord, MA. 144p.

USACE. 2013e. Maintenance Dredging of the Federal Navigation Project in Hyannis Harbor, Hyannis, Massachusetts. 30 Day Public Notice, April 2, 2013. New England District, U.S. Army Corps of Engineers, Concord, MA. 7 p.

USACE. 2013f. Maintenance Dredging of the Federal Navigation Project in the Scaborough River, Scarborough, Maine. 30 Day Public Notice, May 20, 2013. New England District, U.S. Army Corps of Engineers, Concord, MA. 6 p.

USACE. 2013g. National Grid Generation, LLC, Northport Power Plant, Permit Application for Maintenance Dredging and Beach Nourishment. Public Notice Number NAN-2013-00163-EHA, dated July 22, 2013. New York District, U.S. Army Corps of Engineers, New York, NY. 10 p.

USACE. 2013h. 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. 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. 2014b. 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. 2014c. 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. 2014d. Application for Maintenance Dredging and Beach Nourishment of Several Sites in the Town of Edgartown, Massachusetts. Revised Public Notice NAE-2011-1511, May 27, 2014. New England District, U.S. Army Corps of Engineers, Concord, MA. 11 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. 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. 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.

U.S. Department of the Interior (US DOI). 2015. Long Beach West Restoration Project. Environmental Achievement Awards - 2011. Southern New England – New York Bight Coastal Program, U.S. Fish and Wildlife Service, Rhode Island. Available at http://www.doi.gov/greening/awards/2011/lbwrp.cfm.

U.S. Fish and Wildlife Service (USFWS). 1996. Piping Plover (*Charadrius melodus*) Atlantic Coast Population Revised Recovery Plan. Hadley, MA. 236 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. 2006. Long Island National Wildlife Refuge Complex Comprehensive Conservation Plan and Environmental Assessment. Hadley, MA. Various paginations + appendices.

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

USFWS. 2009. Piping plover (*Charadrius melodus*) 5-year review: summary and evaluation. Northeast Region, Hadley, Massachusetts. 206 pp.

USFWS. 2010. Rising to the urgent challenge: Strategic plan for responding to accelerating climate change. Washington, D.C. 32 pp.

USFWS. 2012. Comprehensive Conservation Strategy for the Piping Plover (*Charadrius melodus*) in its Coastal Migration and Wintering Range. U.S. Fish and Wildlife Service. Hadley, MA. 125 p. + appendices.

USFWS. 2013. Nantucket National Wildlife Refuge Comprehensive Conservation Plan. Sudbury, MA. 438 p.

USFWS. 2014. 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.

Ward, L.G., P.S. Rosen, W.J. Neal, O.H. Pilkey, Jr., O.H. Pilkey, Sr., G.L. Anderson, and S.J. Howie. 1989. *Living with Chesapeake Bay and Virginia's Ocean Shores*. Durham, NC: Duke University Press. 236 p.

Williams, S. J., and B. Gutierrez. 2009. Sea-level rise and coastal change: Causes and implications for the future of coasts and low-lying regions. *Shore and Beach* 77(4):13-21.

Wines, R. 2008. The History of Hallockville: The Museum Farm, the Neighborhood and the Surrounding Land Including Jamesport State Park. Available at http://www.hallockville.com/hallockville-history/#riverhead-harbor. Accessed June 15, 2015.

Woods Hole Group and Aubrey Consulting, Inc. 2006. Saco River and Camp Ellis Beach Section 111 Project. Final Draft Report. Prepared for the U.S. Army Corps of Engineers, New England District. Rayham, MA. 253 p.

Appendix A

Table A-1. The 57 coastal communities in Massachusetts and the county in which each is located. The communities are listed from north to south, progressing clockwise around Cape Cod. Note that Cohasset in Norfolk County is inset within Plymouth County and Plymouth County contains coastline both north and south of Cape Cod and is separated accordingly.

Community	County
Salisbury	Essex
Newburyport	Essex
Newbury	Essex
Rowley	Essex
Ipswich	Essex
Gloucester	Essex
Rockport	Essex
Manchester	Essex
Beverly	Essex
Salem	Essex
Marblehead	Essex
Swampscott	Essex
Lynn	Essex
Nahant	Essex
Revere	Suffolk
Winthrop	Suffolk
Boston	Suffolk
Quincy	Norfolk
Weymouth	Norfolk
Hingham	Plymouth
Hull	Plymouth
Cohasset	Norfolk
Scituate	Plymouth
Marshfield	Plymouth
Duxbury	Plymouth
Kingston	Plymouth
Plymouth	Plymouth
Sandwich	Barnstable
Barnstable	Barnstable
Yarmouth	Barnstable
Dennis	Barnstable
Brewster	Barnstable
Orleans	Barnstable
Eastham	Barnstable
Wellfleet	Barnstable
Truro	Barnstable

Community	County
Provincetown	Barnstable
Chatham[21]	Barnstable
Harwich	Barnstable
Mashpee[22]	Barnstable
Falmouth	Barnstable
Bourne	Barnstable
Marion	Plymouth
Wareham	Plymouth
Mattapoisett	Plymouth
Fairhaven	Bristol
New Bedford	Bristol
Dartmouth	Bristol
Westport	Bristol
Gosnold[23]	Dukes
Oak Bluffs	Dukes
Edgartown	Dukes
West Tisbury	Dukes
Chilmark	Dukes
Aquinnah[24]	Dukes
Tisbury	Dukes
Nantucket	Nantucket

[21] Note that Truro, Wellfleet, Eastham and Orleans each have coastlines on both Cape Cod Bay in the west and the Atlantic Ocean in the east, the latter of which covers the coastline between Provincetown and Chatham.
[22] Note that Dennis, Yarmouth and Barnstable each have coastlines on both Cape Cod Bay in the north and Nantucket Sound in the south, the latter of which covers the coastline between Chatham and Mashpee.
[23] Gosnold contains the Elizabeth Islands, including Cuttyhunk Island. The other communities within Dukes County are on Martha's Vineyard.
[24] Note that West Tisbury and Chilmark cross all of the island of Martha's Vineyard and has coastline along Vineyard Sound in the north and the Atlantic Ocean in the south, the former of which covers the coastline between Aquinnah and Tisbury.

Table A-2. Sandy oceanfront beaches that are in public or NGO ownership in Massachusetts, the county in which each is located, and approximate length of sandy beach in each visible in Google Earth imagery from March 2012 prior to Hurricane Sandy. Note that a number of sandy beach parcels that have been conserved on Nantucket that are less than 500 ft (152.4 m) in length are excluded here (Sources: See Table 1).

Public / NGO Land	County Location	Approximate Beach Length in Miles
Salisbury Beach State Reservation	Essex	3.49
Plum Island Beach (The Point)	Essex	0.28
Parker River NWR	Essex	6.17
Sandy Point State Reservation	Essex	0.73
Crane Estate	Essex	4.01
Wingaersheek Beach	Essex	0.63
Cape Hedge Beach	Essex	0.38
Good Harbor Beach	Essex	0.43
White Beach	Essex	0.14
West Beach	Essex	0.14
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	0.25
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	1.04
Yerrill Beach	Suffolk	0.84
Long Island, Boston Harbors NRA	Suffolk	2.80
Rainsford Island, Boston Harbors NRA	Suffolk	0.68
Nantasket Beach Reservation	Plymouth	1.26
Sandy Beach	Norfolk	0.22
Sandy Cove Beach	Norfolk	0.16
Bassing Beach	Plymouth	0.52
Egypt Beach	Plymouth	0.22
Conservation Park	Plymouth	0.68
Rexhame Beach	Plymouth	0.64

Public / NGO Land	County Location	Approximate Beach Length in Miles
Green Harbor Beach	Plymouth	0.07
Duxbury Beach	Plymouth	3.86
Plymouth Long Beach	Plymouth	3.09
White Horse Beach	Plymouth	0.15
Manomet Beach	Plymouth	0.16
Ellisville Harbor State Park	Plymouth	0.22
Shifting Lots Preserve	Plymouth	0.37
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	0.83
Sandy Neck	Barnstable	6.1
Chapin 4x4 Beach	Barnstable	0.73
Chapin Memorial Beach	Barnstable	0.41
Mayflower Beach	Barnstable	0.26
Corporation Beach	Barnstable	0.19
Cold Storage Beach	Barnstable	0.17
Sea Street East Beach	Barnstable	0.11
Crowes Beach	Barnstable	0.64
Wing Island Beach	Barnstable	0.51
Paines Creek Beach	Barnstable	0.29
Breakwater Landing Beach	Barnstable	0.06
Cape Cod Sea Camps Bay Beach	Barnstable	0.22
Spruce Hill Beach	Barnstable	0.12
Nickerson State Park	Barnstable	0.79
Skacket Beach Condos Beach	Barnstable	0.11
Skacket Beach	Barnstable	0.17
Rock Harbor Beach	Barnstable	0.09
Dyer Prince Beach	Barnstable	0.18
Boat Meadow Beach	Barnstable	0.14
First Encounter Beach	Barnstable	0.54
Saltworks Association & Sunken Meadow Beaches	Barnstable	0.06
Wellfleet Bay Wildlife Sanctuary	Barnstable	0.50
Fox Island Salt Marsh	Barnstable	0.27
Indian Neck Beach	Barnstable	0.24
Mayo (Kendrick) Beach	Barnstable	0.22
Cape Cod National Seashore	Barnstable	55.59

Public / NGO Land	County Location	Approximate Beach Length in Miles
Corn Hill Beach	Barnstable	0.13
Pilgrim Beach	Barnstable	0.28
Monomoy NWR	Barnstable	13.59
Hardings Beach	Barnstable	1.27
Ridgevale Beach	Barnstable	0.34
Forest Street Beach	Barnstable	0.51
Pleasant Street Beach	Barnstable	0.04
Red River Beach	Barnstable	0.18
Merkel Beach (Snow Inn Road)	Barnstable	0.32
Allen Harbor Beach	Barnstable	0.16
Pleasant Road Beach	Barnstable	0.09
Sea Street Beach	Barnstable	0.10
West Dennis Beach	Barnstable	1.22
Bass River Beach	Barnstable	0.15
Parkers River Beach (East & West)	Barnstable	0.09
Seagull (Center) Beach	Barnstable	0.28
Great Island Easement (Yarmouth)	Barnstable	1.56
Kalmas Ocean Beach	Barnstable	0.46
Keyes Beach	Barnstable	0.19
East (Town) Beach	Barnstable	0.12
Covell's Beach	Barnstable	0.12
Craigville Beach	Barnstable	0.23
Dowses Beach	Barnstable	0.46
Dead Neck Island	Barnstable	1.34
Sampson Island	Barnstable	0.45
Poponesset Spit Beach	Barnstable	0.89
Poponesset Beach	Barnstable	0.11
Waquoit Bay NERR (South Cape Beach State Park)	Barnstable	1.42
South Cape Beach	Barnstable	0.26
Waquoit Bay NERR (Washburn Island)	Barnstable	0.87
Menauhant Beach	Barnstable	0.42
Acapesket Improvement Association Beach	Barnstable	0.22
Bristol 1 Beach	Barnstable	0.23
Bristol 2 Beach	Barnstable	0.16
Falmouth Heights Beach	Barnstable	0.28
No Name Beach	Barnstable	0.09
Surf Drive Beach	Barnstable	0.32

Public / NGO Land	County Location	Approximate Beach Length in Miles
Mill Road Beach	Barnstable	0.12
Nobska Beach Association Beach	Barnstable	0.19
Stoney Beach (MBL)	Barnstable	0.04
Sippewissett Beach Trust Beach	Barnstable	0.11
Wood Neck Beach	Barnstable	0.11
Chapoquoit Beach	Barnstable	0.35
Little Island Beach Preserve	Barnstable	0.13
Jetty Lane Beach	Barnstable	0.15
Old Silver 2 Beach	Barnstable	0.24
Megansett Beach	Barnstable	0.09
Wings Neck Trust Association North Beach	Barnstable	0.16
Tahanto Associates, Inc., Beach	Barnstable	0.10
Monument Beach	Barnstable	0.22
Mashnee Island Dike	Barnstable	1.84
Stony Point Dike	Plymouth	0.73
Little Harbor Beach	Plymouth	0.40
Swift's Neck Beach	Plymouth	0.19
Piney Point Beach	Plymouth	0.20
Planting Island Beach	Plymouth	0.18
Silver Shell Beach	Plymouth	0.13
unnamed Town beach off Aucoot Road (Mattapoisett)	Plymouth	0.11
Hollywoods Beach	Plymouth	0.09
Peases Point Beach	Plymouth	0.10
Bay Road Beach	Plymouth	0.07
Land Trust Reservation Beach	Plymouth	0.55
Antasawomak Beach	Plymouth	0.45
Mattapoisett Land Trust Beach	Plymouth	0.14
Leisure Shores Beach	Plymouth	0.07
Howard Beach	Plymouth	0.04
Nasketucket Bay State Reservation	Plymouth	0.65
West Island State Reservation	Bristol	1.57
West Island Town Beach	Bristol	0.99
Winseganett Beaches	Bristol	0.88
Manhattan Avenue Beach	Bristol	0.09
Fort Phoneix State Reservation	Bristol	0.35
O'Tools Extension, O'Tools, Tower 1-4 Beaches	Bristol	0.35
Tabor Beaches	Bristol	0.28

Public / NGO Land	County Location	Approximate Beach Length in Miles
J Beach, 400 North and Kids Beaches	Bristol	0.30
Jones Town Beach	Bristol	0.10
Nonquitt Beach	Bristol	0.40
Round Hill Condos Beach	Bristol	0.20
Round Hill Beach	Bristol	0.42
Salter's Point South Beach	Bristol	0.22
Mishaum Beach	Bristol	0.10
Demarest Lloyd State Park	Bristol	0.87
Barney's Joy Beach	Bristol	0.92
East Beach	Bristol	0.27
Horseneck Beach State Reservation	Bristol	3.59
Baker's Beach	Bristol	1.10
Beach Avenue Beach	Bristol	0.35
Elephant Beach	Bristol	0.41
C & K Club Beach	Bristol	0.36
Coatue Preserve	Nantucket	3.62
Coskata - Coatue Wildlife Refuge	Nantucket	8.72
Nantucket NWR	Nantucket	0.58
The Haulover	Nantucket	0.46
Squam Pond	Nantucket	0.08
Sesechacha Heathlands Wildlife Sanctuary	Nantucket	0.25
Sankaty Beach tract (off Butterfly Lane)	Nantucket	0.14
Low Beach tracts	Nantucket	0.48
USCG LORAN Station	Nantucket	0.53
Tom Nevers Beach	Nantucket	0.44
Wanoma Way beach tracts	Nantucket	0.35
Tom Nevers Road beach	Nantucket	0.19
South Shore beach tract	Nantucket	0.10
Madequecham & Tom Nevers Preserve	Nantucket	1.27
Surfside Beach	Nantucket	0.14
Surfside 2 Beach	Nantucket	0.26
Miacoment & Sewerbeds Beaches	Nantucket	0.96
Smooth Hummocks beach	Nantucket	0.28
Mioxes Pond breach tracts	Nantucket	0.32
Reedy Pond beach tracts	Nantucket	0.36
Cisco Beach	Nantucket	0.49
Sanford Farm & Ram Pasture	Nantucket	1.06

Public / NGO Land	County Location	Approximate Beach Length in Miles
Head of the Plains	Nantucket	0.30
Smith Point / Esther Island	Nantucket	1.52
Little Neck tract	Nantucket	0.08
Warren's Landing tract	Nantucket	0.12
Warren's Landing Beach	Nantucket	0.19
Eel Point Preserve	Nantucket	1.19
Eel Point Road tracts	Nantucket	0.12
40th Pole 2 Beach	Nantucket	0.10
Dionis Beach	Nantucket	0.18
Capaum Pond Beach	Nantucket	0.16
Washing Pond Beach	Nantucket	0.04
Muskeget Island	Nantucket	2.58
Cape Poge Wildlife Refuge (East Beach)	Dukes	5.47
Cape Poge Light	Dukes	0.09
Leland Beach	Dukes	1.49
Wasque Point	Dukes	0.68
Norton Point Beach	Dukes	2.38
South (Katama) Beach	Dukes	0.97
Long Point Wildlife Refuge	Dukes	1.19
Lucy Vincent Beach	Dukes	0.66
Squibnocket Beach	Dukes	0.76
Squibnocket Pond	Dukes	0.93
Moshup Trail tracts	Dukes	0.15
Moshup Beach	Dukes	1.88
Lobsterville Beach	Dukes	1.75
Menemsha Beach	Dukes	0.23
Menemsha Hills Reservation	Dukes	0.82
Great Rock Bight	Dukes	0.20
Cedar Tree Neck Sanctuary	Dukes	0.85
Lambert's Cove Beach	Dukes	0.45
Mink Meadows beach	Dukes	0.32
Eastville Point Beach	Dukes	0.18
Yacht Club beach	Dukes	0.11
Marinelli's Beach	Dukes	0.06
Pay Beach	Dukes	0.27
Joseph Sylvia State Beach	Dukes	1.82
Little Beach	Dukes	1.00

Public / NGO Land	County Location	Approximate Beach Length in Miles
Gosnold WMA (Cuttyhunk Island)	Dukes	0.12
Noman's Land Island NWR	Dukes	2.83
	TOTAL	**217.49**

Table A-3. Public and semi-public beaches in Massachusetts, from north to south, where private property is immediately adjacent to the beach.

Location	County	Approximate Length of Sandy Beach (miles)
Back Beach	Essex	0.19
Front Beach	Essex	0.13
Pebble Beach	Essex	0.23
Long Beach	Essex	0.61
Magnolia Beach	Essex	0.42
Black Beach	Essex	0.31
Singing Beach	Essex	0.46
Mingo Beach	Essex	0.10
Tudor Beach	Essex	0.22
XYZ Beach	Plymouth	0.77
A Street Ocean Beach	Plymouth	0.77
Kenburma Beach	Plymouth	0.41
Whitehead Beach	Plymouth	0.23
Gunrock Beach	Plymouth	0.17
Minot Beach	Plymouth	0.51
Sand Hills Beach	Plymouth	0.15
Peggotty Beach	Plymouth	0.14
Humarock Beach	Plymouth	2.63
Fieldston Beach	Plymouth	1.20
Brant Rock Beach	Plymouth	0.33
Sagamore Beach	Barnstable	1.38
East Sandwich Beach	Barnstable	0.91
Longhill Beach	Barnstable	0.10
Carltow Beach	Barnstable	0.12
Brewster Park Sunhouse Beach	Barnstable	0.11
Sears Point Beach	Barnstable	0.12
King's Grant Beach	Barnstable	0.08
Pilgrim Pine Acres Beach	Barnstable	0.10
Sea Pines Beach	Barnstable	0.15
Ocean Edge Beach	Barnstable	0.18
Quail Acres Beach	Barnstable	0.05
Bay View Road Beach	Barnstable	0.32
Dunes Association & Cranberry Cottages Beaches	Barnstable	0.21
Town Landing Beach	Barnstable	0.08

Location	County	Approximate Length of Sandy Beach (miles)
Seasurf Beach	Barnstable	0.11
Day's Cottages Beach	Barnstable	0.16
Town Landing - Breakwater Beach	Barnstable	0.27
637 Commercial Street Beach	Barnstable	0.23
Kendal Lane Beach	Barnstable	0.09
333 Commercial Street Beach	Barnstable	0.09
Ryder Street Beach	Barnstable	0.10
29 Commercial Street Beach	Barnstable	0.17
Tides Motel Beach	Barnstable	0.07
Atlantic Avenue, Zylpha & Wyndmere Bluffs Beaches	Barnstable	0.14
Old Mill Point Association Beach	Barnstable	0.40
South Village Beach	Barnstable	0.10
Great Island Ocean Club Beach	Barnstable	0.26
West Hyannipsort Beach Association Beach	Barnstable	0.56
915 Craigville Road Beach	Barnstable	0.11
Craigville Beach Club Beach	Barnstable	0.06
New Seabury Inn Beach	Barnstable	0.42
Maushup Village	Barnstable	0.14
Yacht Club & Tides Hotel Beaches	Barnstable	0.11
FBBC & Falmouth Associates - 564 Surf Drive Beaches	Barnstable	0.39
Bikepath Beach	Barnstable	0.48
Fay Road Beach	Barnstable	0.11
Valley Road Beach	Barnstable	0.37
Seacoast Shores Associates, Inc. Beach	Barnstable	0.09
Saconessett Hills Association	Barnstable	0.14
Chapoquoit Associates - Front Beach	Barnstable	0.19
Seaquest Motel Beach	Barnstable	0.17
Old Silver 1 Beach	Barnstable	0.15
Bayshore Homeowners Association Beahc	Barnstable	0.53
Wild Harbor Beach	Barnstable	0.16
New Silver Beach (Silver Beach Improvement Association)	Barnstable	0.21
Swift's Beach	Plymouth	0.13
Crescent Beach	Plymouth	0.20
Mattapoisett Shores Association Beach	Plymouth	0.17
Brant Beach	Plymouth	0.31

Location	County	Approximate Length of Sandy Beach (miles)
Anthony's Beach	Bristol	0.16
Chappy Beach Club beach	Dukes	0.12
	TOTAL	**21.56**

Table A-4. Sediment placement projects in Massachusetts, from north to south, constructed prior to 1961 lacking project details such as precise location, project lengths and sediment volumes (Haddad and Pilkey 1998). No additional reports of sediment placement activities on these beaches since 1961 were located during this assessment.

Location
Wingersheek Beach, Gloucester
Singing Beach, Manchester
Dane Street Beach, Beverly
Salem Willows, Salem
Palmers Cove, Salem
Collins Cove, Salem
Forrest Beach Park, Salem (now may be Forest River Park)
Fisherman's Beach, Swampscott
between First and Second Cliff, Scituate
Brant Rock, Marshfield
West Dennis Beach, Dennis
South Yarmouth Beach, Yarmouth
east and west of Parker's River, Yarmouth
Kalmus Park Beach, Barnstable
Maganset Beach, Falmouth
Wild Harbor, Falmouth
Pocasset Beach, Bourne
Monument Beach, Bourne
Little Harbor, Wareham
Long Beach, Wareham
Parkwood Beach, Wareham
Pinehurst Beach, Wareham
Hamilton Beach, Wareham
Swift Beach, Wareham
Silver Shell Beach, Marion
Water Street Beach, Mattapoisett
Pope Beach, Fairhaven
Children's Beach, Nantucket

Appendix B

Table B-1. The RI CRMC issued permits for at least 69 individual properties from 2000 through September 2012 that involved sediment placement activities on sandy beaches and their dunes. Two of these locations (The Misquamicut Club and the Town of Westerly's Town Beach) had previously been modified by sediment placement activities. Some properties have received multiple permits in that time period. The addresses or locations and the approximate lengths of beach (in feet) modified are listed in alphabetical order by town. Property lengths were obtained using Google Earth and, wherever possible, property boundary data from individual towns. Data provided by Janet Freedman, RI CRMC, May 2015.

Address	Town	Property Width (ft)
760 Charlestown Beach Road	Charlestown	189
Beavertail Road, Town of Jamestown	Jamestown	700
1 Atlantic Drive	Little Compton	21
100 Shaw Road	Little Compton	185
South Shore Beach, Town of Little Compton	Little Compton	1,440
1105 Succotash Road	Narragansett	50
129 Boston Neck Road	Narragansett	210
175 Bonnet Point Road	Narragansett	1,060
31 Beach Row	Narragansett	140
Beach Row, Kenyon Condo Association	Narragansett	65
81 Stanton Avenue	Narragansett	125
89 Stanton Avenue	Narragansett	115
Boston Neck Road, Town of Narragansett	Narragansett	2,580
34 Ocean Avenue/Baileys Beach	Newport	1,320
590 Ocean Avenue	Newport	290
Ocean Avenue, Hazard's Beach	Newport	700
Matunuck Beach Road, Town of South Kingstown	South Kingstown	1,365
855 Matunuck Beach Road	South Kingstown	100
935A, B & C Matunuck Beach Road	South Kingstown	50
995 Matunuck Beach Road	South Kingstown	50
1001 Matunuck Beach Road	South Kingstown	50
Matunuck Beach Road, The Last Word	South Kingstown	75
1023 Matunuck Beach Rd	South Kingstown	135
Matunuck Beach Road, Narragansett Salt Water Fishing Club	South Kingstown	80
1039 Matunuck Beach Road	South Kingstown	95
Green Hill Ocean Drive, Mautucket by the Sea	South Kingstown	150
142 Green Hill Ocean Drive	South Kingstown	40
146 Green Hill Ocean Drive	South Kingstown	60
150 Green Hill Ocean Road	South Kingstown	45
156 Green Hill Ocean Drive	South Kingstown	55
162 Green Hill Ocean Drive	South Kingstown	50

Address	Town	Property Width (ft)
240 Cards Pond Road	South Kingstown	35
820 Charlestown Beach Road	South Kingstown	130
865 Charlestown Beach Road	South Kingstown	70
872 Charlestown Beach Road	South Kingstown	50
892 Charlestown Beach Road	South Kingstown	55
896 Charlestown Beach Road	South Kingstown	40
902 Charlestown Beach Road	South Kingstown	65
910 Charlestown Beach Road	South Kingstown	85
920 Charlestown Beach Road	South Kingstown	105
926 Charlestown Beach Road	South Kingstown	55
944 Charlestown Beach Road	South Kingstown	100
954 Charlestown Beach Road	South Kingstown	100
980 Charlestown Beach Road	South Kingstown	105
1002 Charlestown Beach Road	South Kingstown	80
1154 Charlestown Beach Road	South Kingstown	835
Atlantic Avenue, The Misquamicut Club	Westerly	3,050
35 Atlantic Avenue	Westerly	70
45 Atlantic Avenue	Westerly	95
77-83, 85, 103, 121, 127 & 129 Atlantic Avenue, Misquamicut Fire District	Westerly	785
89 Atlantic Avenue	Westerly	180
137 Atlantic Avenue	Westerly	120
139 Atlantic Avenue	Westerly	55
141 Atlantic Avenue	Westerly	95
145 Atlantic Avenue	Westerly	95
155 Atlantic Avenue	Westerly	100
159 Atlantic Avenue	Westerly	260
301 Atlantic Avenue	Westerly	80
311 Atlantic Avenue	Westerly	315
337 Atlantic Avenue	Westerly	150
365 Atlantic Avenue, Town of Westerly	Westerly	575
379 Atlantic Avenue	Westerly	50
425 Atlantic Avenue	Westerly	50
439 Atlantic Avenue	Westerly	50
461 Atlantic Avenue	Westerly	50
651 Atlantic Avenue	Westerly	400
665 Atlantic Avenue	Westerly	420
151 Bay Street, Watch Hill Fire District	Westerly	475
Wawaloam Drive, Weekapaug Fire District	Westerly	550
	TOTAL	**21,570 ft (4.09 miles)**