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Case Study: Restoring Beaches and Dunes through the Hurricane Sandy Coastal Resilience Program

Contract # 5359

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Case Study: Restoring Beaches and Dunes through the Hurricane Sandy Coastal Resilience Program

Prepared by Abt Associates, September 2019

Summary

Purpose

This case study forms part of a larger 2019 evaluation of the Hurricane Sandy Coastal Resilience Program (Hurricane Sandy Program) of the U.S. Department of the Interior (DOI) and the National Fish and Wildlife Foundation (NFWF). It provides an analysis of the ecological and community benefits of beach and dune restoration projects.

Scope

We examined 10 projects, encompassing 42 project sites, in the Hurricane Sandy Program portfolio that restored beach or dune habitat to improve wildlife habitat or protect and sustain coastal community resources or activities.

Findings

Key findings identified using archival materials, a survey and interviews of project leads, and peer-reviewed literature include:

- Nearly 11 linear miles and more than 140 acres of beach and dune habitats have been restored through the Hurricane Sandy Program, providing critical habitat for beach-dependent wildlife, including two federally threatened birds [red knot (*Calidris canutus rufa*) and piping plover (*Charadrius melodus*)], and protecting important community resources from coastal storm surge-related flooding and erosion.
- Nine of the 10 projects successfully completed their proposed activities by the time of this evaluation.
- Most projects were delayed relative to their proposed timelines, primarily due to seasonal limitations on restoration work, permitting delays, and the need for additional data collection or design work.
- Completed projects have generally met or exceeded their design objectives (i.e., linear feet or area restored).
- All ecologically focused projects have already observed improved outcomes for critical species in restored areas.
- Community-focused projects that have restored beaches and dunes to protect nearby community resources are functioning as expected, and have withstood recent coastal storms.
- To sustain their protective and ecological benefits, beaches and dunes may need to be re-nourished in the future.
- Generally, projects are recovering as quickly as expected after restoration, but more monitoring is needed to understand long-term outcomes.

Conclusion

Hurricane Sandy Program investments in restoring beaches and dunes are generally on track to improve ecological and community resilience in nearby areas. Early project results show that beach and dune restoration have increased available nesting habitat for the federally threatened piping plover, which can help sustain or increase their populations over time. The federally threatened red knot also appears to be benefiting from restoration-related increases in a key food source used during migration (i.e., horseshoe crab eggs), which may in turn improve survival and reproduction of this species in breeding areas. Early observations also suggest that restored and stabilized beaches and dunes have been resilient to recent storms, and have provided enhanced protection to nearby community resources. However, these observations are preliminary, and additional years of recovery and monitoring data are needed to more fully understand the likely long-term ecological and community benefits of beach and dune restoration actions.

1. Introduction

This case study forms part of a larger 2019 evaluation of the DOI and NFWF Hurricane Sandy Coastal Resilience Program (Hurricane Sandy Program). Between 2013 and 2016, the Hurricane Sandy Program, administered through DOI and NFWF, invested over $302 million to support 160 projects designed to improve the resilience of ecosystems and communities to coastal storms and sea level rise.[1] The program supported a wide array of activities, including aquatic connectivity restoration, marsh restoration, beach and dune restoration, living shoreline creation, community resilience planning, and coastal resilience science to inform decision-making. Each of these activities has a distinct impact on ecosystem and community resilience.

DOI and NFWF drafted the following questions to serve as the focus of the evaluation:

1. To what extent did projects **implement activities** as intended? What factors facilitated or hindered project success?
2. What **key outcomes** were realized for habitat, fish and wildlife, and human communities?
3. Is there evidence that investments in green infrastructure are **cost-effective** compared to gray infrastructure?
4. Did investments in tools and knowledge related to resilience **improve decision-making**?
5. What **information is needed** to better understand the long-term impacts of investments in resilience?

The evaluation includes six case studies, each providing a deeper level of analysis on a subset of the projects.

1.1 Purpose

This case study provides an in-depth analysis of the ecological and community resilience benefits of beach and dune restoration projects that were designed to improve wildlife habitat and/or protect and sustain key community resources or activities. The case study focuses on evaluation questions #1, #2, and #5 (above).

1.2 Scope

The case study examined 10 projects, encompassing 42 project sites, in the Hurricane Sandy Program portfolio that restored beach or dune habitat (see Section 3 for a more detailed description of the portfolio of beach and dune restoration projects and Appendix A for a full list of relevant projects).

1.3 Organization

The remainder of this document is organized as follows:

- Section 2 provides an overview of the methods and information sources used for this case study
- Section 3 provides a detailed overview of the beach and dune restoration projects included in the Hurricane Sandy Program
- Section 4 discusses key case study findings, organized by evaluation question and topic
- Section 5 provides a brief conclusion.

[1] The evaluation covers these 160 projects. In some cases DOI and NFWF reinvested unspent funds in new, additional projects after the December 2016 cutoff date, which are not included in the evaluation.

2. Methods Overview

This case study integrates information from the following information sources:

- Archival materials from Hurricane Sandy Program project files (e.g., proposals, interim and final reports)
- A survey of project leads via a web-based instrument
- Interviews with five project leads (i.e., grant recipients) who led beach and dune restoration projects
- Interviews with NFWF and DOI staff
- Quantitative information provided by project leads in their reports (e.g., miles of habitat restored)
- Literature searches addressing specific contextual issues (e.g., typical lag time between beach restoration activities and key ecological outcomes).

A more detailed description of evaluation methods can be found in Abt Associates (2019).

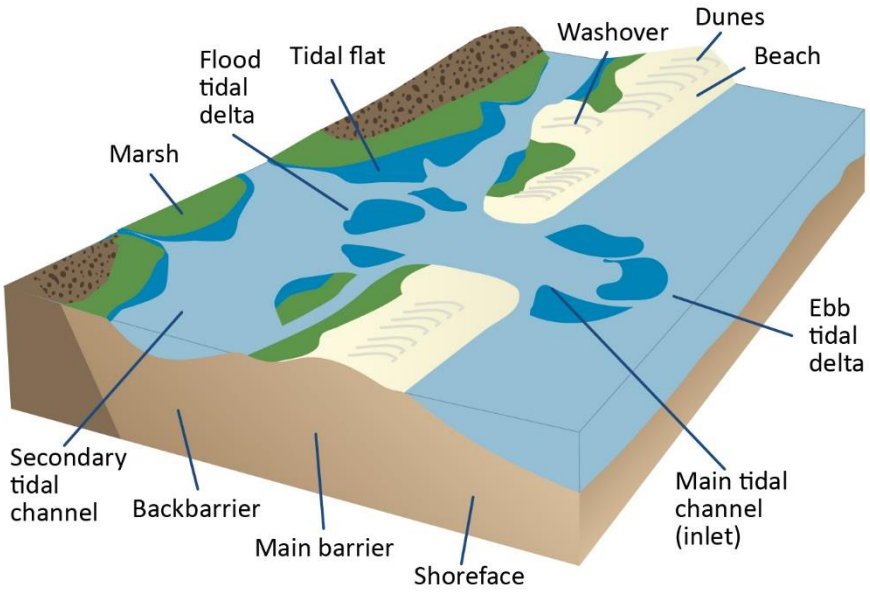
3. Overview of Projects

Beaches and coastal dune systems are critical elements of many coastal environments, and provide numerous benefits to wildlife and people, including:

- Supplying important habitat for aquatic and terrestrial fauna and flora
- Supporting many types of outdoor recreation
- Protecting coastal communities and resources from storm damage by absorbing damaging waves and mitigating storm surge.

Beaches and dunes, particularly those located on barrier islands, are not stable landforms, even in highly pristine natural areas. Rather, they migrate and change shape due to winds, waves, and currents; and changes in sea levels (NC Natural, 2011; Figure 1). For example, ocean currents and waves can stack sand along the shore and landward of the beach to form dunes, and tidal currents can also create deltas near tidal inlets (Wang and Roberts Briggs, 2015). Storms, however, can wash sand over beaches and dunes and into backbarrier areas, and also redistribute sand along the shore or to offshore areas (Wang and Roberts Briggs, 2015). However, when embedded in highly developed coastal areas, the ability of beaches and dunes to migrate can be constrained, and their tendency to do so can put key ecosystems or infrastructure at risk. Thus, increasing the resilience of beaches and dunes to coastal storms can benefit the habitats and coastal communities that depend on these beach and dune systems in their current configurations.

Figure 1. Beaches and dune systems are dynamic and evolving systems that change over time as winds, waves, and storms redistribute sand.



Source: Adapted from Wang and Roberts Briggs, 2015.

Intense coastal storms are a specific key threat to habitat and coastal communities. In fact, multiple beach and dune sites along the Atlantic Coast experienced severe damage from Hurricane Sandy, including erosion and flooding (Box 1). Hurricane Sandy also covered beaches in debris, which interfered with recreational access and horseshoe crab spawning, an important food resource for birds and wildlife. Restoring beaches and dunes can improve coastal resilience by supporting critical coastal habitats and sustaining barriers to storm surge and erosion.

Overall, the Hurricane Sandy Program invested more than $27.8 million in beach and dune restoration in 10 projects (Table A.2), 7 of which also included other resilience activities; the total funding for all of the activities in the 10 projects was $46.2 million.[2] The beach and dune projects were implemented in five states (Delaware, Massachusetts, New Jersey, New York, and Rhode Island; see Figure 2 and Table A.2). These projects typically implemented one or two major types of activities: (1) beach or dune nourishment (i.e., placing sand acquired through dredging on an eroding beach or dune), or (2) hard structure installment (e.g., groins or jetties). Hard structures are built perpendicular to a shoreline and reduce erosion by trapping sand suspended in currents, which promotes beach widening (NOAA, 2000). These two major activities were sometimes paired with others, including planting vegetation or installing fencing, which can improve surface stability, enhance sand accretion, and thus slow beach erosion.

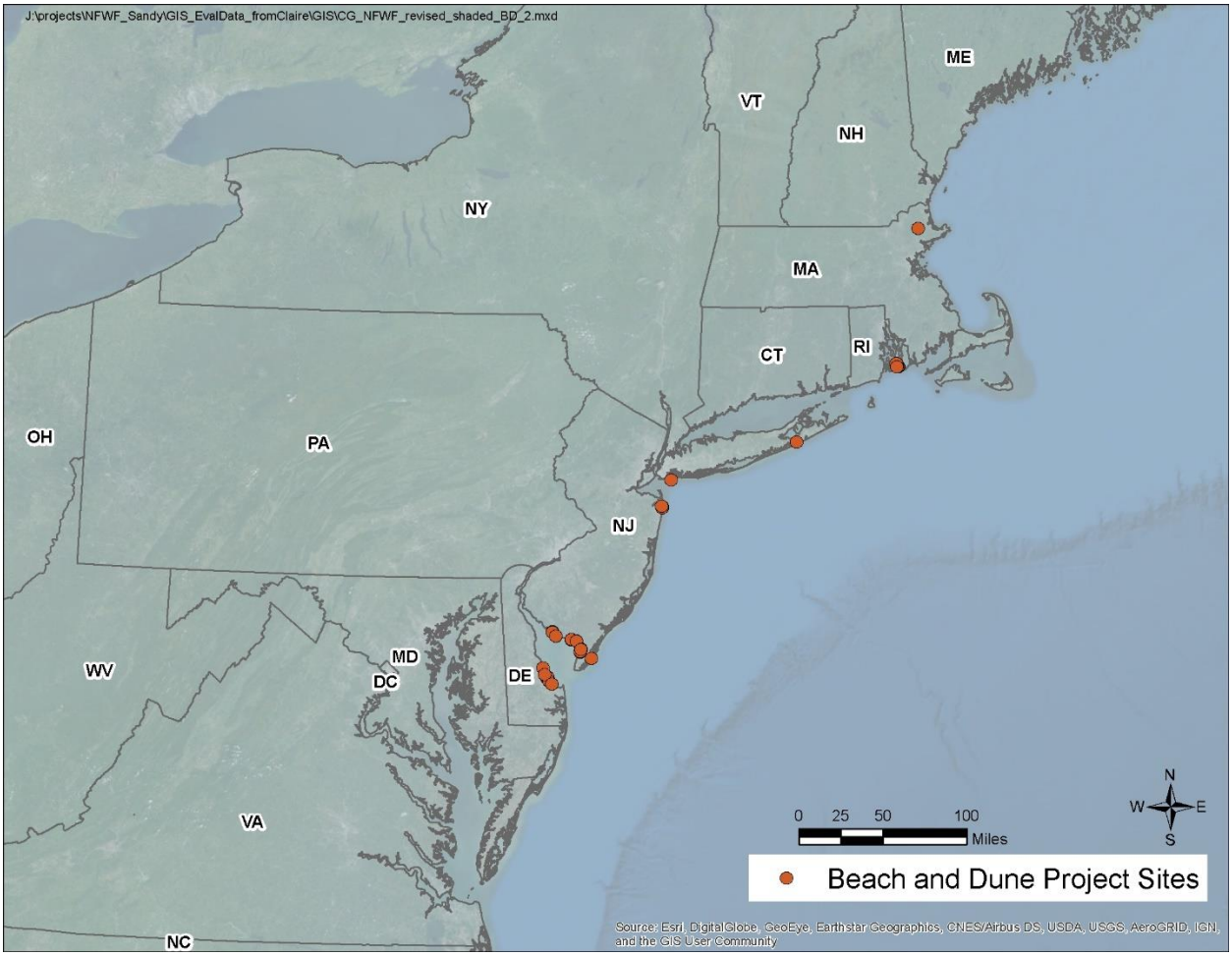
[2] Table A.2 presents the amount of project funding specifically allocated to beach and dune restoration activities. For three projects, this is the full project funding amount; and for seven projects, this is a subset of the total project funding. The allocation was based on available project documentation.

Box 1. Example of Hurricane Sandy damage to beach habitat.

The Borough of Monmouth Beach, NJ, suffered extensive damage from Hurricane Sandy, in part due to prior degradation and loss of nearby beach, dune, and marsh habitats that could have helped protect the borough from storm surge. During Hurricane Sandy, streets were flooded with up to six linear feet of water and approximately 33% of homes were damaged or destroyed. Over $6 million of damage was inflicted on the borough's infrastructure, including sewer and stormwater systems, buildings, and waterfront structures. The Monmouth Beach Elementary School incurred over $2.5 million of damages, and over 300 students were displaced to neighboring schools for almost the entire year.

Source: T&M Associates, 2019.

Figure 2. Location of beach and dune restoration activities.[a]



a. Since some projects conducted restoration activities in multiple sites (see Appendix A), the number of beach and dune projects sites (dots) in the figure exceeds 10.

The 10 projects implemented varied in size, location, cost, purpose, and restoration activities undertaken (Tables A.1 and A.2). However, all of the projects adopted one of two primary goals: habitat restoration or community protection (Box 2; Table A.1).

Box 2. Key beach and dune restoration goals.

Habitat restoration: Projects that restore and create beach or dune habitat, specifically to support horseshoe crabs and migratory shorebirds.

Community protection: Projects that restore beaches or dunes to prevent erosion, enhance shoreline resilience, and mitigate flooding.

Sources: Breese, 2018; project final reports.

4. Findings

Topic: Project Implementation (PI)

Finding PI.1: Nine of the 10 projects successfully completed their proposed activities.

Nine of the 10 projects included in this case study were completed[3] at the time of the evaluation, with one project still in progress. Of the nine that were completed, one was completed in 2014, one in 2016, one in 2017, five in 2018, and one in 2019.

Finding PI.2: Most projects were delayed relative to proposed timelines, primarily due to seasonal limitations on restoration work, permitting delays, and the need for additional data collection or design work.

Nearly every project in the beach and dune restoration portfolio experienced significant delays compared to proposed completion estimates. The data available through official contract amendments submitted to NFWF and DOI show that 8 of the 10 projects requested extensions for completing their work, with many projects requesting multiple contract extensions. These projects were delayed by an average of nearly two years (651 days). The most commonly cited cause of delays noted by project leads were seasonal limitations on restoration work, permitting delays, and the need for additional data collection or design work (Box 3).

[3] While our evaluation generally provides findings elicited through the review of archival materials received through December 2018, project status information reflects information gathered through April 2019 (updated project status information was obtained through a supplementary web search in March 2019 and an updated spreadsheet provided by NFWF).

Finding PI.3: Completed projects have generally met their design objectives.

Archival materials suggest that the nine completed beach and dune restoration projects typically met or exceeded their design goals, but some projects did not meet their proposed linear miles or area restored. More specifically, of the nine completed projects, five met or exceeded the linear miles restored that were proposed and one project fell short by a only a modest amount (0.17 linear miles). Two of the nine completed projects fell significantly short of what was proposed; more specifically, one achieved just 1.69 of the 3 proposed linear miles restored, and the other achieved 2.74 of the 5.73 proposed linear miles. For the latter project, at least part of the shortfall was due to challenges with permits – only 3.75 miles of the proposed 5.73 were approved for restoration through the permitting process. Five of the completed projects also proposed to restore a specific area of habitat; four achieved their restoration goals and one fell short by 4 acres (of the 30 acres proposed).

Like other on-the-ground projects, however, project reports and interviews with project leads suggest that beach and dune projects may need at least some adaptive management or maintenance after initial restoration efforts are complete. For example, one project noted that coastal storms occurring soon after restoration actions were completed damaged recently planted vegetation; these areas will likely need to be replanted. Another project's location was hit by a winter storm and the restored areas experienced serious damage from overwash and losses in elevation. More specifically, the project site lost approximately 42,000 cubic yards of sand, which moved to a near-shore bar.

Box 3. Factors that contributed to the delay of beach and dune restoration projects.

Seasonal limitations

In contract amendments and the survey, six project leads noted that the weather- and seasonal-dependent nature of beach and dune restoration activities contributed to delays. Weather events and growing seasons can limit the time available to perform restoration (e.g., vegetation planting), and work was sometimes delayed for months waiting for appropriate working conditions to return. In addition, permit conditions can restrict some construction activities, including dredging and beach and dune nourishment, to specific times of the year to avoid harming wildlife (e.g., during migration or breeding seasons).

Permitting delays

Five project leads described challenges with the permitting process as being a source of delays. For example, one project noted that before dredge materials could be approved for use in a restoration project, testing for contaminants on that material had to be analyzed and reviewed before the permitting process could move forward.

Additional data collection or design work

Three project leads noted that they needed to gather additional data or adjust their project designs given onsite conditions, which caused unexpected project delays. For example, one project noted that because sand resources were obtained for less than originally budgeted, beach restoration activities were expanded. This required additional time to design and implement those additional activities.

Source: Images and delay information from project reports and archival materials.

Topic: Project Outcomes (PO)

4.1 Human Community Outcomes

Finding PO.1: Four linear miles and 75 acres of community-focused beach and dune habitats have been restored to protect nearby community resources, and are functioning as expected.

Project lead-reported data show that the community-focused projects have restored 4 linear miles and 75 acres of beach and dune habitats.[4] These restored beaches and dunes can help protect inland resources, such as housing, roads, and recreational areas, by absorbing waves and reducing storm surge and related flooding and erosion. Preliminary observations from four of the five community-focused projects suggest that these restored beaches and dunes are performing as expected. More specifically, the four projects found that the dunes restored were stable and resilient to recent coastal storms (Box 4). In addition, one project, classified as primarily ecologically focused, noted that the restored beach withstood recent storms and reduced flooding in nearby residential and agricultural areas.

Box 4. Shoreline stabilization: Early observations.

A project in Massachusetts had three nor'easters pass over its restored dunes. **The dunes remained intact** but grasses that were not yet well-established were damaged.

Plantings and fencing installed at Great Marsh, MA (project final report).

Project leads in Rhode Island noted that **restored dune elevations held** against nor'easters and high tides, with no overtopping or washing out.

Middletown Beach Commission members at Sachuest Beach, RI (Dave Hansen, NewportRI.com).

[4] These data include projects that have not yet been completed, and thus the final number of miles and acres restored may change; for active projects, we assumed that projects will achieve the proposed miles and acres restored. Restored areas reported here are also distinct from those reported under Finding PO.2.

Box 4. Shoreline stabilization: Early observations.

A New Jersey project created a resiliency dune to protect a nearby coastal community. Following two major storms, the project reported that **the resiliency dune held**.

Project area and nearby community at Seven Mile Island, NJ (project final report).

A New Jersey project that constructed and enhanced coastal dunes noted that while nearby beaches were eroded during recent nor'easters, there was **no damage to restored dune areas**.

Dune restoration at Monmouth Beach, NJ (Stacy Small-Lorenz, National Wildlife Federation).

4.2 Habitat, Fish, and Wildlife Outcomes

Finding PO.2: Approximately 7 linear miles and 68 acres of beach and dune habitats have been restored by ecologically focused restoration projects, providing critical habitat for beach-dependent birds, including the federally threatened red knot and piping plover, as well as other beach-dependent wildlife.

Project lead-reported data show that ecologically focused beach and dune restoration projects have restored approximately 7 linear miles and 68 acres of beach and dune habitats.[5] Archival material and a literature review suggest that these restored areas can provide important habitat for critically important coastal species (Box 5).

For example, habitat loss is known to be a key factor contributing to the declines of the red knot and piping plover (USFWS, 2015), and restoring even small amounts of habitat can improve their survival. More specifically, beaches that provide high-quality habitat to support breeding horseshoe crabs can provide critical support to the red knot during their migration in the spring, when they rely on horseshoe crab eggs during stopovers on the Atlantic Coast (USFWS, 2015). In addition, the piping plover feeds and breeds on beaches, and suitable beach habitat has been in decline due to a combination of human development, human disturbance, predators, and storm-related disturbance and erosion (USFWS, 2007).

[5] These data include projects that have not yet been completed, and thus the final number of miles and acres restored may change; for active projects, we assumed that projects will achieve the miles and acres restored that were initially proposed. Restored areas reported here are also distinct from those reported under Finding PO.1.

Box 5. Examples of representative species noted by project leads as likely to benefit, or that are already benefiting, from beach and dune restoration projects.[a]

The red knot, a federally threatened species, use the Delaware Bay as an important stopover habitat on their migration between South America and the Arctic.

The piping plover, a federally threatened species with approximately 2,000 breeding pairs in the Atlantic region, depend on beach habitat for feeding and nesting; habitat loss is a key factor contributing to their decline.

The American oystercatcher (*Haematopus palliatus*) is a shorebird species that roost in beach, dune, and marsh areas. After being hunted to near-extinction in the 19th century, the species is rebounding and serves as an indicator species for health of the coastal environment.

The horseshoe crab (*Limulus polyphemus*) species live in shallow waters and are known to nest on mid-Atlantic beaches, and their eggs are an important food source for migrating birds such as red knots.

a. See Finding PO.3 and Box 6 for observed improvements in wildlife utilization of restored beach/dune habitats.

Sources: USFWS, 2007, 2015, 2019a, 2019b; University or Michigan Museum of Zoology, 2019. Image credits: birds (Gregory Breese, USFWS; Kirk Rogers, USFWS; USFWS, 2019b); horseshoe crab (Wetlands Institute, 2013).

Finding PO.3: All ecologically focused projects have already observed improved outcomes for critical species in restored areas.

Project-lead reporting shows that all projects that were primarily focused on improving habitat for wildlife already observed positive outcomes by the time of the evaluation (Box 6). More specifically, projects observed increases in horseshoe crab breeding activity, bird utilization of beach habitat, bird breeding activity, and bird weight gains on restored beaches (Box 6). In fact, one project observed an increase in the nesting success of breeding piping plovers after beach restoration (Figure 3). Three of these projects also noted that restored areas were resilient to recent storms, showing very little erosion and suggesting that the benefits provided by these projects may be sustained over many years (see Finding PO.5 below).

In addition, while not the major focus of their restoration activities, two community-focused beach restoration projects also reported positive ecological outcomes. For example, one project noted that piping plovers and oystercatchers were nesting in restored beach areas, and nests in these elevated areas seemed less likely to be flooded than those established on lower, un-nourished areas. The project also noted that non-standardized counts of spring and fall migratory birds were higher after restoration. Another project simply noted that piping plovers were utilizing the newly restored area.

Box 6. Ecological benefits: Early observations of resilience improvements through improved habitat integrity and extent.

A New York project reported **increased horseshoe crab spawning and egg density, and greater increases in red knot weights during stopovers** on restored beaches compared to non-restored beaches.

The project team captures knots, turnstones, and sandpipers in the Delaware Bay (Stephanie Feigin, Conserve Wildlife NJ).

After beach restoration in Delaware, a project reported shorebirds **foraging and roosting in the new habitat**, along with horseshoe crab spawning.

Shorebirds at Mispillion Harbor, DE (Katie Peikes, Delaware Public Media).

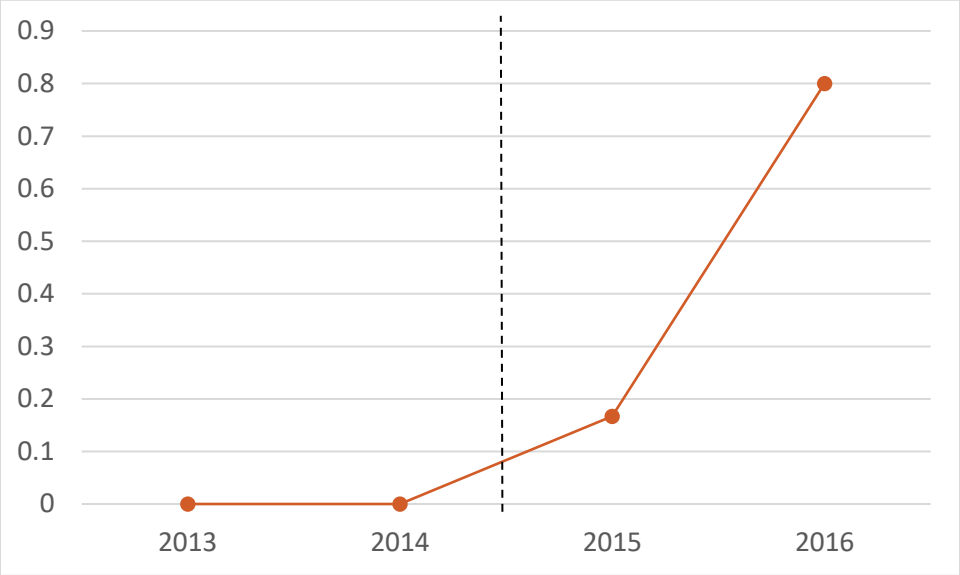
A New Jersey project restored three beaches and reported **improved horseshoe crab spawning and shorebird use**.

Horseshoe crabs spawning as restoration finishes at Reed's Beach, NJ (Shane Godshall, American Littoral Society).

A project in Delaware reported the **return and nesting of piping plovers, American oystercatchers, and least terns** on the restored beach. The project also noted an **increase in horseshoe crab abundance from pre-Hurricane Sandy numbers.**

Piping plover and horseshoe crabs on Fowler Beach at Prime Hook National Wildlife Refuge (Julie McCall, Delaware Online).

Figure 3. Number of piping plover chicks fledged per nesting pair on Stone Harbor Point before (2013 and 2014) and after (2015 and 2016) beach restoration.



4.3 Trajectories of Outcome Achievement

Finding PO.4: Generally projects are recovering as quickly as expected after restoration, but more monitoring is needed to understand long-term outcomes.

The benefits of most beach and dune restoration projects funded through the Hurricane Sandy Program will take time to materialize after restoration activities are completed. To better understand and convey the potential timing of the achievement of key outcomes, the Abt Associates (Abt) evaluation team developed conceptual timelines of recovery after restoration using information from key peer-reviewed articles in combination with professional judgment from our team's subject matter experts (Figure 4).

More specifically, while some components of beach and dune restoration may begin to recover immediately following restoration actions (e.g., stabilization, sand accretion), they may require more than 10 years to reach maximum function (Morton et al., 1994; Jones et al., 2008; Vestergaard, 2013; Walker et al., 2013; Figure 4).

Surface stabilization and storm protection, two of the primary reasons for implementing a beach and dune restoration project, begin immediately following restoration actions and improve over time, unless a severe storm damages the site. Initial beach or dune nourishment and vegetation planting provide needed stabilization and sand supply. Subsequently, the restored area tends to accrete more sand, and the dune gains more stability over time as the vegetation matures (Morton et al., 1994; Feagin et al., 2005, 2015; Acosta et al., 2013; Vestergaard, 2013; Walker et al., 2013; Sigren et al., 2014).

Figure 4. Site recovery following beach and dune restoration activities over time.

Realization timeframe[a]	Year 0 (pre-project)	Short-term (1–2 years) outcomes 2015–2022	Mid-term (3–7 years) outcomes 2017–2027	Long-term (10+ years) outcomes 2024+
Vegetation	Native vegetation is sparse or non-existent	Absent storm disturbance, initial plantings begin to establish and provide early stabilization to beaches and dunes	Absent storm disturbance, vegetation cover, species richness, and spatial structure begin to mature; further stabilization provided	Dune vegetation continues to establish and mature; absent storm disturbance, may approach natural conditions after 24+ years
Habitat/ wildlife use	Site supports few or no representative species	Absent storm disturbance, invertebrates and arthropods begin to recolonize and may support birds and other wildlife	Absent storm disturbance, wildlife such as horseshoe crabs, piping plover, oystercatchers, and prey species continue to recolonize	Absent storm disturbance, wildlife such as horseshoe crabs, piping plover, oystercatchers, and prey species continue to recolonize
Surface stability and storm protection	Provides little to no storm protection	Absent storm disturbance, vegetation and increased elevation provide improved stability and short-term storm protection	Absent storm disturbance, more mature vegetation and ongoing accretion/stabilization provide improved storm protection	Absent storm disturbance, more mature vegetation and ongoing accretion/stabilization provide improved storm protection

a. Assuming projects completed between 2014 and 2020.

Sources: **Vegetation**: Morton et al., 1994; Feagin et al., 2005; Acosta et al., 2013; Pickart, 2013; Vestergaard, 2013. **Habitat/wildlife use**: Rakocinski et al., 1996; Jones et al., 2008; professional judgment. **Surface stability and storm protection**: Morton et al., 1994; Feagin et al., 2005, 2015; Vestergaard, 2013; Walker et al., 2013; Sigren et al., 2014.

Early observations from Hurricane Sandy Program projects noted in Findings PO.1 and PO.3 above are generally consistent with what the literature and Abt team experts identified as likely short-term outcomes of beach and dune restoration (i.e., outcomes that would be observed one to two years after restoration; Figure 4). For example, there have been increases in horseshoe crab reproduction, bird habitat utilization, and bird nesting success in restored sites (Box 6; Figure 3). In addition, newly restored beaches and dunes have stabilized in multiple project areas, showing little damage in the face of significant coastal storms that occurred after restoration (Box 6). These improvements in wildlife and stabilization would generally be expected to improve over time unless an extreme coastal storm causes extensive damage or erosion; after such an event, new restoration actions may be required to sustain desired ecological and community benefits (see Finding PO.5).

Finding PO.5: To retain their protective and ecological values, beaches and dunes will likely need to be re-nourished in the future.

While the evidence described above suggests that completed restoration projects have successfully increased wildlife habitat, stabilized beach and dune coastal areas, and are providing improved protection to communities from coastal storms, the restored areas will likely need to be re-nourished and maintained to sustain those benefits. As noted in the overview of projects, beach and dune systems are naturally highly dynamic, being changed and eroded by waves, wind, and sea level rise. In fact, the literature suggests that restored beaches and dunes will typically need to be re-nourished every three to seven years (NOAA, 2000; Speybroeck et al., 2006). However, major storm events can quickly erode areas to pre-project profiles and require re-nourishment more quickly. For example, in Ocean City, New Jersey, a $2.5 million beach nourishment project lasted just 2.5 months before a major storm eroded the beach and necessitated emergency re-nourishment (NOAA, 2000). On the other hand, as noted in Box 4, some of the Hurricane Sandy Program projects have demonstrated resilience to storms that have occurred post-restoration. The need for re-nourishment will likely depend on the severity of the storm event and other environmental factors, such as sea level rise.

It is important to note that many beach and dune restoration projects are done with the explicit knowledge that future storms are likely to damage restored sites, and they may need active and ongoing maintenance, management, and re-nourishment. In fact, a given restoration project could be considered a success if it successfully protects inland ecosystems and infrastructure during a storm, even if the restored beaches and dunes are severely damaged during that storm and the project requires re-nourishment.

Topic: Information Gaps (IG)

Finding IG.1: Long-term monitoring is needed to understand the full benefits of beach and dune restoration projects, and this may be provided through additional new funding from NFWF and DOI.

Given the time lags between restoration actions and full ecological and community benefits (Figure 4), it will likely take many years to understand the full benefits of the beach and dune restoration actions undertaken through the Hurricane Sandy Program. Recognizing the need for more data to assess beach and dune restoration success, NFWF and DOI are supporting

additional, long-term monitoring for all projects in this case study through 2024 (see Table A.2). Projects will be tracking beach and dune dimensions (e.g., height, width), vegetative cover, and avian habitat use (e.g., abundance, distribution, breeding productivity).

Socioeconomic monitoring will also assess how beach and dune restoration affect human well-being, primarily by evaluating reductions in hazardous flooding and the resulting impact on human health and safety, recreation, and infrastructure. These data will improve understanding of the quality and longevity of the habitat and protection provided by the beaches and dunes restored through the Hurricane Sandy Program.

5. Conclusion

Overall, these findings suggest that investments the Hurricane Sandy Program has made in restoring beaches and dunes are on track to improve both ecological and community resilience in nearby areas. Early project results typically show that beach and dune restoration has increased available nesting habitat for the federally threatened piping plover, which can help sustain or increase their populations over time. The federally threatened red knot also appear to be benefiting from restoration-related increases in horseshoe crab eggs, which are helping the red knot increase weight gains during spring migration stopovers; this may in turn improve survival and reproduction in breeding areas. Early observations also suggest that restored and stabilized beaches and dunes have been resilient to recent storms, and have provided enhanced protection to nearby communities. However, these observations are preliminary, and many more years of recovery and monitoring data are needed to more fully understand the likely long-term ecological and community benefits of beach and dune restoration actions. Of particular interest will be understanding how long the benefits of beach and dune restoration will last in the face of future coastal storms and sea level rise.

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Appendix A. Project Summaries

Table A.1. Primary goals of the beach and dune restoration projects, along with project-specific activities and goals.

Primary goal	State	Project ID	Location	Activities	Project-specific goals
Community protection	MA	NFWF-41766	Plum Island and Salisbury Beach	Dune nourishment, vegetation planting, mobi mat and snow fencing installation.	Stabilize vulnerable areas and protect homes, infrastructure, and other community resources.
	NJ	NFWF-43986	Monmouth Beach	Beach nourishment, dune construction/restoration, sand fencing installation, vegetation planting.	Protect the Borough of Monmouth Beach (~ 3,200 residents) from storm surge.
	NJ	NFWF-41991	Stone Harbor Point	Beach/dune nourishment, vegetation planting.	Protect the Borough of Stone Harbor Point (~ 800 residents) from storm surge.
	NY	NPS-1A	Riis Beach	Beach nourishment.	Protect recreational and cultural resources and reduce human-wildlife conflict.
	RI	NFWF-41795	Second Beach at Sachuest Bay	Beach/dune nourishment, geotextile reinforcement, mobi mat installation.	Protect Second Beach, a key recreational resource, from storm surge and sea level rise.[a]
Habitat restoration	DE	NFWF-43281	Beaches in Mispillion Harbor Reserve and Milford Neck Conservation Area	Beach/dune nourishment, vegetation planting, rock sill improvement.	Restore and stabilize habitat for spawning horseshoe crab and foraging shorebirds, and protect newly restored beaches from coastal storms.
	DE	USFWS-15	Prime Hook National Wildlife Refuge	Beach nourishment, vegetation planting.	Restore and stabilize habitat for spawning horseshoe crab and foraging shorebirds, and protect newly restored marsh from coastal storms.
	NJ	USFWS-06	Pierce's Point, Reed's and Moore's Beach	Debris removal, dune/berm construction, beach nourishment.	Restore and stabilize habitat for spawning horseshoe crab and foraging shorebirds.
	NJ	NFWF-43429	Beaches in Cape May and Cumberland counties	Beach nourishment.	Restore and stabilize habitat for spawning horseshoe crab and foraging shorebirds.
	NY	NFWF-44225	Shinnecock Reservation	Beach nourishment, vegetation planting, rock installation.	Restore shoreline to protect nearby wildlife habitat and tribal resources from storm surge and sea level rise.[b]

a. We categorized the NFWF-41991 project as a community resilience project; however, it is also providing notable ecosystem benefits, including habitat for nesting and migratory shorebirds.

b. We categorized the NFWF-44225 project as an ecological resilience project; however, it is also providing notable community benefits, including protecting recreational and cultural resources and upland tribal housing.

Table A.2. Beach and dune restoration projects supported through the Hurricane Sandy Program.[a] This table presents the amount of project funding specifically allocated to beach and dune restoration activities. For three projects, this is the full project funding amount; and for seven projects, this is a subset of the total project funding. The allocation was based on available project documentation. All dollars rounded to the nearest hundred.

Project identification number	Project title	Project state	Project lead organization	Award amount	Reported matching funds	Area restored (length restored in feet, area in acres)[c]
				Values represent beach and dune activities only[b]		
NFWF-41766	Coastal resiliency planning and ecosystem enhancement for northeastern Massachusetts	MA	National Wildlife Federation	$882,000	$479,200	5,280 feet, 20 acres
NFWF-41795	Strengthening Sachuest Bay's coastal resiliency, Rhode Island	RI	Town of Middletown	$1,602,800	$451,000	5,280 feet, 23 acres
NFWF-41991	Increasing Seven Mile Island's beach resiliency, New Jersey	NJ	New Jersey Audubon Society	$1,280,000	$53,400	Not reported, 26 acres
NFWF-43281	Restoring Delaware Bay's wetlands and beaches in Mispillion Harbor Reserve and Milford Neck Conservation Area	DE	Delaware Department of Natural Resources	$4,050,000	$1,367,300	3,485 feet, 7.5 acres
NFWF-43429	Creating a resilient Delaware Bay Shoreline in Cape May and Cumberland counties, New Jersey	NJ	American Littoral Society	$4,275,000	$229,000	14,467 feet, 56.5 acres
NFWF-43986	Strengthening Monmouth Beach's marshes and dunes, New Jersey	NJ	Monmouth Beach, New Jersey	$1,246,000	$1,225,000	5,280 feet, 6 acres
NFWF-44225	Improving Shinnecock Reservation's shoreline habitats, New York	NY	Shinnecock Indian Nation	$1,399,700	$117,200	3,010 feet, 3.73 acres
NPS-1A	Mitigate impacts from artificial groin to Jacob Riis Beach to restore habitats and recreation resources	NY	U.S. Army Corps of Engineers Civil Works; National Park Service	$3,453,200	$0	5,280 feet, not reported
USFWS-6	Increase resilience of beach habitat at Pierce's Point, Reed's Beach, and Moore's Beach, New Jersey	NJ	U.S. Fish and Wildlife Service	$1,650,000	$0	5,914 feet, not reported
USFWS-15	Prime Hook National Wildlife Refuge coastal tidal marsh/barrier beach restoration	DE	U.S. Fish and Wildlife Service	$7,922,000	$544,000	8,923 feet, not reported

a. All projects have secured additional, long-term monitoring funding through NFWF and DOI.

b. Costs in the table do not represent the full cost of the project and may not reflect total match.

c. These data include projects that have not yet been completed, and thus the final number of acres restored may change; for active projects, we assumed that projects will achieve the proposed acres restored.