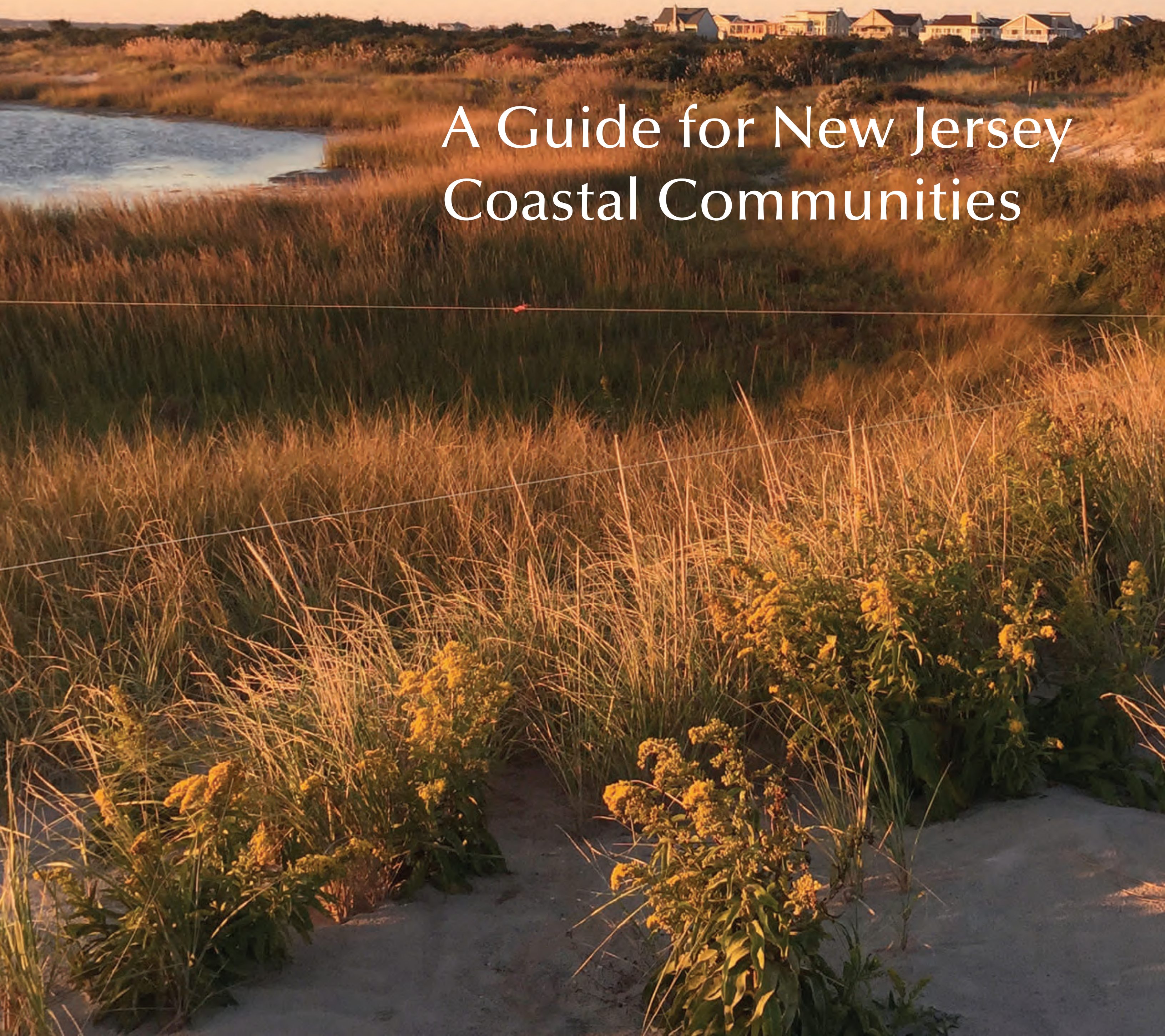
Building Ecological Solutions to Coastal Community Hazards

A Guide for New Jersey Coastal Communities



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Building Ecological Solutions for Coastal Community Hazards available at: **www.nwf.org/CoastalSolutionsGuideNJ**
Cover: View from Stone Harbor Point, New Jersey. Photo: Stacy Small-Lorenz

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A Guide for New Jersey Coastal Communities

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Photo: Steven Jacobus

Tidal marshes at Stone Harbor, New Jersey.

Photo: Stacy Small-Lorenz

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Executive Summary

There is growing recognition that ecosystems play an important role in sustaining coastal communities, both people and wildlife, in the face of mounting hazards. Today's decisions about coastal management and ecosystem stewardship will ultimately determine the fate of New Jersey's coastal regions, where natural and human systems are intertwined (Fig. 1).

More and more, New Jersey coastal communities face growing hazards, ranging from high winds and frequent flooding, to storm surges, sea-level rise projections up to 4.5 feet, inundation, erosion, land subsidence, and saltwater intrusion into freshwater sources. Some of the associated risks include property damage, degraded natural areas, local land loss, contaminated drinking water, and threats to public health and safety. Climate change exacerbates these risks.

To effectively adapt and thrive in the face of such powerful forces requires a clear understanding of the protective role that natural features and ecological processes play in shaping and sustaining the coast. This guide challenges and empowers coastal communities to consider ecological solutions to help prepare for and adapt to a wide range of coastal hazards.

Rather than attempt to provide all possible answers, we offer approaches to coastal resilience that work with nature, rather than against it, resulting in optimal outcomes for the people and wildlife that inhabit coastal regions.

We provide an overview of four systems prevalent in coastal New Jersey: 1. developed areas of coastal communities, 2. beach and dune complexes, 3. coastal forests and shrublands, and 4. tidal marshes. We describe how coastal ecosystems protect human communities by maintaining elevation and buffers against the elements, providing much needed resources and invaluable habitat for fish and wildlife. We also describe ways in which these systems, without proper management, are vulnerable to natural and human threats.

Today's decisions about coastal management and ecosystem stewardship will ultimately determine the fate of New Jersey's coastal regions, where natural and human systems are intertwined.

Photo: Stacy Small-Lorenz

Bald Eagle, *Haliaeetus leucocephalus.*

Photo: Lynda Bare

For all four systems, we provide readers specific, actionable solutions as options to enhance ecological function and increase community resilience in ways that benefit people and wildlife. A few of the overarching recommendations in this guide include:

- Inventory and map coastal ecosystems in and around your community (e.g., beaches & dunes, coastal forest and shrublands, and tidal marshes).
- Conduct a climate vulnerability assessment and incorporate sea-level rise and projected coastline changes into land use zoning and open space planning.
- Protect or restore coastal ecosystems where needed, especially where gaps and points of vulnerability leave your community exposed to coastal hazards.
- Use practices that reduce the volume and rate of stormwater runoff to help alleviate flooding threats and water pollution associated with heavy precipitation events.
- Promote groundwater conservation and recharge practices to stave off saltwater intrusion into freshwater ecosystems, protect local drinking water sources, and reduce local land subsidence.
- Re-engineer hardened shorelines to reduce erosive impacts and allow for sediment and water flows that sustain and nourish coastal ecosystems.
- Promote the use of native vegetation in public and private landscaping.
- Promote measures to protect dunes, dune-building processes, and dune vegetation.
- Identify and remove or re-design barriers to marsh migration in response to sea-level rise.
- Enforce and expand no-wake zones where needed to reduce erosion of shorelines and tidal marshes.
- Prioritize "living shorelines" over rigid armoring for shoreline stabilization.
- Avoid mosquito control practices that impair marsh conditions and repair damage to tidal marshes from manmade ditches and pools where possible.
- Apply best management practices for wildlife when restoring or managing natural systems for human benefits.
- Recognize private landowners who demonstrate exemplary ecological stewardship.

We developed this guide with community leaders, land use planners, green teams, and educators in mind. It is our hope that by highlighting ecological solutions to New Jersey's coastal hazards, we can help communities prepare and adapt to ongoing and future changes, strengthening long-term coastal resilience for both people and wildlife.

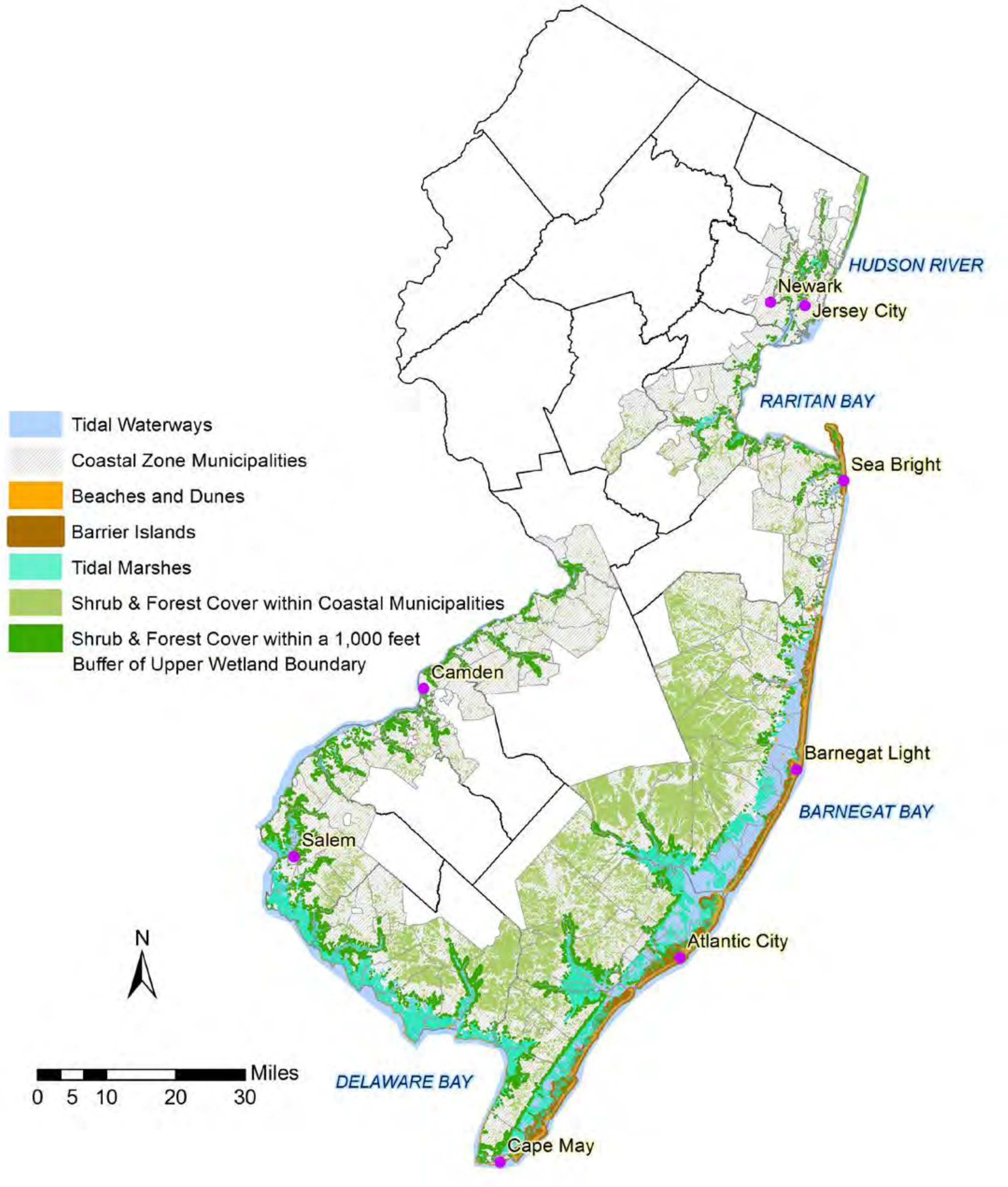


Figure 1. New Jersey coastal ecosystems: tidal marsh, beaches and dunes, barrier islands, coastal forest and shrublands. Feature data source NJDEP LULC 2012. This map is for informational purposes only.

Introduction

New Jersey is known for its lively shore towns, and in many ways, life in its coastal communities is deeply connected to the natural world. The state's 239 coastal communities are the heart of its economy and coastal heritage, and they depend on the vibrant and dynamic natural systems that are an integral part of their landscapes, from tidal marshes that support valuable fisheries to beaches that generate millions of dollars in tourism revenue annually. However, they also face some challenges, looking into the future.

New Jersey coastal communities face the daunting reality of being positioned on the frontline of mounting coastal hazards, and year-round coastal populations have been steadily declining. Coastal economies rely heavily on natural systems for tourism, fisheries, drinking water, navigation and coastal defenses and are vulnerable to the growing hazards of sea-level rise, storms, erosion, land loss, inundation, and saltwater intrusion.

This guide advances practices that can help coastal communities to become safer and more sustainable in ways that work with, rather than against, nature. It describes ecological solutions to coastal community hazards, including measures to protect open space or enhance and protect coastal ecosystems (including beaches and dunes, coastal forests and shrublands, and tidal marshes) in ways that increase elevation and reduce erosion and flooding risks. In addition, Low Impact Development (LID) strategies can significantly reduce mounting coastal hazard risks and provide tremendous additional benefits to coastal communities (Reeve and Kingston 2014, Bridges et al. 2015).

Dune restoration at Monmouth Beach, New Jersey.

Photo: Stacy Small-Lorenz

For example:

- Sandy beaches and well-vegetated dunes provide recreational opportunities while providing wildlife habitat and protecting coastal communities from hurricanes and nor'easter storms.
- Dense coastal forests and shrublands provide erosion protection and windbreaks, providing a buffer against storm deposits of sand and debris, and shelter for migratory birds and butterflies, bringing nature closer to home.

This guide advances practices that can help coastal communities to become safer and more sustainable in ways that work with, rather than against, nature.

- Healthy, intact tidal marshes are the essential backbone of an active fishery while buffering uplands from erosive wave energy and storm surge.

- Urban design and coastal land use planning should incorporate sea-level rise and coastline migration projections. Incorporating projected changes into open space planning and land use zoning now serves the interest of more resilient coastal communities into the future.

- Application of Low Impact Development principles and native landscaping has multiple benefits, from managing stormwater to recharging potable drinking water supplies.

This work is the result of a three-year collaboration among many New Jersey partners and The National Wildlife Federation. It provides numerous targeted actions that will help communities adapt to the "new normal" of coastal change, in ways that make use of natural landscape features like elevation, topography, vegetation, and dynamics like tides and sediment flows.

Ecological solutions are suggested in each section, organized into three clear categories:

- Land Use Planning and Zoning
- Conservation Practices
- Public Education and Outreach

A full checklist of suggested ecological solutions is compiled in Appendix 1.

Some of the recommendations might be immediately actionable in your community and build on work that is already underway. Others might require time and planning, depending on where your community is in the process of vulnerability assessments, long-term planning, and adopting ecological solutions. The starting point will likely differ for each community.

Incorporating projected changes into open space planning and land use zoning now serves the interest of more resilient coastal communities into the future.

Photo: Steven Jacobus

A shared commitment to healthy coastal ecosystems will result in a more vibrant and sustainable future for our coastal communities.

Communities are already developing and applying ecological solutions throughout the state. As you consider the proposed solutions, you may want to peruse the case studies for examples and reach out to those communities. In addition, we encourage municipal and county officials to engage their residents in this issue. Start a Sustainable Jersey **Green Team** in your community or, if you already have one, empower them to participate. Much more can be accomplished when local stakeholders participate, so bring residents, anglers, birders, hunters, boaters, and others to the table.

The key to achieving true resilience is for coastal communities to engage a broad range of constituencies in the planning and implementation of pro-active hazard mitigation and resilience strategies that incorporate both ecological and engineering solutions (NJDEP 2016a). At the same time, it is essential to view protecting human and natural systems not as trade-offs, but as mutually beneficial endeavors.

We recognize that the recommendations in this guide are just starting points, and the starting point for your community depends on your needs, goals, local vulnerabilities and resources. Knowledge of these topics will continue to grow, as well. We encourage you to expand your coastal networks, participate in regional and statewide resilience working groups, and keep sharing lessons and asking questions. A shared commitment to healthy coastal ecosystems will result in a more vibrant and sustainable future for our coastal communities.

The key to achieving true resilience is for coastal communities to engage a broad range of constituencies in the planning and implementation of pro-active hazard mitigation and resilience strategies that include both ecological and engineering solutions.

Photo: Steven Jacobus

View from Stone Harbor Bird Sanctuary. Stone Harbor, New Jersey.

Photo: Stacy Small-Lorenz

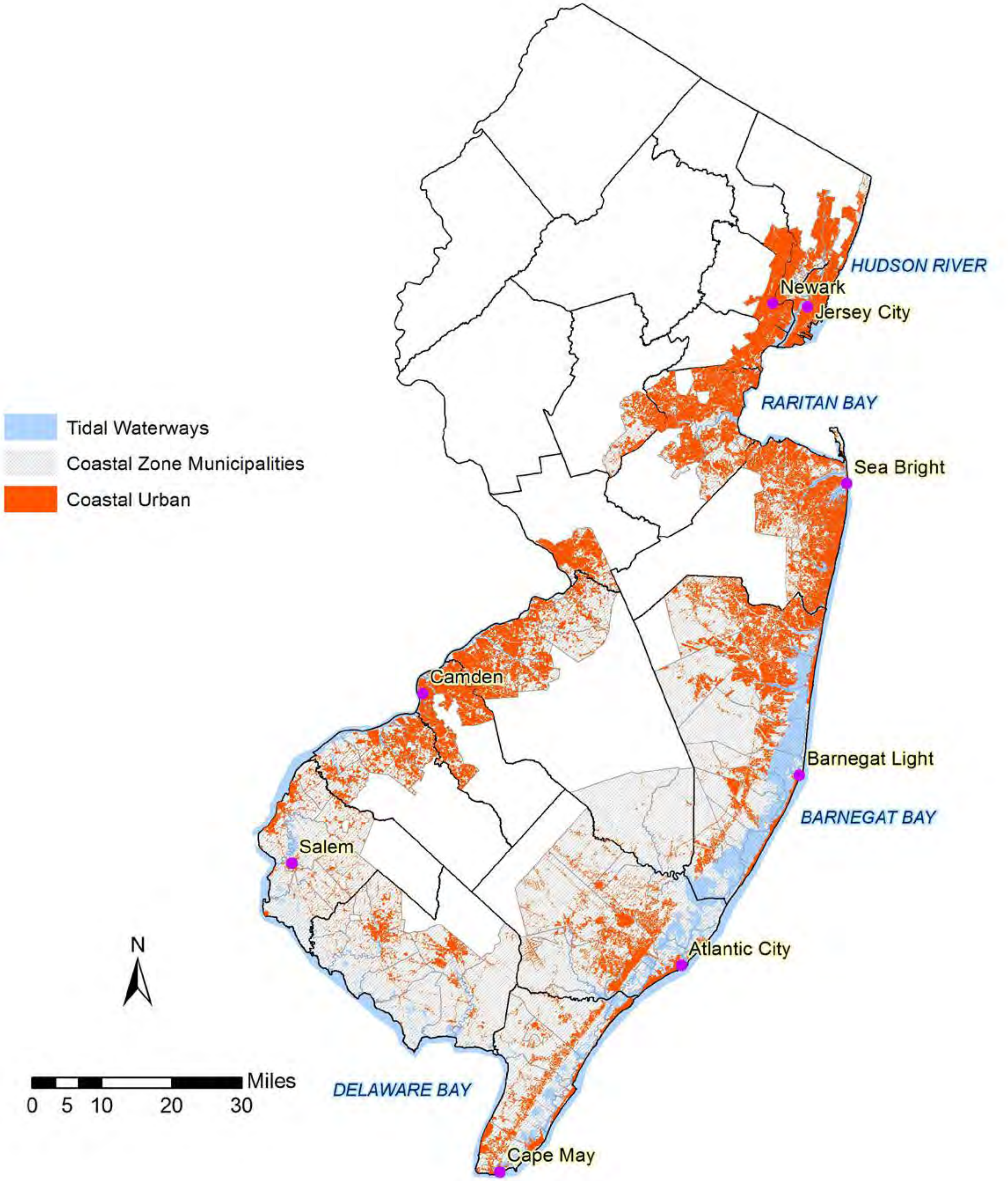


Figure 2. New Jersey coastal urban land use.

Feature data source NJDEP LULC 2012. This map is for informational purposes only.

Coastal Communities in New Jersey

Overview of New Jersey Coastal Communities

New Jersey is a peninsula surrounded by the Delaware River to the west, Delaware Bay to the south, and the Atlantic Ocean, Raritan Bay, and Hudson River to the east. Nearly 1,800 miles of the state's shoreline are tidally influenced, giving us far more coastal communities – 239 to be precise – than a beach traffic report would imply (NJCAA 2014).

New Jersey is the nation's most densely populated state, and more than half of its people (1.8 million as of 2011) live in coastal counties (Fig. 2). However, [year-round populations] have been [reported to be declining] since 2000 in some shore towns (Wilson and Fischetti 2010, Considine and Stirling 2011).

New Jersey's coastal communities are comprised of residential and commercial development, agriculture, industry, critical infrastructure, and historic and cultural facilities, embedded in a diverse array of natural systems. Many of these coastal communities are situated in or near low-lying areas, such as naturally dynamic shores or floodplains. This makes them especially vulnerable to an array of coastal hazards, including storm surges and wind damage, back-bay and inland flooding, episodic and chronic erosion, polluted runoff, and intrusion of saltwater into freshwater sources. Soil saturation from increasingly heavy precipitation also puts higher elevation coastal communities at risk for landslides.

Sea-level rise, more intense coastal storms, and heavier precipitation associated with climate change are likely to exacerbate many of these hazards, which could worsen their impacts on communities (NJCAA 2014).

In light of these risks, the New Jersey Department of Environmental Protection has engaged a number of partners to develop and implement

Many of New Jersey's coastal communities are situated in dynamic, low-lying areas. Atlantic City is built on a barrier island, backed by the tidal marshes of Absecon Bay.

Photo: Steven Jacobus

tools and strategies to help coastal communities address their vulnerability to the impacts of coastal hazards now and in the future and to facilitate the development of strategies to improve long-term coastal resilience. This guidance is part of that effort.

Protective Values of Ecosystems for New Jersey Coastal Communities

All human communities are surrounded by ecological landscapes that benefit them in multiple ways, and nowhere is that more apparent than along the coast. New Jersey coastal ecosystems, especially **beaches and dunes, coastal forests and shrublands,** and **tidal marshes** provide economic, recreational, aesthetic, habitat, and risk reduction benefits while providing habitat for myriad wildlife species (Bridges et al. 2015).

Key Vulnerabilities of Coastal Communities

The following is a general overview of some of the major natural hazards faced by New Jersey's coastal communities.

Sea-level Rise. For the nation's coastal communities, accelerating sea-level rise is one of the most direct and certain consequences of climate change.

While sea-level is rising rapidly around the globe because of ocean dynamics like thermal expansion and melting glaciers and sea ice, sea-level is **rising much faster** along the New Jersey shore than the global average (Miller et al. 2014). In the 20th century, sea-level rose by 12 inches at immobile bedrock locations (Bayonne, Trenton, Camden), but during the same period, sea-level rose even more (16 inches) along the coast from Sandy Hook to Cape May. This difference is attributed to coastal soil compaction caused by both natural effects and groundwater withdrawal.

The New Jersey shoreline has always been dynamic. Over the last 20,000 years, its shoreline has moved inland more than 75 miles because of sea-level rise. However, 20th century rates of sea-level rise exceeded those of the previous 4,000 years (Miller et al. 2013). Exactly how much and how fast sea-level will rise in coming decades is uncertain because it depends on the global rate of greenhouse gas emissions and the rate Greenland and Antarctica's ice sheets will melt with rising temperatures (Cooper et al. 2005, Rignot et al. 2011). Thus, scientists generally offer a range of possible scenarios. Likely ranges for projected estimates for sea-level rise are 1-1.8 feet by 2050 and 2.4-4.5 feet by 2100 under a high emissions scenario (Kopp et al. 2014, Kaplan et al. 2016).

Sea-level has been rising much faster in southern New Jersey than the global average, up to 16 inches over the past century.

Photo: Stacy Small-Lorenz

Dunes absorb high wave energy from coastal storms. Damage to Stone Harbor dunes from Winter Storm Jonas in 2015.
Photo: Stacy Small-Lorenz

Sea-level rise exacerbates storm surge and erosion. Ultimately, it will cause permanent inundation of current coastal lands. Research shows that up to 3 percent of New Jersey's land area will be inundated under a sea-level-rise scenario of 48 inches, which is plausible over the next century (Cooper et al. 2005). This would affect thousands of homes, businesses, and critical infrastructure such as sewage plants, the energy grid, roads and bridges, hospitals and schools. NJ Flood Mapper is a useful tool for visualizing local sea-level rise impacts (Rutgers 2017).

Coastal Storm Damage. New Jersey is no stranger to extreme coastal storms. Hurricanes, tropical storms, and nor'easters can have a range of devastating and costly impacts, including coastal flooding, storm surge and wind damage, inland flooding, and significant coastal erosion (NJCAA 2014).

One of the primary hazards from coastal storms is storm surge (NJCAA 2014). Storm surge occurs when storm-driven winds push ocean water toward the shore. They can lead to considerable

As the frequency of heavy rainfall events increases throughout the mid-Atlantic region with climate change, the potential for significant riverine and urban flooding and polluted runoff will grow.

coastal flooding and property damage, especially when the surge coincides with the astronomical high tide. In addition, the combination of storm surge, tides, and waves can severely erode beaches and damage buildings and critical infrastructure – especially those that are aging and vulnerable.

To date, coastal storms have caused billions of dollars in damage to property and infrastructure, affecting lives and livelihoods in many of New Jersey's coastal communities (Halpin 2013). Rising sea-levels and increasingly intense coastal storms are likely to exacerbate coastal flooding and storm damage in the coming decades (Horton et al. 2014, Reed et al. 2015). As sea-level rises, storm surge emanates from an elevated base. Already, a rise in relative sea-levels along the Mid-Atlantic coast has increased the probability that the region will experience additional storm surge events comparable to the severity of Hurricane Sandy (Sweet et al. 2013). What was considered in 1950 to be a once-in-a-century storm surge now occurs more frequently.

Inland Flooding and Polluted Runoff. While a combination of factors, including land use and flood controls, can affect riverine and urban flooding risks to communities, those risks are largely driven by heavy rainfall and rapid snowmelt. Indeed, inland and coastal flooding is one of the most significant hazards to New Jersey communities. Since the mid-1950s, the majority of New Jersey's Major Disaster Declarations were associated with flood events (FEMA 2016).

Development situated in floodplains is especially vulnerable. Although New Jersey has strengthened its floodplain management efforts, including requiring all new structures to be constructed at two feet above base flood elevation, development continues in hazard-prone areas (NJDEP 2011). Development as much as hundreds of miles inland can exacerbate flooding downstream in coastal communities because it removes forest cover and other habitats that naturally attenuate flooding by capturing and storing rainfall (NJDEP 2016d).

In addition, built infrastructure can aggravate flooding. Construction of dikes or levees for flood control in one area can lead to increased flooding in other areas. In urban communities, where there is a concentration of roads, parking lots, and

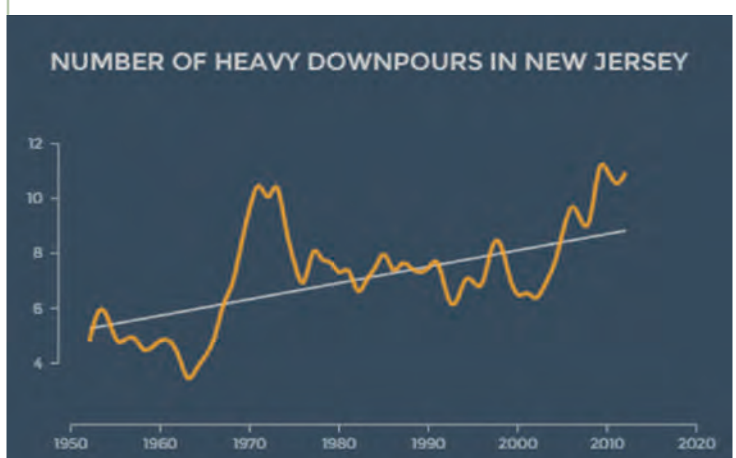
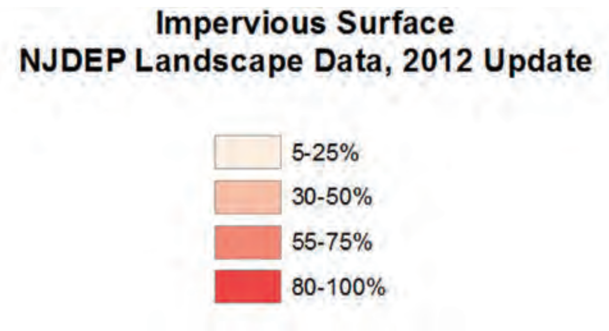


Figure 3. Heavy downpours are on the rise in New Jersey and throughout the mid-Atlantic region. Heavy downpours defined as days where total precipitation exceeded the top 1 percent of all rain and snow days in the study period.

Graphic courtesy of Climate Central



other areas covered by impervious surfaces, heavy downpours and runoff can overwhelm stormwater infrastructure that was not designed to accommodate such extreme rainfall levels. Moreover, when increased runoff does spill into our waterways from urban, industrial, and agricultural areas, it can carry a range of pollutants, including metals, suspended solids, hydrocarbons, pathogens, and nutrients (NJDEP 2016e).

As the frequency of heavy rainfall events increases throughout the mid-Atlantic region with climate change, the potential for significant riverine and urban flooding and polluted runoff will grow (Melillo 2014). Here in the Northeast, the frequency of heavy rainfall events (i.e., when more than 2 inches of rain falls within a 48 hour period) already has increased by nearly 75 percent since the late 1950s (Horton et al. 2014). This is quite apparent in New Jersey's increasing heavy precipitation trends (Fig. 3).

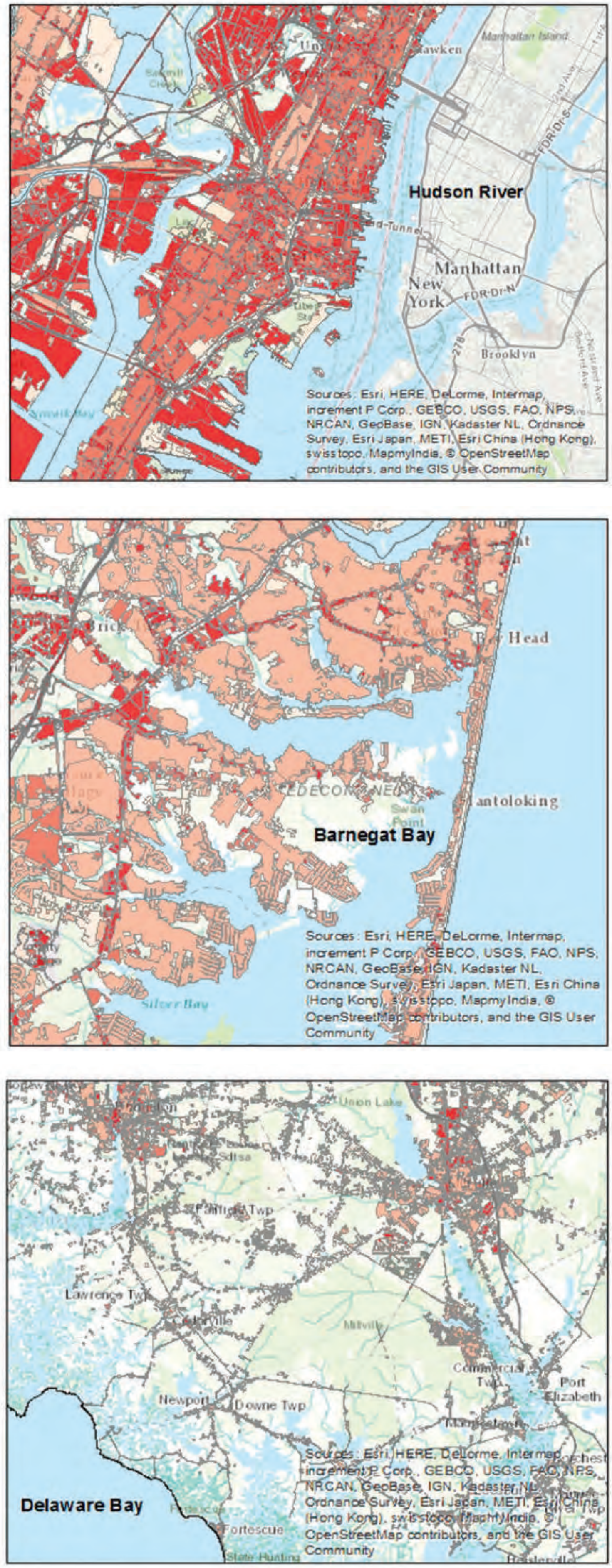


Figure 4. New Jersey coastal communities range dramatically in their amount of paved, impervious surface cover. Those with high amounts of impervious surfaces are exposed to more extreme heat and flood risks and should explore ways to reduce impervious surfaces and increase shade and permeability across the landscape, using native vegetation.

Map: Stacy Krause

As human development has increased along New Jersey's shorelines, coastal erosion has become a significant problem in many areas.

Photo: Stacy Small-Lorenz

Shoreline Erosion. Erosion is the breakdown and loss of materials such as soils, sand, and vegetation along the shoreline. Erosion can result from natural processes (e.g., waves, tides, and wind) and human activities (e.g., wake from watercraft, hard structures in erosive areas). It can occur gradually over time or episodically from events such as storms (NOAA 2016a).

Natural coastal systems can be highly dynamic. Erosion in one area may be offset by sediment deposition and land-forming in another area, from season to season and from one storm to the next. However, as human development has increased along New Jersey's shorelines, coastal erosion has

Hard armoring such as seawalls, groins, and bulkheads, which are intended to protect coastal property, can actually worsen erosion locally and on adjacent lands.

Photo: Steven Jacobus

become a significant problem in many areas. More than a quarter of New Jersey's Atlantic beaches are severely eroding (Cooper et al. 2005).

Rising sea-levels and more intense storms are likely to exacerbate erosion in many areas. Based on current trends, a conservative prediction for sea-level rise of 1 foot could cause areas of the New Jersey shoreline to recede through erosion by as much as 120 feet (Zhang et al. 2004). In addition, heavy rainfall or snowmelt can trigger landslides in higher elevation locations like Atlantic Highlands, by oversaturating unconsolidated soils on steep slopes.

In addition to putting property and infrastructure at risk, erosion can diminish coastal habitats, particularly in areas where human activities have limited natural sources of sediments or stabilizing vegetation. Furthermore, hard armoring such as seawalls, groins, and bulkheads, which are intended to protect coastal property, can actually worsen erosion locally and on adjacent lands (Gittman et al. 2016)

Saltwater Intrusion. Saltwater intrusion into coastal freshwater systems – surface and groundwater – has become a growing problem for New Jersey's coastal communities and freshwater ecosystems. This is because multiple factors including sea-level rise, ditching, coastline erosion, drought, and groundwater withdrawals draw saltwater into brackish or freshwater systems (Barlow 2003, Konikow 2013, Masterson et al. 2013). Saltwater is unfit for human consumption, including drinking water, gardening and agriculture. Therefore, saltwater intrusion can result in abandoned wells. Excessive saltwater intrusion into groundwater and surface water can also kill off coastal vegetation, hastening erosion and exposing coastal communities more directly to the forces of wind and water (Barlow 2003).

Excessive saltwater intrusion into groundwater and surface water can kill off coastal vegetation, hastening erosion and exposing coastal communities more directly to the forces of wind and water.
Photo: Stacy Small-Lorenz

Exposure to Extreme Temperatures. As temperatures increase, paved surfaces exacerbate urban heat islands, posing hazards to human health and ecosystems (Bell et al. 2008). Tree canopy alleviates urban heat-island effects, with numerous other benefits, ranging from windbreaks to migratory bird habitat (NJDEP 2014a). New Jersey coastal communities range dramatically in their amount of paved, impervious surface cover. Those communities with the most impervious surfaces are subject to more extreme heat and flooding risks and should therefore explore solutions to reduce impervious surfaces and increase shade and permeability across the landscape with native vegetation (Fig. 4, p 14).

Ecological Solutions for Coastal Communities

As coastal communities rebuild from past storms and anticipate future hazards, it is ever more important to look to the future and manage for changing conditions. As the adage goes, an ounce of prevention is worth a pound of cure. In the face of a rapidly changing environment, we can pro-actively reduce risks to lives and livelihoods in ways that benefit people and nature. Because all communities, rural or urban, sit within larger ecological landscapes that have the potential to buffer communities from coastal hazards, ecosystems and natural features can be an important part of the solution, when properly managed (Bridges et al. 2015, Martin and Watson 2016).

There is growing recognition that emphasizing natural and nature-based approaches for reducing coastal hazards can offer tremendous benefits to society, not just today, but for many years to come (Bridges et al. 2015). In U.S. Army Corps of Engineers parlance, natural approaches are those that rely on existing or restored natural

In a rapidly changing environment, we can pro-actively reduce risks to lives and livelihoods in ways that benefit both people and nature.

Photo: Stacy Small-Lorenz

systems (e.g., wetlands, beaches and dunes, and riparian forests) for their risk reduction and other associated benefits. Riparian forests and floodplains capture, disperse, and store floodwaters to reduce downstream flooding impacts at the coast; intact tidal marshes buffer coastal communities from the forces of water and erosion, while supporting valuable fisheries; beaches and dunes serve as a first-line of defense for New Jersey coastal towns while providing habitat for beach-dwelling wildlife. In contrast to hard or traditional "gray" engineered structures, natural systems have at least some ability to repair themselves from damage and potentially adapt to changing conditions over time, but can also be more dynamic (Sutton-Grier et al. 2015).

Nature-based approaches mimic the risk reduction functions of natural systems but are created by humans (e.g., living shorelines, engineered dunes). These approaches can offer equal or better hazard protection compared to hard infrastructure, while avoiding the negative impacts of the latter (Bridges et al. 2015). In developed areas, the most sustainable coastal resilience strategies will likely be those that integrate both ecological and engineering practices (Feagin et al. 2015, Sutton-Grier et al. 2015).

In this guidance, we refer to a range of natural and nature-based approaches as ecological solutions. In this section, we offer specific actions that municipalities, urban and land use planners, and other stakeholders can take to address specific hazards within our communities. In the following sections, we describe activities related to surrounding ecosystems, including beaches and dunes, coastal forests and shrublands, and tidal marshes that can also improve coastal community resilience.

Waterfront open space is part of Hoboken, New Jersey's coastal resilience planning.

Photo: Steven Jacobus

Land Use Planning and Zoning

- **Integrate climate change, sea-level rise, and projections for coastal ecosystem migration** into municipal master plans, environmental resource inventories, mapping, and related planning and hazard mitigation documents.

- **Develop a municipal open space plan** that considers projected sea-level rise, expands and connects ecosystems throughout the municipality, coordinates with regional open space planning, maintains ecosystem integrity, and incorporates wildlife migration corridors and road crossings.

- **Develop and implement watershed management plans** that consider increasing precipitation trends and coastal flooding projections, aiming to protect and expand hydrological connectivity of wetlands and waterways.

- **Develop overlay zoning** to acquire and manage land as open space, allowing for projected ecosystem migration.
  - Prioritize land acquisitions and open space protections in these zones.
  - Incentivize easements for ecosystems to migrate via overlay zones and non-contiguous density transfers.

- **Establish local development setbacks,** which is a way to keep structures and people out of harm's way while providing ecological benefits. These setbacks from protective ecosystems such as tidal marshes, beaches and dunes, and maritime forest-shrub systems can help mitigate hazards such as sea-level rise, nuisance flooding, and storm surge and don't have to be limited to state requirements.

- **Establish/enhance minimum requirements for design features** (such as structure elevation) and siting that will maintain public safety and services during extreme events but that do not adversely affect nearby habitats or disrupt ecological processes, for example, damaging native vegetation or blocking flows of water and sediment.

- **Consider moving, elevating, or removing property and infrastructure in hazard-prone areas** to reduce risks to people, particularly in cases where it may not be cost-effective to continue rebuilding infrastructure as flooding increases in the future. Also accommodate for habitat migration in response to sea-level rise and other coastal processes.
  - Community buy-out programs such as the Blue Acres Floodplain Acquisition program can support such efforts.
  - Support and prioritize habitat restoration in those areas to enhance community benefits such as recreation, flood attenuation, and groundwater recharge, while sustaining fish and wildlife species.

Strategically placed nature-based features, such as constructed wetlands, can reduce flood risks for surrounding communities.

Photo: Stacy Small-Lorenz

- **Consider wildlife movements, culvert capacity, and road crossings** in infrastructure design and land use planning.

Conservation Practices

- **Reduce reliance on or re-design engineered hard structures,** such as seawalls and bulkheads, to reduce erosion impacts and improve ecosystem function, such as allowing for sediment transport.
  - Inventory shorelines by type and condition and develop mitigation priorities for erosion, flooding, and habitat migration.
  - Identify and assess hard-armored shorelines that may be "softened," removed or re-designed to minimize erosion and scour.
  - Use mapping tools to identify where current and potential development impedes coastal ecosystem migration and accretion from sea-level rise.

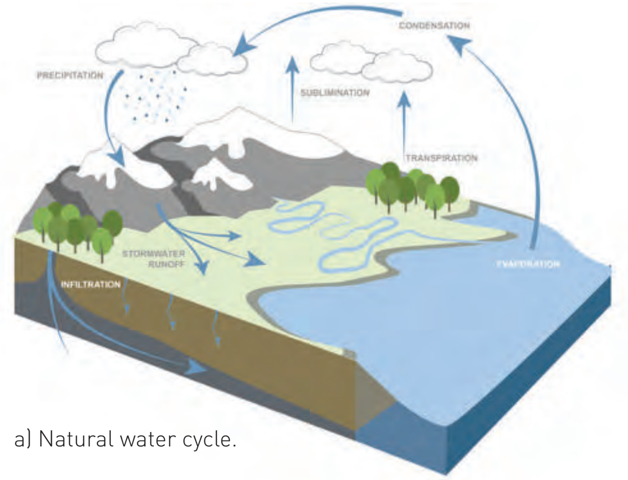
- **Encourage restoration of natural systems or use strategically placed nature-based features,** such as living shorelines, as more natural alternatives to bulkheads in strategic areas, where they may buffer coastlines from erosion, while supporting habitat, recreation, and other valuable services.
  - Reduce regulatory barriers and create incentives for using natural and nature-

based features for shoreline protection. One state-level example is New Jersey's permit fee waiver for living shorelines (State of New Jersey 2016).

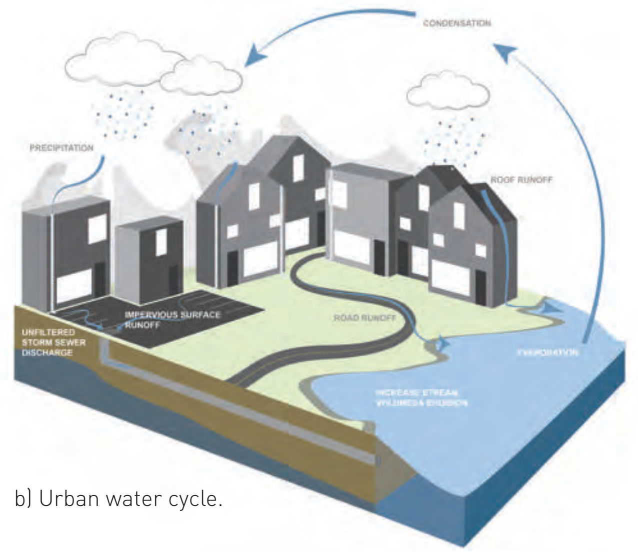
- Purchase and designate coastal land as open space for multiple uses, such as recreation, flood attenuation, conservation, and groundwater infiltration while honoring key ecosystem needs.
- Promote programs and initiatives that reward use of natural and nature-based features to reduce coastal flooding and erosion, such as the online tool, Getting to Resilience, made available through the New Jersey Resilient Coastal Communities Initiative and the Sustainable Jersey certification program. The Federal Emergency Management Agency's Community Rating System creates another opportunity to promote open space and natural infrastructure (FEMA 2015).

- **Facilitate practices that reduce the volume and rate of runoff** to help alleviate flooding and water pollution associated with heavy precipitation events.

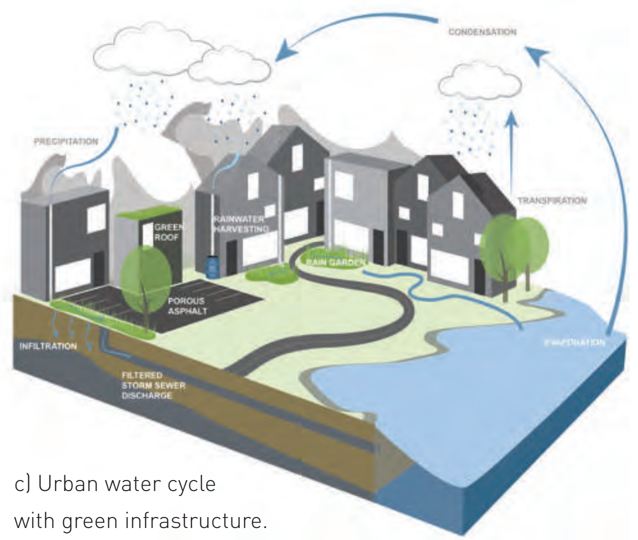
- **Require Low Impact Development (LID) strategies** for all existing and future development projects to manage rainwater where it falls, rather than directing it to the nearest storm drain (Fig. 5) Refer to resources such as the New Jersey Stormwater Best Management Practices Manual for recommendations (NJDEP 2016e).
    - Establish additional buffer zones around waterways and coastal natural areas beyond current state requirements to accommodate more extreme events. In particular, evaluate buffer zones for effectiveness, and incorporate relevant climate change projections into project location and design.



a) Natural water cycle.



b) Urban water cycle.



c) Urban water cycle with green infrastructure.

Figure 5. a) Natural water cycle; b) Urban impervious surfaces can lead to polluted runoff into rivers, bays and streams; c) Urban green infrastructure, such as native tree canopies, rain gardens and green roofs, can help alleviate polluted runoff, especially as heavy precipitation increases.

Graphic: Rutgers Cooperative Extension Water Resources Program

- Encourage and incentivize the use of rain barrels and green roofs to facilitate stormwater management and re-use.
- Increase tree canopy by retaining, protecting and planting native coastal tree species on public and private lands. In addition to helping retain water, shade trees and shrubs can provide other benefits, such as moderating temperatures in urban areas during heat waves, retaining soil moisture, and providing habitat for birds and other wildlife.
- Inventory, inspect, and test function and pollutant loads in stormwater basins to reduce polluted runoff in the face of increasing heavy precipitation. Ensure that stormwater basin capacity accounts for future projections of heavy precipitation and flooding.
- Improve the infiltration and pollution-removal functions of existing stormwater basins.

- **Encourage groundwater protection and conservation** to reduce the risk of saltwater contamination due to sea-level rise and groundwater overdraft.
  - Establish voluntary or regulatory groundwater conservation programs aimed at maintaining aquifers at levels adequate to minimize saltwater intrusion and land subsidence.
  - Enhance efforts to increase the amount of freshwater added back into the groundwater (i.e., groundwater recharge) through LID strategies designed to accommodate increasing precipitation and floodwaters.
  - Incentivize rain gardens and bio-swales using native vegetation to facilitate groundwater infiltration and create habitat.
  - Encourage restoration and expansion of native vegetation in both upland and flood-prone areas to reduce runoff into bays and rivers and to help recharge groundwater.

Open space setbacks, combined with native vegetation, provide storm buffers, habitat, and a whole host of ecosystem services to coastal communities.

Photo: Steven Jacobus

When choosing plants, consider native species that are more likely to be resilient to changing climate conditions. In addition, consider supporting native seed banks to help restore and re-vegetate areas damaged by storm events.

Public Education and Outreach

- **Encourage residents to adopt native demonstration gardens** and take responsibility for planting and maintaining them for water infiltration and habitat. Also, encourage residents to take responsibility for long-term monitoring and maintenance of living shorelines and other restoration projects.

- **Promote understanding of native vegetation benefits.**
  - Engage community groups to inventory and map natural systems, including trees and shrub cover.
  - Develop native species planting lists and support species diversity.
  - Develop outreach programs and ordinances that discourage or restrict the use, sale, or transport of invasive, non-native species that impair ecosystems.

- **Recognize and reward private landowners** who demonstrate excellent stewardship of coastal ecosystems.

- **Educate property owners about CDC-approved, ecologically sound personal protection measures that can be taken to reduce disease risk from container-breeding mosquitoes around homes and businesses**, in order to reduce public pressure on wetlands **(CDC 2016b).**

- **Raise awareness and stewardship of wildlife crossings.**

Water conservation garden in Cape May City, New Jersey.

Photo: Stacy Small-Lorenz

Decision Support Tools

Determining which solutions are appropriate for your community, as well as when and how to apply them, may seem daunting. A number of decision support tools are available to help your community get started.

Coastal Vulnerability Assessment (CVA). The Municipal Coastal Vulnerability Assessment (CVA) is both a process and tool to help communities make incisive and sound decisions on near and long-term coastal management, restoration, and resiliency measures. The CVA categorizes the degree to which a community's assets (e.g., built, natural, social, etc.) will be impacted by projected sea-level rise and storm events, and analyzes the consequences those vulnerabilities pose to the community. By accounting for vulnerability and consequences associated with future flood events, local officials will be better informed to make critical decisions regarding land use planning, mitigation, adaption measures, and public investments.

Getting to Resilience. This online self-assessment process is a tool that assists communities to reduce vulnerability and increase preparedness by linking planning, mitigation, and adaptation. Through this assessment, you will find out how your preparedness can be worth valuable points through FEMA's Community Rating System and Sustainable Jersey.

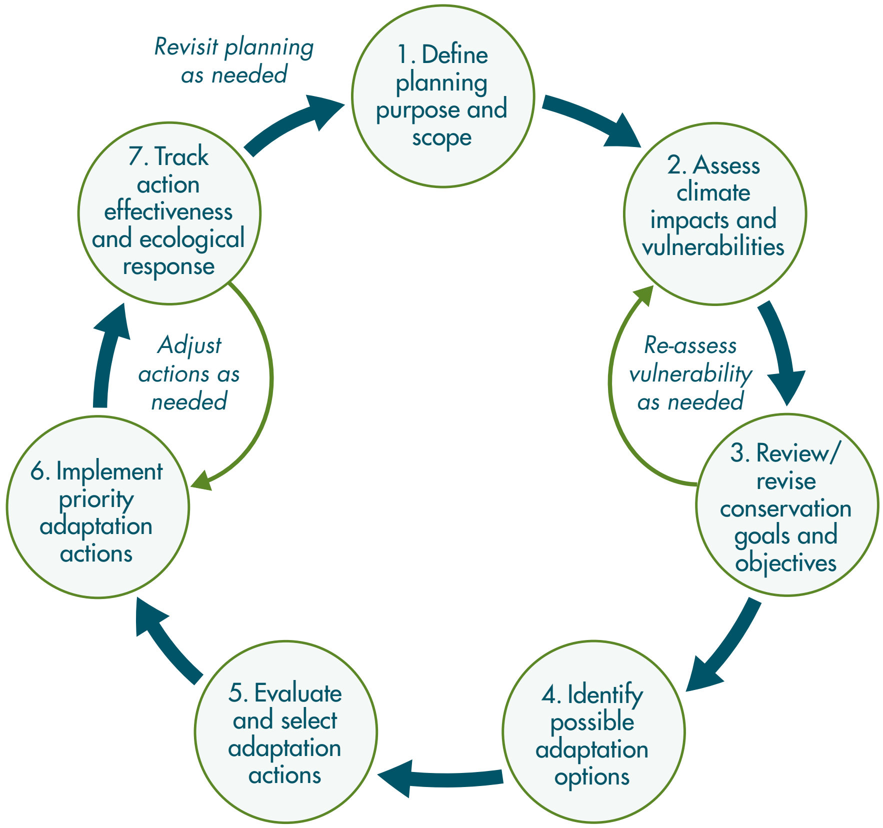


Figure 6. Climate smart conservation planning cycle (Stein et al. 2014).

Coastal Vulnerability Index Mapping. The New Jersey Coastal Management Program developed Coastal Vulnerability Inventory (CVI) maps for New Jersey's entire coastal area, covering 239 municipalities over four sea-level-rise scenarios – present day (2014), 2030, 2050, and 2100. In addition, a CVI-based map was created for each NJ coastal community.

Rutgers Municipal Flooding Hazard Map Products. Municipal map packets are provided for all municipalities in the CAFRA (Coastal Area Facility Review Act) zone. These map packets include maps of coastal hazards, overlaid with critical facilities and evacuation routes.

Climate Smart Conservation. (Stein et al. 2014) presents a 7-step "climate-smart" planning cycle (Fig. 6) that asks users to first state their problem and management goals, then evaluate key climate and non-climate vulnerabilities and re-evaluate goals to ensure that they are "climate-smart."

For example, factoring sea-level rise and increasingly heavy precipitation into land use planning will require planners to think about threats to transportation infrastructure, utilities, freshwater sources (including drinking water) key assets, historical landmarks, and emergency facilities. It may also stimulate thinking about future inland migration of ecosystems and human populations, which may prompt a completely new host of zoning and land use decisions. New climate-smart goals will likely cause a shift away from preserving the status quo. Instead they may facilitate change, accommodate inland migration of coastal ecosystems, establish inland re-development priorities, and protect key cultural and natural assets, while increasing a community's overall adaptive capacity.

The climate-smart cycle encourages planners to think "outside the box" to identify a wide array of innovative solutions to management challenges and then apply criteria to evaluate options, based on practical considerations. The final steps

The climate-smart cycle encourages planners to think "outside the box" to identify a wide array of innovative solutions to management challenges and then apply criteria to evaluate options, based on practical considerations.

are implementation, tracking, and monitoring outcomes, the results of which may inform a revision of the original goals.

It is possible to enter the climate smart cycle at any point. With a goal of increased coastal community resilience using ecologically sound approaches, an excellent first step is to conduct climate vulnerability and ecological assessments of natural features in the landscape surrounding your community. The next step would be to review whether current land use practices, policies and regulations sufficiently consider climate threats and natural resources. Goals may need to be revised to account for the findings of a climate vulnerability assessment (CVA) (Glick et al. 2011).

Climate-Smart Scenario Planning. Used in combination with climate smart planning guidance, scenario planning is a valuable tool that community decision-makers and coastal land use planners can use to envision different but plausible futures (Rowland et al. 2014). It involves strategic planning exercises that consider coastal hazards like sea-level rise, storm surge and precipitation projections alongside other factors of major consequence. They can be especially valuable where uncertainties exist around the timing and magnitude of such future events and exactly how they will interact with other land use decisions. Historically rooted in military strategy and regularly applied to emergency response and natural disaster planning, scenario planning can also help sort out long-term risk reduction, conservation, and land-use-planning options.

It can also help land use and conservation planners identify and organize the most effective options for restoring and conserving the most

Boardwalk at Cape May Meadows. West Cape May, New Jersey, in background.

Photo: Stacy Small-Lorenz

important protective natural features like beaches and dunes, coastal forest and shrublands, and tidal marshes. It can also motivate a community to identify gaps in protection and impediments to ecological processes. The advantage of scenario planning is that it is designed to work with uncertainty and factors outside users' control, while allowing planning teams to identify robust and innovative solutions in a changing and increasingly uncertain climate.

Restoration Explorer. This web-based application, which is one of many on the online Coastal Resilience Tool, empowers communities to visualize what types of "Living Shoreline" techniques may be appropriate at a given location along the coast. Living Shorelines are an alternative approach to shoreline stabilization, using natural elements to buffer the shoreline from the effects of waves and currents. Also included in the tool is the Future Habitat application, which allows communities to better visualize where marshes may be lost in the future and identify areas where marshes could migrate in the future.

Ecological Solutions in Action:

Developed Areas

Hudson County

Hoboken is increasingly vulnerable to flooding from extreme storms, high tides, and overtaxed infrastructure. To address this, Together North Jersey, with funds from HUD, created the Hoboken Green Infrastructure Strategic Plan. This plan establishes a framework for implementing low-impact-development principles and practices to manage stormwater and reduce Hoboken's vulnerability to coastal flooding. The plan focuses on best management practices for green storm water infrastructure that are not only relevant to Hoboken's geography and topography, but are cost-effective and resilient.

This plan divides Hoboken into three zones with particular characteristics relevant to managing stormwater runoff. Gray zones mark stormwater 'detention' areas where above-ground green infrastructure practices, such as rainwater harvesting, should be implemented due to a shallow depth to bedrock. Green zones mark areas of 'infiltration' where stormwater can percolate through bedrock and soil. In these areas, vegetated green infrastructure practices, such as rain gardens and bioswales, will be prioritized. Blue zones consist of 'retention' areas – parts of the city with the lowest elevations that tend to capture and retain stormwater runoff. These areas are more appropriate for practices that retain water, such as constructed wetlands or subsurface storage.

With this plan, Hoboken has created a viable strategic framework for urban resilience that can address the impacts of natural hazards while creating urban wildlife habitat and encouraging residents to adopt ecological practices in their daily lives.

Ocean County

Brick Township's riparian buffer ordinance aligns with New Jersey's wider "State Development and Redevelopment Plan (SDRP)," which calls for the creation and maintenance of riparian corridor buffers near water sources. The ordinance recognizes how critical buffers are for water quality, wildlife habitat and recreation. Following the SDRP, the Brick Township riparian buffer ordinance creates additional requirements that must be followed in the absence of NJDEP or other regulatory agency jurisdiction.

Central to this ordinance is the requirement that "all major subdivisions, minor subdivisions and site plans" implement a 300-foot wide riparian buffer along any waterbodies that fall within these property bounds. Linking with broader ecological solutions, this ordinance strongly encourages the use of native vegetation in the buffers. Further, it prohibits a wide variety of activities that could damage, fragment or disturb the buffer, including: use of fertilizers, pesticides and other chemicals; vehicular traffic and parking; removal of vegetation; waste disposal and facilities; and junkyard, commercial or industrial storage.

Harvey Cedars' fertilizer application requirements, published within their general ordinance code, recognize the adverse impact of synthetic fertilizers on soil and water quality and prohibit the application of fertilizers under certain conditions and timeframes. For example, fertilizer applications on impervious surfaces and during winter months (December 15th through February 15th) are prohibited, as are phosphorous fertilizers (with some exceptions) and the dumping of vegetation debris into "waterbodies, retention or detention areas, drainage ditches or stormwater drains." With this ordinance, Harvey Cedars promotes reduction in water pollution and protection of aquatic life, vegetation, soil and groundwater quality.

Green Infrastructure Strategy for the City of Hoboken. Credit: North Jersey Sustainable Communities Consortium.

Atlantic County

Galloway Township's Green Grounds and Maintenance Policy establishes an "integrated, environmentally friendly approach" to public municipal land management. This approach reflects the municipality's goal of increasing native vegetation on municipal grounds along with green stormwater management initiatives, water conservation practices, and reducing the use of synthetic fertilizers and pesticides. With this policy, the township strives to implement best management practices for low-impact development and serve as a model of ecological stewardship for community residents.

Ventnor City's water conservation ordinance is an excellent example of how municipalities can instill a water stewardship ethic within their communities. This ordinance restricts the use of the city's public water supply for "the sprinkling of lawns, flowers and grass and also for building purposes" to specific times and days during the week. It also prohibits wasting municipal water "by reason of breaks, open valves, open pipes or by any other cause or causes." With this ordinance, the City of Ventnor can more effectively protect its water supply and provide for a more resilient future.

Cape May County

Stone Harbor Boro has implemented a water conservation ordinance restricting the use of the city's public water to certain times and days, with some exemptions for more efficient irrigation systems. Stone Harbor has also acknowledged how their water conservation efforts play into larger initiatives to address drought throughout the state, encouraging its citizens to take up extra efforts to reduce unnecessary water use. Similar to Ventnor, these water conservation efforts position Stone Harbor for a more resilient future.

Salem County

Woodstown's conservation overlay ordinance prioritizes the protection of ecological features and ecosystems in their municipal land use planning. It seeks to minimize fragmentation of ecosystems that are sensitive to, or threatened by, development through the establishment of environmental requirements for public and private developers. By prioritizing biodiversity, threatened and endangered species, ecologically sensitive areas, and connectivity between landscapes, Woodstown exemplifies an ecological approach to land use and development that enhances community resilience.

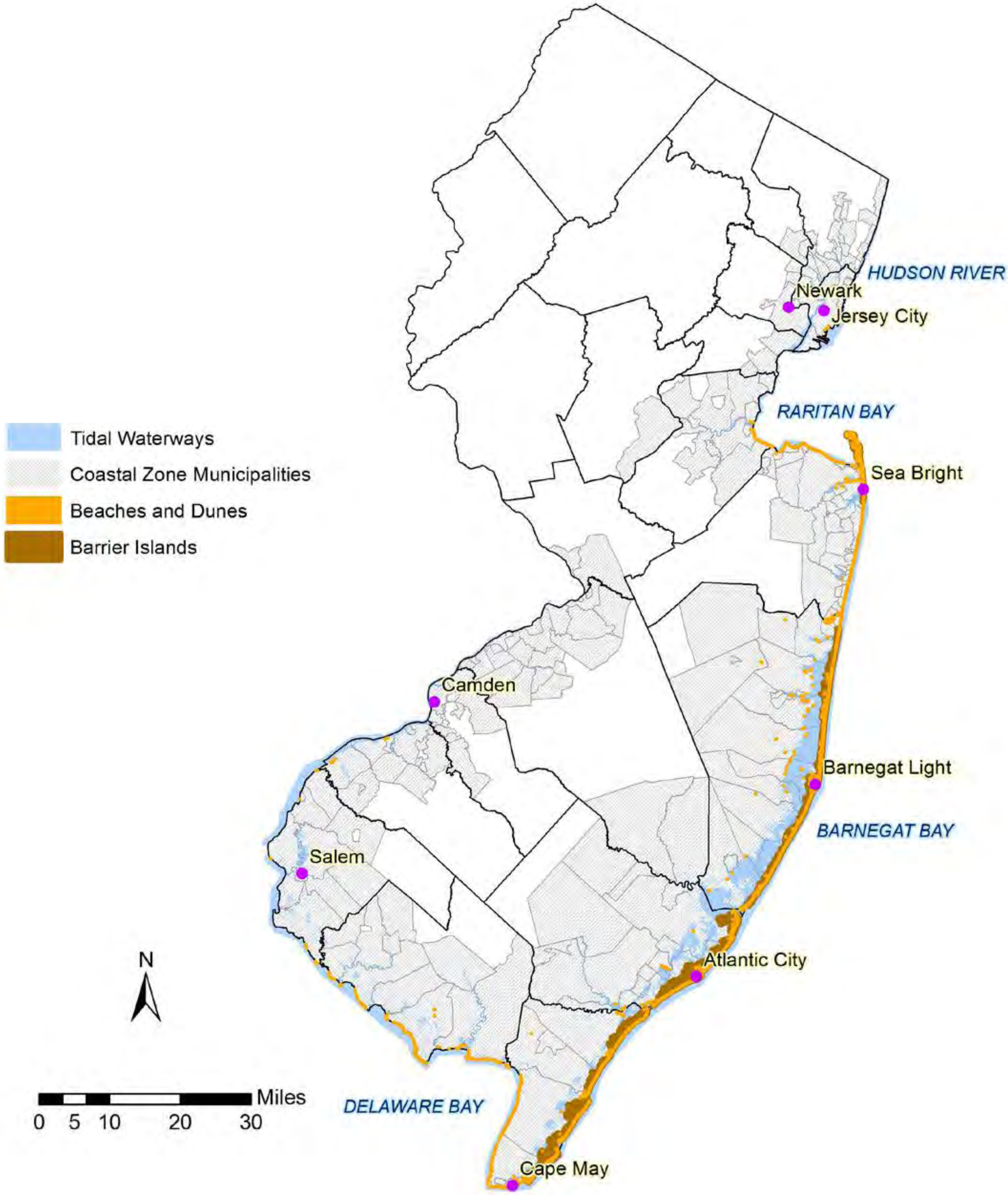


Figure 7. New Jersey beaches, dunes and barrier islands.
Feature data source NJDEP LULC 2012. This map is for informational purposes only.

Beaches and Dunes

Overview of New Jersey Beaches and Dunes

Summer visitors to the Jersey Shore enjoy its seemingly placid and picturesque setting. As vacation season arrives, beach umbrellas sprout up like confetti along the water's edge of popular destinations, and many Americans cherish childhood memories of boardwalk bike rides, saltwater taffy, and dolphins playing in the Atlantic surf.

The history and culture of New Jersey have always been closely tied to its beaches. Well-managed beach and dune systems are vital to its economy, coastal resilience, and biodiversity. Its scenic beaches, which draw millions of visitors from around the world, contribute hundreds of millions of dollars to local economies, while providing wildlife habitat and valuable ecosystem services such as protection and recreation (Costanza et al. 2006).

Based on a picture postcard view of the Jersey Shore, some might assume that New Jersey's famous beaches are usually static and tranquil, but that is not the case. Anyone who has ever had their face sandblasted by a strong Nor'easter wind or even felt the shift and drift of sand around their ankles at the water's edge will realize, at some level, that these are constantly changing environments.

Maintaining permanent cities and towns in such inherently unstable environments calls for a great deal of active management and intentional decision-making that must take into consideration ecological features and dynamics to increase the resilience of the system. For many coastal communities, beaches and dunes serve as a vital frontline of defense against coastal storms, and the beach and dune profile, or topography, plays an important role in the extent of storm exposure a community faces.

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Photo: Stacy Small-Lorenz

Figure 8. Components of a beach and dune system. The beach and dune profile factors into the degree of protection afforded to a community.

Photo: Steven Jacobus

We humans also share New Jersey beaches with increasingly vulnerable wildlife that require beach and dune habitat for their very survival (Appendix 2). These areas host both resident and migratory species from throughout the western hemisphere for nesting, raising young, and fueling up along long-distance migration routes. Therefore, beach and dune management practices have significant consequences for the wildlife that share our beaches.

Sea-level rise, powerful coastal storms, increasingly heavy rainfall events and recurrent nuisance flooding are increasing the awareness of how rapidly the Jersey Shore is changing.

> Check the Regulations

See [Coastal Zone Management Rules N.J.A.C. 7:7](#) for more information.

- ✔ N.J.A.C 7:7-9.1 (Special Areas) Purpose and Scope
- ✔ N.J.A.C 7:7-9.16 Dunes
- ✔ N.J.A.C 7:7-9.22 Beaches

Pro-active planning that recognizes this changing environment and takes into consideration sea-level rise and related factors, in combination with sound ecosystem management, will create a more resilient system for coastal inhabitants, assets, infrastructure and wildlife in the decades to come.

Profile of a Beach and Dune System

The "beach-dune complex" or "sand dune system" refers to a marine beach system and may include a sandy or gravelly beach, foredunes, secondary dunes, backdunes, and any areas of loose sand or gravel deposited by daily wave and wind action (Fig. 8). Sea-level rise, tides, waves, wind and coastal vegetation helped to build New Jersey's barrier islands, beaches and dunes, and these forces will continue to (re)create, erode, and move these features.

Beach and dune profiles vary widely amongst New Jersey coastal communities and even throughout the year, due to human influences and natural forces. Dunes are constantly being fed and protected by the beach, and the dune system protects the land behind it (Beatley et al. 2002). In the absence of barriers and if open space is available, the beach and dune complex may transition gradually into wetland habitat further inland.

Some New Jersey beaches are wide and stable or growing, while others are very narrow and rapidly eroding. Some areas, the majority of Monmouth County for example, lack dune systems, while others have multiple layers of dunes, such as in Barnegat Light or Avalon. In New Jersey, dunes can reach 8 to 15 feet tall and may grow several feet vertically in a single year. Some communities manage dunes by planting vegetation to provide stability and protection from erosion and storm damage (Wootton et al. 2016).

A System in Constant Flux

The geology of the New Jersey Atlantic coast consists mainly of loose deposits of gravel, silt, and sand. New Jersey's famous sand beaches and barrier islands are the product of millions of years of geological activity, sediment movement and deposition. The sediment in Monmouth, Ocean, Atlantic and Cape May County's coastline is unconsolidated and highly dynamic, so it is continually being shaped and re-shaped by wind and water (Sopkin et al. 2014).

A number of factors control the shape of a beach and dune profile. These include beach elevation and topography, vegetation, waves, winds, tides, and currents that are constantly depositing, transporting, and moving loose material from the sea to the shore, the shore to the sea, and between beaches (Brodie et al. 2017). Currents, waves, and wind continuously transport sand along the shore, in a process known as "longshore or littoral drift" (Fig. 9).

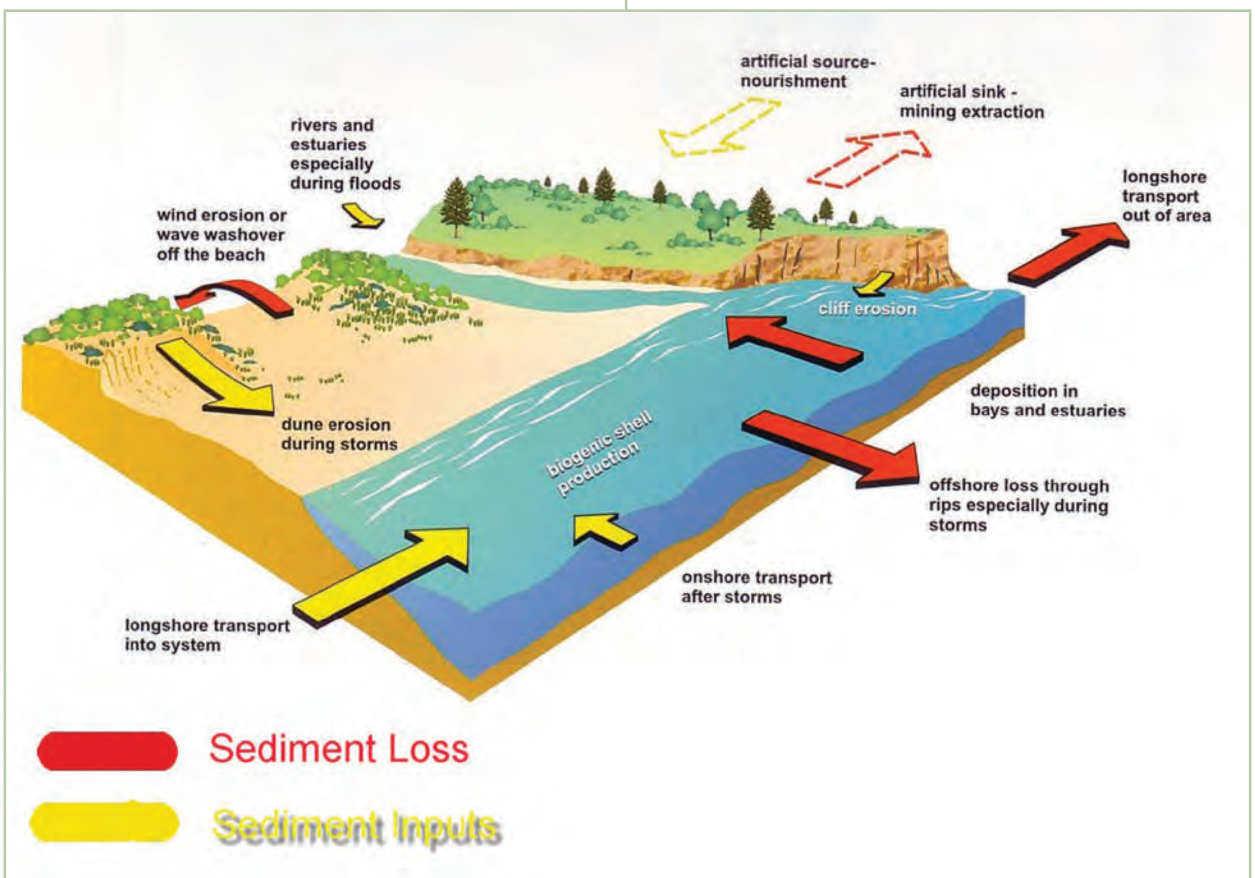


Figure 9. A number of factors control the shape of a beach and dune profile. These include beach elevation and topography, vegetation, waves, winds, tides, and currents.

Credit: Steven Newman, adapted from New South Wales Department of Land and Water Conservation (2001)

Dune evolution is affected by a variety of factors, including the short-term effects of wind speed, precipitation and water levels alongside the sequencing of storm events (Brodie et al. 2017). Storms can significantly redraw the contours of a beach and destroy decades' worth of dune build-up in a matter of hours (Beatley et al. 2002). Over time, sea-level rise has had a profound effect on shaping the shoreline.

Along developed coastlines, hard-armored shorelines can prevent the inland migration of dunes and block some or all of the littoral drift, starving beaches of sand and inhibiting dune building.

Winter beaches typically look very different from summer beaches. Winter is usually a time of beach erosion, with more frequent storms and stronger wave energy, while summer is a time of accretion, with waves generally depositing sand onto the shore. Sand, eroded from the dune during a large storm, may be swept into the surf zone and transported out to bars or carried to a downdrift beach. Beach nourishment projects also influence seasonal beach profiles.

During winter months, natural forces tend to narrow the beach and may cause steep scarps in the dune systems. Winter beaches are generally narrower and lower and often have one or more bars. These bars generally work their way onshore during the summer, restoring the beaches elevation and width.

Season-to-season and year-to-year, dunes will migrate in response to a number of factors, including sea-level rise (Wootton et al. 2016). The shape of the dunes changes with the availability of sand on the beach berm, wind conditions, storm surge and wave action. The seaward toe of the dune typically moves landward in the winter, when erosion is more prevalent, and seaward in the summer, when sand deposition is more prevalent.

Recognizing the protective value of dunes, some communities create a single temporary winter berm by bulldozing sand around structures before storm events. While this provides some minimal measure of storm protection, this approach does not begin to compare to the protection provided by a natural dune system, with its multiple layers of defense and stabilizing vegetation.

Along developed coastlines, hard-armored shorelines can prevent the inland migration of dunes and block some or all of the littoral drift, starving beaches of sand and inhibiting dune building. This accelerates coastal erosion and leads to land loss at the seaward side of the beach, ultimately causing beach contraction.

Barrier Island vs. Mainland Beaches

Beaches in New Jersey can be classified in various ways. Perhaps the simplest classification separates them into barrier island and mainland beaches. While both consist of sand that is influenced by waves, wind and other processes, they do have some distinctions.

Barrier islands are thin strips of land fronted by the ocean and backed by a bay or lagoon. Barrier islands function as critical frontline buffers to the mainland against storm surge, sea-level rise, and erosion.

On a barrier island, a beach and dune system in its natural state typically transitions from simple herbaceous plant communities dominated by beachgrass and seaside goldenrod, to more diverse woody shrub and forest, and then gradually into wetland habitat farther inland. Dunes are continuously being fed, re-shaped, and protected by the beach. In turn, the dune system protects the land and wetlands behind it (Beatley et al. 2002).

Barrier islands bear the full brunt of coastal storms and are extremely dynamic in nature, which makes them inherently risky places to develop. As popular as barrier islands are for tourism and beachfront development, they are always in motion, and efforts to pin them down prove to be a losing battle. Nevertheless, the human desire to put down roots by developing on barrier islands is strong, even with exposure to severe coastal storms. In 2012, barrier islands experienced the full force of Hurricane Sandy impacts in New Jersey (Bilinski et al. 2015).

Mainland beaches differ from barrier islands in that they are connected to the mainland. New Jersey has two predominant types of mainland beach. The first forms at the base of an eroding bluff or upland feature, where the sediment from the bluff is what sustains the beach. To prevent erosion of the bluff, hard armoring structures are often constructed. When this happens, the natural supply of sediment ends and the beach may erode.

The second type of mainland beach is known as a barrier spit and forms as a result of longshore sediment transport. Barrier spits form as the longshore drift moves sediment preferentially in one direction resulting in an elongated sand

Barrier islands are thin strips of land fronted by the ocean and backed by a bay or lagoon. Barrier islands function as critical frontline buffers to the mainland against storm surge, sea-level rise, and erosion.

Photo: Steven Jacocbus

Figure 10. In 2012, Superstorm Sandy breached the barrier island at Mantoloking Bridge and Route 35, joining the ocean and the bay and destroying houses. Over the course of the last 5 years, the recovery has moved slowly. Other coastal communities with strong beach and dune complexes tended to have much less damage.

Photos: a,c,d) Steven Jacobus; b) AP

peninsula. Historically, these barrier spits would commonly break off in a process known as breaching, at which point they become a barrier island.

Accelerated Change is the New Norm

Because of historic sea-level rise since the last glacial period, the New Jersey coastline has migrated inland from its Pleistocene-era (~12,000 years ago) position at the very edge of the continental shelf. Sea-level rise in the 21st century is projected to accelerate this inland migration of New Jersey's Atlantic coastline, with real impacts on its beaches, coastal communities, culture and, potentially, coastal economies

Adding complexity to an already complex system, manmade structures and beach management efforts disrupt natural beach and dune building/ erosion processes, which may exacerbate the effects of sea-level rise and intensifying coastal storms. One can see precedent for this tracing back to the early 20th century, when dunes were leveled and vegetation cleared in some communities, leaving them exposed to powerful storms, sometimes with devastating consequences. Some communities have managed to rebuild while others, such as South Cape May, are gone forever, commemorated only as place names on a map.

When people clear dune vegetation, they often install hard structures in its place, thinking these will provide more stability. Such structures, whether they are groins, seawalls, bulkheads, or development, often dramatically re-shape the coastline locally or downdrift, causing scour as wave energy is deflected, or by blocking sand transport and "starving" neighboring beaches and dunes of sand.

Vegetated dune systems and wider beaches provide protection against storm surge, erosion and inland land loss.

Photo: Steven Jacobus

Protective Values of Beaches and Dunes

Beaches and dunes play a valuable role in protecting communities from coastal hazards such as storm surge, flooding and wave energy (Wootton et al. 2016). Wider beaches and vegetated dunes afford the greatest amount of protection for beachfront communities, in comparison to narrow beaches and no dunes, as evidenced during Superstorm Sandy (Barone et al. 2014).

Beaches reduce coastal storm risk by breaking waves and thereby dissipating wave energy before it hits the dunes and landward infrastructure. In the process, the beach slows the velocity of the water before it hits inland assets, like houses and streets.

Dunes backing a beach can act as additional barriers that reduce flooding and wave energy on the landward side of the dune (Bridges et al. 2015) and hence the landward infrastructure.

While they provide stability, dunes are continuously evolving in response to waves and wind (Bridges et al. 2015). And even while storms may erode dunes, the sand is often deposited just offshore, providing a store of sand for beach recovery in the following season (Bridges et al. 2015).

Vegetated dune systems and wider beaches provide protection against storm surge, erosion and inland land loss. Like hard-engineered shoreline structures, they attenuate waves, but unlike such structures, they also have some capacity to keep pace with sea-level rise as long as there is an available sediment source. This sediment source may either be natural (riverine, bluff erosion, etc.) or anthropogenic (beach nourishment). It has been shown that communities with vegetated dune complexes, engineered dunes, and/or development setbacks behind secondary dunes, combined with wider beaches, were generally afforded greater protection from Hurricane Sandy storm surge than those without (Barone et al. 2014).

Well-established dune vegetation increases the overall strength and integrity of dune systems, helping them withstand storms, wind and wave erosion.

Photo: Stacy Small-Lorenz

Well-established dune vegetation increases the overall strength and integrity of dune systems, helping them withstand storms, wind and wave erosion. Dune vegetation also contributes to land building and erosion control by trapping and holding sand and increasing soil cohesion. At the same time, vegetated dunes serve as windbreaks and storm-surge barriers, while providing habitat for birds and other coastal wildlife (Wootton et al. 2016). There is some evidence that suggests older, more naturally deposited dunes may be more resistant to erosion than newer, artificially created dunes (Bridges et al. 2015).

The formation of coastal dunes is closely linked to vegetation; with time and sediment supply, vegetation directly contributes to dune building (Feagin et al. 2015). When enough sand is present, vegetation typically increases dune height and volume. Plants act as windbreaks, allowing sand to settle and accumulate, while roots help to secure the sand underground.

Grasses are pioneering dune-builders and generally are generally more effective than other plant types at accumulating sand. Dune grasses can even put out roots from nodes when their flexible grass blades are buried beneath sand in storms, creating a root network that helps to capture and hold sand (Charbonneau et al. 2017).

Sea-beach amaranth *(Amaranthus pumilus)* also plays a role. This threatened plant has only recently returned to New Jersey beaches (Kelly 2013). It is a sprawling, low-lying plant, valuable for beach ecosystems in terms of coastal resiliency because its spreading roots provide stability, and its partially buoyant seeds are adapted to move with changing coastal landscapes (NJDEP 2014b). Eventually, forbs and more rigid and sensitive woody vegetation can establish in relatively sheltered backdunes.

Vegetation increases stability of a dune not only by capturing and holding sand, but through biological processes that increase sand cohesion, or the ability of particles to stick together. Plants can add organic matter and increase clay

Sea-beach amaranth contributes to dune building, with spreading roots that provide stability.

Photo: Lilibeth Serrano

Attempts to introduce non-native vegetation to increase dune resilience have often proven to be detrimental, exacerbating erosion or creating unfavorable habitat conditions for native species.

content by trapping fine particles, both of which can increase soil cohesion and reduce dune erosion. Plants also help retain soil moisture in dunes by providing shaded microclimates, which also increases soil cohesion. Finally, symbiotic fungi known as "AMF" (vesicular-arbuscular mychorrhizal fungi) co-occur with the roots of dune vegetation, contributing to soil aggregation and providing an additional measure of erosion control.

Aboveground vegetation adds roughness to the landscape and can reduce the force and velocity of water flowing inland through friction. Stiffer vegetation can dissipate more energy but woody vegetation has a greater chance of being uprooted as that energy is transferred into root systems. Nevertheless, exposed root systems still contribute to landscape roughness and wave energy dissipation. Plants adapted to sandy dune habitats not only survive, they tend to thrive with disturbance from wind and waves. (Feagin et al. 2015)

Native vegetation therefore plays a key role in shaping beach profiles and influencing coastal resilience, through both physical and biological processes. The resulting elevation gains, increased dune stability and vegetation structure itself provides a layer of coastal protection from the forces of wind and water. Attempts to introduce non-native vegetation to increase dune resilience have often proven to be detrimental, exacerbating erosion or creating unfavorable habitat conditions for native species (Feagin et al. 2015).

Although natural systems have relatively greater capacity to self-repair than hard, rigidly engineered "gray" infrastructure like bulkheads and seawalls, it will not always be to the exact specifications (e.g., location, configuration, beach profile) desired by a community or needed by beach-dependent wildlife in a given location. Beaches and dunes take time to self-regenerate, which oftentimes necessitates active beach and dune planning and management action to meet recreation, community protection, and wildlife needs.

There is also a need to explore hybrid systems that incorporate some structural elements with the more natural elements of beaches and dunes. While some locations have attempted to design seawalls and bury them in sand, there is still not enough research on how these combined systems perform to draw definite conclusions; more investigation is needed. Another concept is to promote setbacks for new structures on the landward side of dunes or to increase elevation in accordance with National Flood Insurance Program (NFIP) standards in order to try to spare structures from the hazards of coastal storms (Barone et al. 2014).

Key Vulnerabilities of Beach and Dune Systems

Beaches and dunes can be considered "sacrificial" features that protect communities by absorbing wave and storm surge impacts during major storms. The amount of protection yielded depends on factors including storm characteristics, geomorphic landscape context, and configuration of beach & dune features. Specific performance factors include berm height and width, beach slope, sediment grain size and supply, dune height, width and volume, and the presence or absence of vegetation.

Destructive waves and storm surge from Hurricane Sandy severely eroded many of the beaches that served as frontline defense for New Jersey's coastal and back-bay communities. However, wide beaches combined with vegetated dunes offered effective protection to people and property, in places (Barone et al. 2014, Sopkin et al. 2014). In subsequent coastal storms Joaquin and Jonas, beaches and dunes continued to prove their worth, as they bore the brunt of the storms' energy in communities that had established beach and dune buffers with ample development setbacks.

Poorly designed hard infrastructure, such as rock groins, jetties, or sea walls, that have been implemented with the intention of holding a beach in place, are actually capable of doing damage by disrupting the natural flow of sediment, which can starve beaches and dunes of sand and hasten downdrift shoreline erosion (Stansfield 1998). The field of coastal engineering is evolving, however, and new concepts are

Hard infrastructure designed to hold beaches in place can also disrupt the flow of sand and hasten downdrift shoreline erosion.
Photo: Steven Jacobus

being considered. Many of them combine natural features and traditional engineering. For example, coastal engineering re-designs that allow for some sediment transport through notched groins have been tested with some success along the northern New Jersey coast.

Managing for Beach-dwelling Wildlife

Beaches and dunes also provide habitat for numerous beach-dwelling species, some of are the state's most vulnerable species, including beach nesting birds, migrating shorebirds, horseshoe crabs, diamondback terrapins and occasionally sea turtles, and northeastern beach tiger beetle.

According to the NJ State Wildlife Action Plan (NJDEP 2008), the largest threats to New Jersey beach and dune habitats and associated wildlife are sea-level rise, development, and human disturbance (direct and indirect). Human and recreational activities, such as beach raking and off-road vehicles, can destroy the integrity of the dunes by disturbing the sediment and vegetation (Kelly 2014, 2016).

It is possible to manage for recreation, community protection, and wildlife habitat simultaneously by applying foresight and best management practices for wildlife. At first glance, managing beaches and dunes for humans and wildlife may seem inherently contradictory. However, there are some outstanding examples of New Jersey coastal communities where beaches and dunes are being managed for a triple win of storm and erosion protection, recreation, and wildlife habitat.

Rather than viewing wildlife as a detraction from their beaches' recreational value, coastal New Jersey communities like Cape May City, Cape May Point, Stone Harbor, Avalon, Brigantine, Monmouth Beach, and Belmar treat wildlife as an asset. These and other coastal communities have embraced their role as habitat stewards and have enjoyed meaningful returns (Small-Lorenz et al. 2016). In the case of Avalon, this includes insurance rate discounts and stellar bond ratings. Cape May City's tourism season has expanded well beyond summer in the form of extended "eco-tourism" seasons, as wildlife enthusiasts are

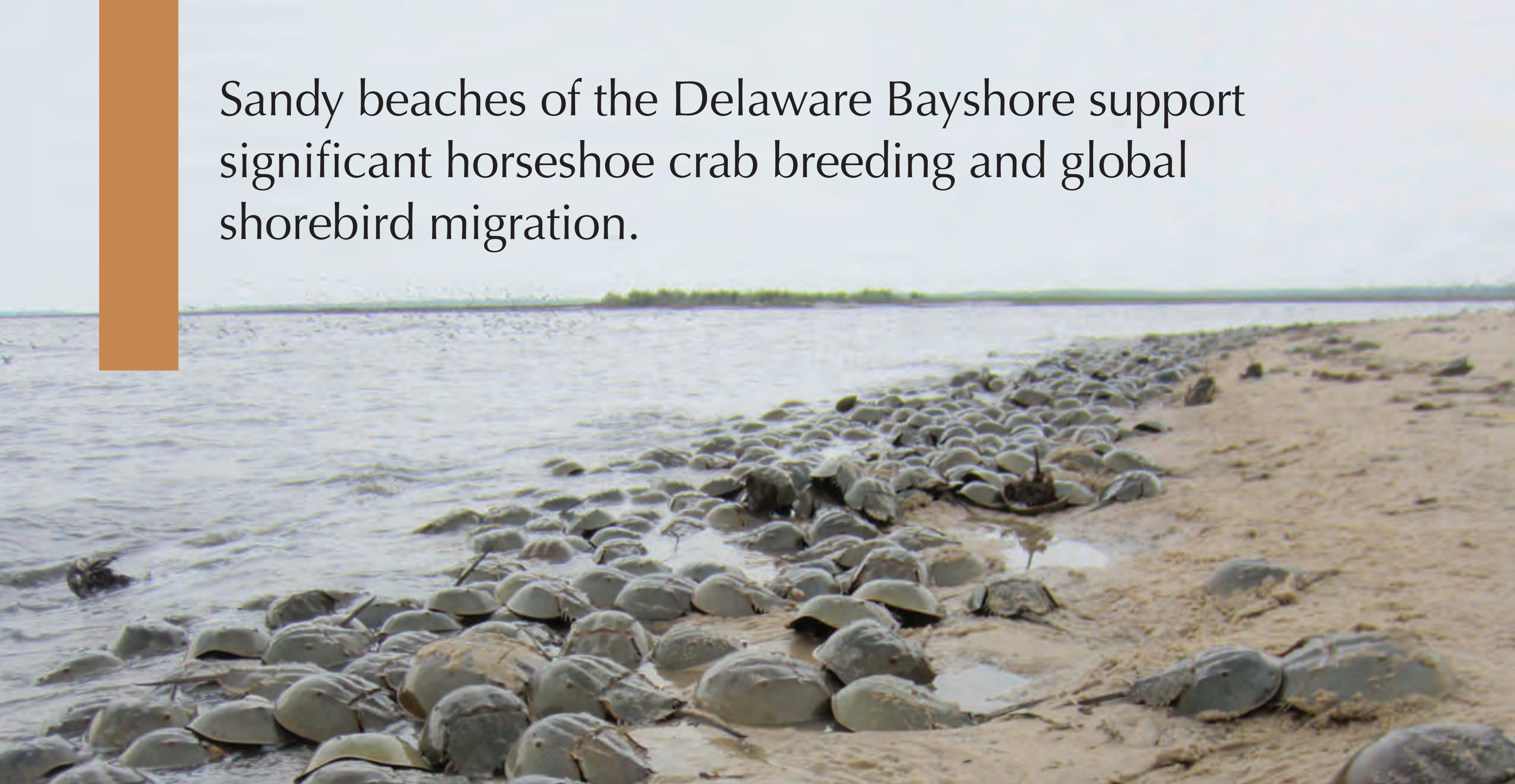
It is possible to manage for community protection, recreation and wildlife by applying foresight and best management practices for beach-dwelling wildlife.

Top: American Oystercatcher, *Haematopus palliates.*

Photo: Kat Vitulano

Bottom: Piping Plover, *Charadrius melodus*.

Photo: Dave Frederick



Restoring or creating beaches and dunes for recreational or risk reduction purposes may attract wildlife of conservation concern, so it is important to plan in advance how to accommodate species' needs while meeting project goals.

Photo: Bill Shadel

attracted from around the world to view migratory birds, butterflies, and marine mammals for over 10 months of the year.

Sand-overwash beaches of the Delaware Bayshore support significant horseshoe crab breeding and shorebird migration of global significance. New Jersey beaches & dunes also host nesting black skimmers, least terns, piping plovers and migrating shorebirds like red knots & whimbrels.

Restoring or creating beaches and dunes for recreational or risk reduction purposes may attract wildlife of conservation concern, so it is important to plan in advance how to accommodate species' needs while meeting project goals, to avoid creating ecological "traps" that draw in sensitive species but don't support their survival and reproduction.

Be aware of specific threats to beach and dune habitat, and the wildlife that depend on it (NJDEP 2008). These include:

- **Efforts to stabilize barrier islands with hard armoring,** including jetties, groins, bulkheads, and intensive dune management (including excessive dune fencing and unnecessarily dense beach grass planting where adequate storm protection already exists), interfere with sand transport needed to create and maintain habitat for beach dwelling species.

- **Dense coastal development** can eliminate and block access to beach and dune habitat and prohibits natural inland dune migration.

- **Sea-level rise** may completely alter the coastal landscape. Habitat will require time and space to migrate inland in response.

- **Vehicle use on beaches** disturbs and harms nesting birds and shorebird flocks, damages foraging habitats, can destroy habitats for northeastern beach tiger beetles. Recreational vehicles on beaches can also crush horseshoe crab eggs (USFWS 2006).

- **Recreational use of some beaches can disturb beach-nesting birds and migrating shorebirds, unless a strategic and balanced beach management plan is put into place** that takes into account both recreation and wildlife needs. Millions of people use New Jersey beaches every year, which can take a heavy toll on sensitive beach nesting species like piping plovers. In addition, it can destroy emerging vegetation, such as sea-beach amaranth (Kelly 2014, 2016).

- **Mechanical beach raking** during migration and nesting seasons reduces foraging habitat for beach nesting birds and migratory shorebirds. It also destroys breeding habitat for northeastern beach tiger beetles and can destroy habitat for rare beach plants, such as sea-beach amaranth (Kelly 2014, 2016).

- **Shoreline modifications** can prevent horseshoe crabs from reaching their spawning areas, or strand them on beaches, unable to return to the sea, leaving them vulnerable to predation.

- **Free roaming pets** disturb nesting birds and can damage and/or prey on nests and chicks. Unleashed dogs may disturb nest sites, leaving eggs and chicks exposed to the elements and predators. Free roaming or feral cats prey upon chicks and other wildlife.

- **Human-associated wildlife** preys upon beach nesting wildlife. Growing predator populations, especially of species that are human-subsidized or accidentally or intentionally provisioned by people (e.g., feral cats, red foxes, crow species, gull species, raccoons, and skunks) impair nesting success and productivity of beach-nesting birds, northern diamondback terrapins, songbirds, and small mammals.

- **Invasive exotic plants** diminish habitat suitability of dunes and reduce the ecological integrity of natural communities. Common invasive species on New Jersey's coasts include the porcelain berry, Japanese honeysuckle and Japanese sedge. Japanese honeysuckle also grows on NJ dunes and beaches.

- **Shoreline hardening,** or "gray infrastructure," usually is intended to protect landward infrastructure and property, but often ignores the function and dynamics of beaches and dunes. However, a certain amount of erosion is part of the fluctuating beach-dune/swale system. Shoreline hardening can solve one problem while creating another, for example, increased erosion and destabilization of adjacent property. While it can stabilize land and protect infrastructure directly upland and inland, it can also result in sediment impoundment, resulting in increased erosion further downstream and passive erosion of the front beach, leading to its eventual disappearance (Snyder and Kaufman 2004). Effective coastal protection balances the local need with the function of the littoral system as a whole.

Shoreline hardening can contribute to beach erosion.

Photo: Stacy Small-Lorenz

Ecological Solutions Involving Beaches and Dunes

The solutions we discuss here incorporate natural features and processes related to beaches and dunes into land management and land use planning. Beach and dune systems yield economic benefits in the form of protection against storm damages and eco-tourism revenue (Schuster 2014). They also yield biodiversity benefits in the form of habitat enhancements and a heightened level of wildlife stewardship.

New Jersey Department of Environmental Protection (NJDEP) regulates dune modification, and communities are encouraged to contact NJDEP in the planning phase of a dune project and to also consult the New Jersey Sea Grant Dune Manual (Wootton et al. 2016). During beach and dune management activities, care should be taken to avoid impairing wildlife habitats. Using best management practices for wildlife can also increase the aesthetic and eco-tourism value of natural features.

Best Management Practices (BMPs) for Beach-dwelling Wildlife

Beach management is not always conducted in a way that is the most sensitive to conserving beach and dunes as habitat. However, best practices for managing beach-dependent wildlife are available. There are some outstanding examples of New Jersey coastal communities taking leadership roles in protecting beach- dependent wildlife while still supporting the beauty, protection, and recreational values of the beach.

Dune stabilization and beach nourishment and management plans should incorporate Best

Dune stabilization, beach nourishment and management plans should incorporate Best Management Practices to do no harm to sensitive beach-dwelling wildlife populations.

Ensuring that beach nourishment materials match the native material is one of several important Best Management Practices for beach dependent wildlife.

Photo: Steven Jacobus

Management Practices (BMPs) to do no harm to beach-dwelling bird populations. These practices may even be codified into local ordinances and implemented through public outreach campaigns and volunteer beach stewardship programs.

Examples of BMPs for beach-dwelling willdife (Rice 2009) include:

- Break up sand fencing to allow for passage of beach nesting birds and other wildlife.
- Use materials for sand fencing that don't provide perches for avian predators.
- Schedule restoration activities outside of nesting season to avoid disturbance to nesting wildlife.
- Maintain buffers around sensitive habitats such as staging and nesting sites:
  - 100 m should be maintained around wading bird colonies, where space allows.
  - 200 m should be maintained around mixed tern/skimmer colonies, where space allows.
  - 100-200 m should be maintained around solitary nests, where space allows.
- Ensure that beach nourishment materials match the native material.

The American Oystercatcher Working Group has published a manual of best management practices for this bird species, which breeds on barrier beaches and back-bay marsh habitats, over-wintering as far north as central New Jersey (AMOYWG 2012).

The New Jersey Field Office of U.S. Fish & Wildlife Service has developed best practices for piping plover and red knot beach habitat (USFWS 2015, 2016). Niles et al. (2013) describe post-Hurricane Sandy beach restoration for horseshoe crab spawning and red knot foraging, including before-and-after photographs of restored beaches.

Red Knots *(Charadrius melodus)* depend on Delaware Bayshore beaches on their long migration journeys. Best practices have been developed to protect their vital stopover habitat.

Photo: Dick Daniels

Types of Ecological Solutions for Beach and Dune Systems

Highest priority strategic actions identified for New Jersey beachfront communities follow, grouped into four broad categories: land use and zoning, conservation practices, public education & outreach, and local ordinances.

Land Use Planning & Zoning

- **Incorporate sea-level rise and projected inland migration of coastal ecosystems into land use and open space planning, including beach management plans.** Beaches and dunes are always in motion and will tend to migrate inland with sea-level rise. Use readily available mapping tools like New Jersey Flood Mapper to visualize coastal migration, and incorporate these projections into future land use planning, zoning, and ordinances (Rutgers 2016).

- **Establish ample development setbacks behind secondary dunes in land use zoning and local building codes that take into account sea-level rise and local projections for inland migration of coastal ecosystems.** Where possible,

Native landscaping is attractive and functional, providing protective storm buffers and habitat for birds and butterflies.

Photo: Stacy Small-Lorenz

cluster development, setting it back from the water's edge with wide natural buffers, significant native vegetation cover, and topographic complexity.

- **Identify points of vulnerability,** such as active erosion, sediment depletion, gaps in landward dunes, low dunes, absence of vegetation, and narrow beaches by surveying beach and dune complexes.

- **Develop climate-smart beach management plans** that address long-term impacts of sea-level rise and coastal hazards.

> Check the Regulations

See [Coastal Zone Management Rules N.J.A.C 7:7]() for more information.

✔ N.J.A.C. 7:7-10 Standards for Beach and Dune Activities

Conservation Practices

- **Promote the use of native dune vegetation in local landscaping** in ocean- and bay-front communities, with the goal of increasing overall native vegetation cover:
  - Protect native dune vegetation and coastal shrub and forest vegetation that is typical of older secondary and tertiary dunes.
  - Establish and protect the full range of dune vegetation communities, age classes, and successional processes from beach grass to maritime forest and scrub communities.
  - Use native herbaceous, shrub and tree plant species to re-landscape sites following efforts to elevate, fortify, or re-locate buildings.
  - Use native dune species as hedgerows around properties, parks and other assets to capture sand and protect against sand deposits onto streets and properties, and to provide an extra layer of protection against storm surge and wind damage.

> Check the Regulations

See [Coastal Zone Management Rules N.J.S.A. 7:7]
for more information

✔ N.J.S.A. 7:7-4.15 Permit-by Rule 15 – placement of sand fencing to create or sustain a dune.

✔ N.J.S.A. 7:7-6.2 General Permit 2 – beach and dune maintenance

- Consider the source and genetic diversity of plant material used in restoration projects and use site-appropriate vegetation to support the evolutionary potential of the dune. Where conditions vary, consider using plants adapted to a range of conditions.

- **Reduce invasive plants** that compete with native vegetation and impair habitat and overall ecological function. For example:
  - Develop and enforce ordinances, with accompanying outreach that discourages or restricts the use, sale or transport of invasive, non-native species that may invade and impair dune vegetation communities.
  - Clean all construction equipment before leaving any site or bringing it to a new site to minimize the introduction of invasive plants.

- **Re-design or retrofit hard infrastructure** in beach and barrier island environments that might contribute to erosion & habitat loss and interfere with sediment transport and vegetation succession.

- **Incorporate wildlife best management practices** into beach and dune management activities, emphasizing community-level actions that protect nesting and foraging areas, protect beach-dependent wildlife from disturbance and predators, and maintain wildlife access to dunes, sand overwash fans, and undisturbed nesting areas.

Examples of BMPs:

- Avoid over-fencing or over-planting beach grasses in foredunes in ways that would block wildlife access for nesting and shelter.
- Allow some sand overwash fans in foredunes to remain undisturbed and accessible for use by beach nesting birds that require open sand for nesting and access to shelter among vegetated foredunes.
- Minimize beach raking during nesting and post-fledging seasons for beach nesting birds and avoid raking the wrack line where shorebirds like Piping Plover forage.
- Seasonal timing can vary by species and location, so consult with wildlife experts to better understand seasonal bird presence and habitat use as it relates to beach management. Develop "Share the Beach" outreach campaigns that promote conservation of beach-nesting birds and shorebirds, highlighting actions that beach visitors should take (or avoid) to protect beach-dependent wildlife.

Share the Beach campaigns can promote conservation of beach-dwelling birds, highlighting actions beach-goers can take to protect vulnerable beach dependent wildlife.

Photo: Stacy Small-Lorenz

- Host beach litter cleanups and litter reduction campaigns that improve beach conditions for human and wildlife visitors.
- Match native sediment type and size when nourishing beaches.
- Predator-proof all public and private outdoor trash receptacles. Establish "carry-in, carry-out" programs, strictly enforce littering ordinances, and actively educate about the harm to wildlife caused by nest predators and plastic pollution.
- Minimize impacts of loose pets, feral cats, and other human-associated predators on beach-nesting birds and migratory shorebirds. Closely manage pets on beaches, feral cats, gulls, raccoons, red foxes and other species that tend to harass or prey upon protected beach-dependent wildlife.

- **Prioritize beach replenishment and dune restoration activities** to fill identified gaps in coastal defenses:
    - Promote ecologically sound beach nourishment activities.
    - Apply best management practices for both coastal resilience and wildlife habitat.
    - Design for continuous secondary, landward dunes with elevated walkovers, instead of cut-through paths, where needed.
    - Plug gaps in secondary landward dunes, where they occur.
    - Explore alternative nourishment strategies including feeder beach concepts, bar nourishments, and mega nourishments that have the potential to reduce negative impacts to coastal habitats and prove to be more cost-effective.

- **Replace cut-through footpaths with elevated dune walkovers** wherever possible to reduce dune erosion and vulnerabilities to storm surge, keeping in mind that an excessive number of crossovers weakens the dune structure and environmental diversity of the dunes. In foredunes, offset gaps can be acceptable and

Replacing cut-through footpaths with dune crossovers can help reduce dune trampling, erosion, and storm surge vulnerabilities.

Photo: Stacy Small-Lorenz

beneficial for wildlife access, especially if the foredunes are not overly fenced.

- **Conserve, restore, and protect native dune vegetation.** Consider ways to restore, create, and strengthen dune complexes that incorporate native, dune-building vegetation and plugs gaps in existing dune formations. Detailed guidance is provided on dune design, plant selection, and planting methods in the [NJ Sea Grant Dune Manual](Wootton et al. 2016).
  - Consider adverse wildlife impacts of selecting non-native vegetation species.
  - Consider the importance of dune vegetation like 'Cape' American beachgrass that captures and retains windblown sand in foredunes. Woody shrubs that grow toward the back of dune complexes in older secondary and tertiary dunes, provide stabilization while acting as windbreaks, in contrast to single lines of temporary, non-vegetated dunes.
  - Consider the dune zone and plant appropriately, as different plant species thrive in different zones of the dune complex.
  - Avoid the mistake of overplanting with a dense monoculture of beachgrass, especially non-native invasive species.
  - Utilize naturally shaped dune complexes in dune-creation projects to achieve the greatest potential community protection and wildlife value. The topography of a dune complex affects its value as habitat. In contrast to linear engineered dunes, natural dune systems are irregularly shaped with complex topography and support a variety of habitat and wildlife.
  - Conserve, restore, or create vegetated dune complexes that can provide several lines of permanent coastal defense and are a lower carbon, lower impact alternative to sole reliance on building emergency dunes with heavy machinery prior to large storms.

Keeping dogs on the leash can help minimize wildlife impacts.

Photo: Stacy Small-Lorenz

Naturally shaped dune complexes with native dune vegetation provide the greatest habitat value.

Photo: Stacy Small-Lorenz

Different plant species thrive in different parts of the dune complex.

Photo: Stacy Small-Lorenz

Establishing vegetated dunes is a more effective and lower carbon alternative to building temporary emergency dunes prior to storms.

Students from Marine Academy of Science and Technology planting dune grass at Sandy Hook.

Photo: Allison Mulch

- Apply beach management best practices for beach-dependent wildlife species like Piping Plover, Red Knot, American Oystercatcher, Black Skimmer, Least Terns and Diamondback Terrapin.
- Allow for recovery of Sea-beach Amaranth, an endangered plant that has only recently returned to NJ beaches, by designating areas free of disturbance (raking, scraping, vehicle access, etc.) during the growing season (May to December) in areas of suitable habitat extending from the toe of the primary dune or edge of established vegetation to the mean high tide line. This sprawling, low-lying plant is valuable for beach ecosystems in terms of coastal resiliency because its spreading roots provide stability and its partially buoyant seeds are adapted to move with changing coastal landscapes.

Public Education and Outreach

- **Establish ecological literacy as a community goal.**
  - Map and inventory the natural systems within and surrounding your community.
  - Provide educational signage and outdoor learning opportunities to promote beach and dunes conservation and advance understanding of surrounding ecosystems, with their many benefits to humans and wildlife (Fig. 11).
  - Pledge to consider ecosystems in all land use planning and local governance decisions.
  - Offer coastal resilience curriculum in schools that explores ecological solutions, available through [New Jersey Audubon.]

- **Establish and enforce local ordinances that protect dunes,** including native dune plants, and beach-dwelling wildlife of conservation concern, in combination with public education and outreach. Volunteer docents can be an enormous asset in reaching the public with conservation outreach messaging in support of local conservation ordinances. Develop creative campaigns to get conservation messages behind local ordinances across to beachgoers.

- **Recognize and reward residents and landowners** who are excellent dune and beach stewards.

- **Participate in coastal community networks** for the express purpose of sharing lessons from beach and dune management.

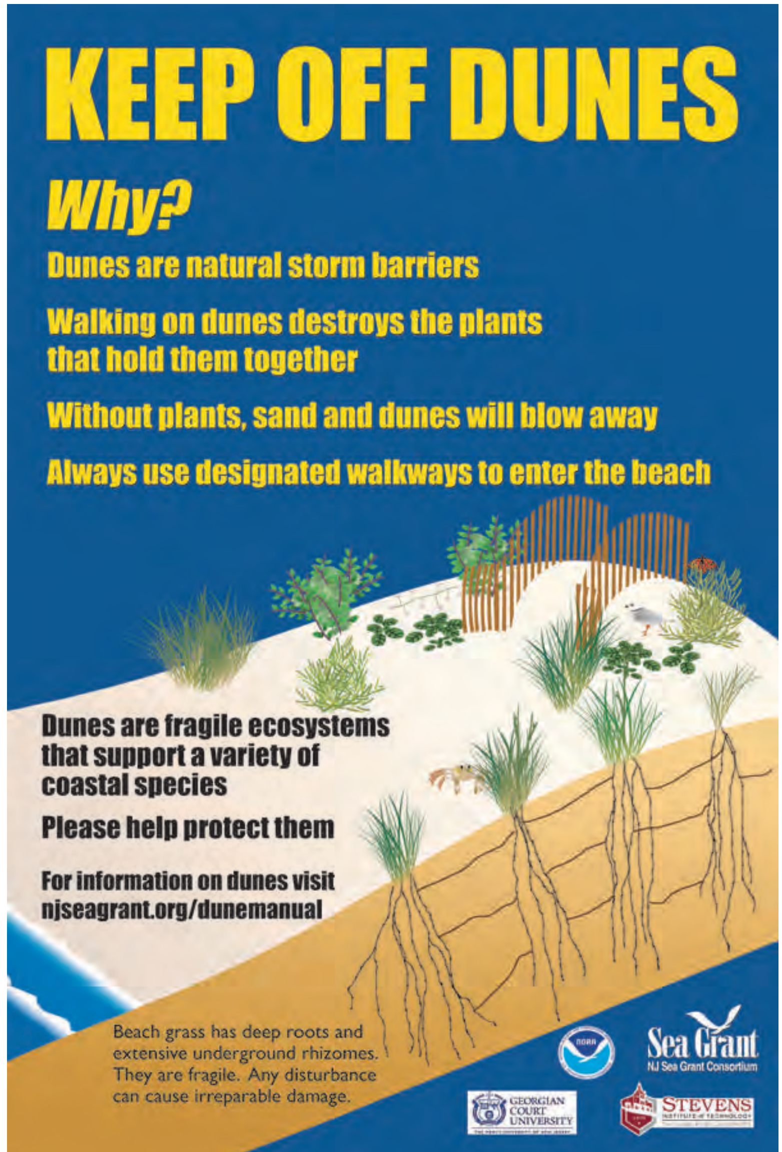


Figure 11. Attractive, educational dune signage is available through New Jersey Sea Grant Consortium.

> Check the Regulations

See [Coastal Zone Management Rules N.J.S.A. 7:7] for more information.

✔ N.J.S.A. 7:7-4.3 Permit-by Rule 3 – placement of public safety or beach/dune ordinance signs on beaches or dunes and placement of signs on the beaches and dunes at public parks.

Ecological Solutions in Action:

Beaches and Dunes

Cape May County

Examples of excellent beach and dune stewardship abound in the barrier island communities of Cape May County, and such efforts have paid off in various ways: extended eco-tourism seasons and financial rewards such as flood insurance discounts and stellar bond ratings. Several that stand out for community-wide open space planning and ecosystem management are Stone Harbor, Avalon, and Cape May Meadows.

Stone Harbor hosts Stone Harbor Point and the Stone Harbor Bird Sanctuary (established by local ordinance), which showcase outstanding examples of coastal shrub and maritime forest vegetation in mature dunes, beach-nesting bird habitat, and tidal marshes. Clustered development set back from the shoreline is buffered by vegetated landscapes from oceanfront storm damages and erosion. Ample walking trails provide residents and visitors alike with abundant recreational opportunities and up-close encounters with nature.

After sustaining severe storm damage where dunes had been flattened in the mid-20th century, the community of **Avalon Boro** embarked on an ambitious dunes restoration program in the 1980's. Now their extensive dune complex supports native vegetation that ranges from beach grass in the younger dunes to mature maritime shrubs and trees in the more mature back dunes. Even on a blustery winter day, the stillness experienced on a walk along their vegetated dunes trail indicates how much of a windbreak the mature dune vegetation provides.

Avalon Boro goes to great lengths to keep sand in the system through annual beach nourishment, which maintains a source of sand for natural dune-building. They also protect native dune vegetation and require native landscaping on properties in or near the dunes, enforced through native plant ordinances and abiding by a forestry plan that is linked to their dunes management plan. Through conscientious maintenance, their dunes continue to grow seaward and have afforded significant protection on the oceanfront side of town against Atlantic storms, by maintaining elevation and preventing erosion.

Historic **Cape May City** has dedicated 3 city blocks by the old Arcade building between Beach Avenue and Decatur Street as a demonstration project to show how to create a diverse, multi-species native dune system. USDA Plants Material Center procured the appropriate native dune plants, such as beach grass, seaside goldenrod, trailing wild bean and saltmeadow cordgrass.

In May 2016, volunteers including representatives from the City of Cape May, the engineering firm Mott MacDonald, NJ Sea Grant Consortium, and the USDA Plants Material Center worked together to get the plants in the ground. The city is working with Mott MacDonald to reopen a walk-over that will provide beach access without impacting the dune system. Cape May has purchased 50 new educational "Keep Off the Dune" signs (Fig. 11). They are also pursuing ecological solutions to address remaining gaps in dune coverage, to prevent oceanfront flooding and sand deposition during big storms on the north end of town.

Ocean County

When a Nor'easter storm flooded **South Seaside Park** in 1992, residents got serious about rebuilding dunes that had been flattened to improve their ocean view. They installed sand fencing and beach grasses so that by the time Hurricane Sandy struck twenty years later, they had protective dunes in place that were 25 feet high and 150 feet wide that minimized water damages.

Midway Beach is a quarter-mile-long community within South Seaside Park. The community began building 25 foot high dunes 30 years ago, using sand fences and beach grass to grow the dune. Only one home in Midway Beach had water damage from Hurricane Sandy.

Dune grass planting at Long Beach Island.

Photo: Linda Weber

Just to the north, **Seaside Heights** suffered significant damage to their boardwalk and pier, where dunes had not been restored. Many will remember the heart-wrenching photographs of their famous roller coaster washed into the ocean.

Monmouth County

Monmouth County Park System has embarked on an extensive dunes restoration project at Seven Presidents Park in **Long Branch**, adjacent to the historic resort and boardwalk area that has been restored since Hurricane Sandy in 2012. The project supports beach recreation, threatened and endangered beach-nesting birds and beach plants, while protecting landward park and community assets. The dunes areas were once residential and municipal recreation complexes, but since dune restoration began in 1983, the dune area has gained 20 feet in elevation and is densely vegetated.

Key elements of park management protect both habitat and community resources. Dune restoration activities continue, with invasive plant removal, sand fencing, and dune grass planting. Park plantings emphasize native species, and beach management practices include post-Hurricane Sandy replenishment and efforts to minimize mechanical beach raking and preserve the wrack line adjacent to sand overwash areas, as Piping Plover habitat.

The community of **Monmouth Beach** has been restoring the dunes in front of their rock sea wall that was damaged in Hurricane Sandy, using sand dredged from Shrewsbury River. Crossovers have been installed in places over the new dunes, which are planted with native beach grass. Monmouth Beach is a popular summer destination for New Yorkers and Least Terns alike, hosting a large nesting colony of this state-endangered bird.

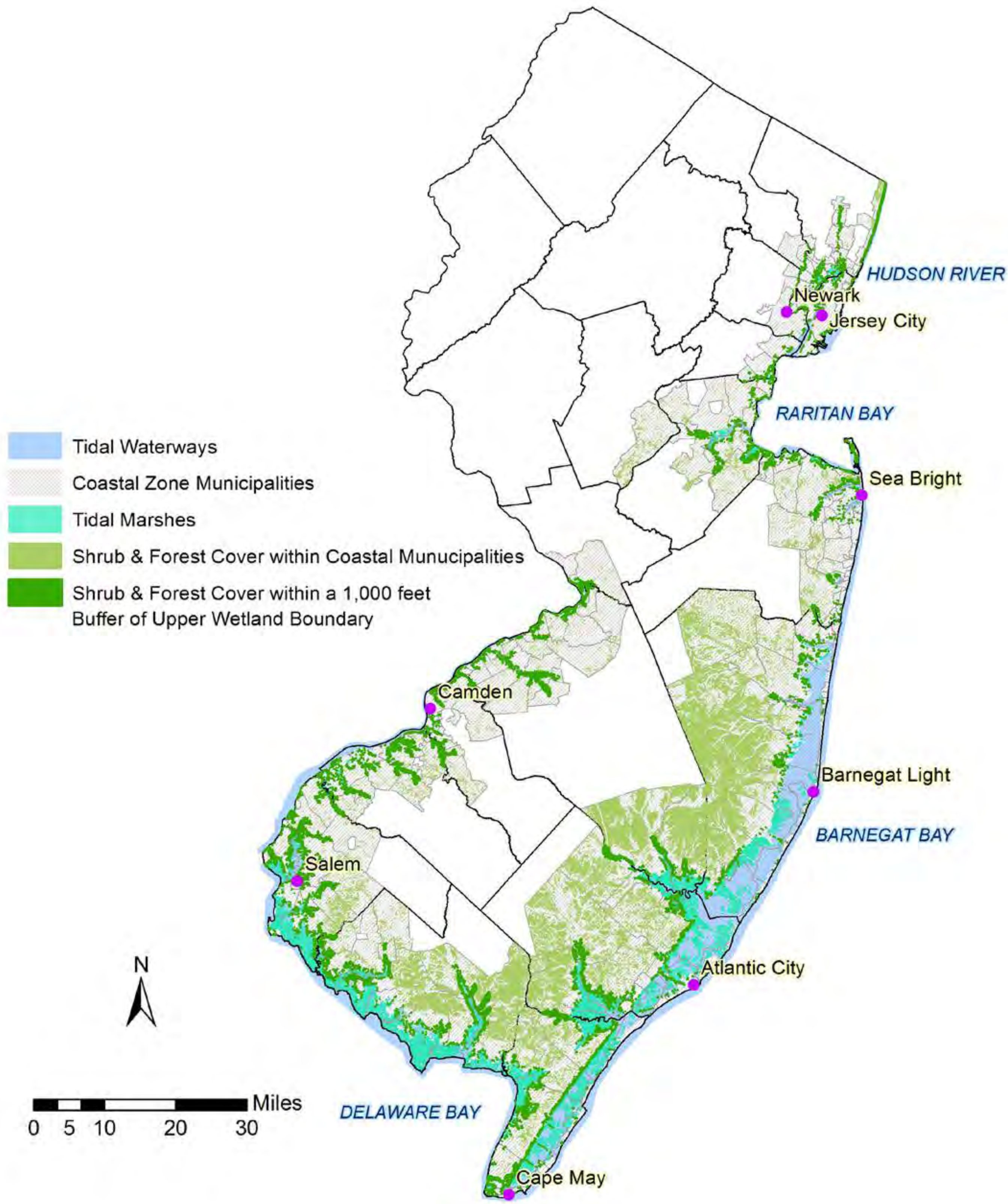


Figure 12. New Jersey coastal forest and shrublands.

Feature data source NJDEP LULC 2012. This map is for informational purposes only.

Coastal Forests and Shrublands

Overview of New Jersey Coastal Forests and Shrublands

Scarce but Valuable Resources

Forest may not be the first thing that comes to mind when one imagines life along the Jersey Shore, but before humans developed much of the coastal uplands, dense maritime forests stood strong and lush on barrier islands and in strands along the coastline within the reach of salt spray. They provided stability against erosion and shelter for countless migratory birds annually.

Much of New Jersey's precious maritime forests and coastal shrublands have been cleared for coastal development, although excellent examples do persist at Sandy Hook National Recreation Area, Island Beach State Park, Forsythe National Wildlife Refuge, and western Cape May County (NJDEP 2008). Remnant coastal forest and coastal shrub cover remains critically important migratory bird habitat (NJDEP 2008).

Such unique coastal shrub ecosystems can be found in dune complexes behind the foredunes, but within reach of salt spray and are characterized by short, "salt pruned" woody plants that may be shrub species or short trees in shrub form. Wind and salt spray from breaking waves on the nearby shore affect the growth patterns of these trees, giving them a sculpted look, sometimes as if they are leaning away from the ocean.

Maritime forest and scrub-shrub vegetation is aromatic and beautifully sculpted by the forces of coastal winds and salt spray. Even in the winter, it has a stillness that can make one forget the close proximity of pounding surf and stinging winds. It is typically characterized by thick vegetation and topographic complexity. Vegetation can

Scarlet Tanager, *Piranga olivacea*, is one of the many migratory songbirds that uses New Jersey coastal forests.

Photo: Francesco Veronesi

Native shrub root systems protect the integrity of dunes and sandy levees by increasing shear strength, trapping clay particles, retaining soil moisture, and contributing organic matter to the sand that increases cohesion.

Photo: Steven Jacobus

include (but is not limited to) eastern red cedar *(Juniperus virginiana),* pitch pine *(Pinus rigida)*, beach plum *(Prunus maritima),* winged sumac *(Rhus copallimum),* American holly *(Ilex opaca),* black cherry *(Prunus serotina),* sassafras *(Sassafras albidum),* northern bayberry *(Myrica pensylvanica)*, serviceberry *(Amelanchier canadensis),* Virginia creeper *(Parthenocissus quinquefolia),* and Virginia rose *(Rosa virginiana)*.

Golden-winged Warbler, *Vermivora chrysoptera*, depends on shrub habitat.

Photo: Mark Peck

Maritime scrub-shrub occurs behind newer frontal dunes, in the more established backdunes. Above ground, its woody vegetation traps and holds sand; underground, its root systems strengthen and stabilize the mature dunes. Native shrub root systems protect the integrity of dunes and sandy levees by increasing shear strength, trapping clay particles, retaining soil moisture, and contributing organic matter to the sand that increases cohesion.

Native coastal shrubs and trees are excellent, attractive choices for **secondary dune stabilization** and landscaping hedgerows, public parks and private properties (Wootton et al. 2016). They are drought- and salt-tolerant, so will typically thrive in coastal communities while conserving water. They are visually attractive spring, summer, and fall. Many native shrubs are suitable for local parks, upland bank stabilization and erosion control projects, and dune restoration projects. Attractive examples can be seen in Belmar, Stone Harbor, Avalon, Cape May City, Cape May Point, and elsewhere.

Protective Values of Coastal Forests and Shrublands

Coastal Forests Provide Shelter from the Storm

New Jersey's coastal forests are critically important stopover and foraging habitat for birds migrating along the Atlantic Flyway (BBP 2010). They also serve as windbreaks in coastal storms, provide erosion protection against the forces of waves, reduce the force of storm surge and related flooding, reducing peak flood height and lengthening time to peak flood (Bridges et al. 2015). They trap sand and debris, buffering against sand and debris deposition onto properties, roadways and natural areas. They contribute to shoreline stabilization and provisioning and storage of groundwater that is the primary source of drinking water for much of coastal New Jersey. Finally, coastal forests and shrublands hold high cultural, spiritual and recreational value and can potentially increase property values.

Key Vulnerabilities of Coastal Forests and Shrublands

Threats and Vulnerabilities

New Jersey's maritime forests and shrublands have suffered widespread clearing for development because they typically occur in places that are desirable for coastal development, upland but close to the shoreline, within reach of salt spray. More recently, saltwater intrusion further threatens this upland coastal vegetation, resulting from erosion, ditching, sea-level rise and inland encroachment of saltwater tides and storm surge, and is contributing to die-off of mature coastal forest stands in southern New Jersey (Titus et al. 2009, Upton 2016).

Saltwater intrusion is contributing to the die-off of New Jersey's coastal forests.

Photo: Steven Jacobus

Yellow-crowned night heron, *Nyctanassa violacea.*

Photo: Kurt Wecker

Clearing and die-off of maritime forests and shrubs accelerates coastal erosion and directly exposes communities to wind and water impacts of coastal storms, as well as sand and debris deposition. Communities where protective shrub and coastal forest buffers have been eliminated will be increasingly exposed and vulnerable to erosion and other storm impacts (Riggs and Ames 2003).

Along with beaches and dunes and back-bay tidal marshes, maritime forest and scrub-shrub is a natural component of barrier islands that helps maintain landform integrity while having high adaptive capacity to barrier island migration (Masterson et al. 2013). Dense barrier island development has eliminated much of the historic maritime forest and shrub cover, in turn leaving barrier island communities exposed to greater natural hazard risks.

Ecological Solutions Involving Coastal Forests and Shrublands

Land Use Planning and Zoning

- **Survey and map coastal shrub and forest patches in your community.** Preserve, restore, protect, create and connect this habitat type wherever possible, using site appropriate native plant species. Identify and protect small and large tracts and areas of high tree/shrub density as storm buffers and habitat. Identify and fill gaps in forest and shrub cover, wherever possible and ecologically appropriate.

- **Map existing open space and projected inland migration of coastal ecosystems in response to sea-level rise.** Designate protected open space to allow space for ecosystems to migrate in response to sea-level rise and establish local zoning to protect coastal forest and shrubland habitat zones.

- **Establish or protect dune vegetation communities and successional processes,** from beach grass to maritime forest and shrub species. Establish development setbacks behind existing dune vegetation stands.

- **Prioritize natural infrastructure for shoreline stabilization purposes,** over new hard armoring.

- **Establish and enforce restrictions on the clearing of native coastal forest and shrub vegetation.**

Along with beaches, dunes and back-bay tidal marshes, maritime forest and scrub-shrub are natural components of barrier islands that help maintain landform integrity.

Photo: Stacy Small-Lorenz

- **Avoid creating or re-engineer existing hard infrastructure in beach and barrier island environments.** Hard infrastructure in these environments can contribute to erosion & habitat loss and interfere with vegetation successional processes.

- **Develop a seed bank of local native plant species** for native landscaping and habitat restoration.

- **Conduct inventories of native trees and shrubs in your community.** Mark and retain native vegetation. Develop planting lists based on native plant communities occurring in local natural areas as reference sites.

Dense barrier island development has eliminated much of the historic maritime forest and shrub cover, in turn leaving barrier islands exposed to greater natural hazard risks.

Stone Harbor Bird Sanctuary hosts an array of birds attracted to its native coastal forest and shrub vegetation.

Photo: Stacy Small-Lorenz

Conservation Practices

- **Establish ordinances and practices** that support establishment, growth and succession of dune vegetation to established maritime shrub and forest cover. Establish and strictly enforce dune-trampling ordinances to allow for establishment and survival of dune vegetation. Prohibit clearing native woody vegetation within dunes and inland.

- **Incentivize and promote landscaping with native maritime forest and shrub vegetation,** where ecologically appropriate. Promote native landscaping through ordinance, outreach/education and incentive programs. Cultivate supply & demand for native plant materials. Use site-appropriate genetic material; where conditions vary, consider using plants adapted to a range of conditions.

- To minimize impacts of saltwater intrusion into groundwater and plant root zones, **establish groundwater conservation and ecological recharge practices.** Conduct groundwater usage audits and establish a strict groundwater budget. Establish groundwater conservation programs aimed at maintaining aquifers at levels adequate to minimize saltwater intrusion and land subsidence, these could range from voluntary to regulatory options: public and school-based education, community groundwater (self)-audits, groundwater conservation incentives, up to metering and regulation. Review policies on groundwater basin transfers. Identify and act upon strategic groundwater recharge opportunities.

- **Incorporate coastal forest and shrub species into stormwater management** practices and incorporate stormwater management into maintenance and management plans for public lands.

- **Train landscape architects and landscape contractors** in principles and techniques for conservation landscaping using native plants and groundwater recharge practices, like rain gardens.

- **Discourage or restrict the use, sale or transport of invasive, non-native species** that impair maritime forest and shrub communities. Actively manage and control invasive species, pests and diseases in existing maritime forest. To minimize the introduction of invasive plants, clean construction equipment before leaving any site and before bringing it to a new site.

- **Minimize impacts of loose pets, feral cats,** and other human associated predators on nesting and migrating birds in coastal forest and shrubland habitat.

Public Outreach and Education

- **Educate the public about the protective and habitat value** of native coastal forest and shrub vegetation.

- **Design and build public demonstration gardens** and native landscaping exhibits with interpretive signage.

- **Develop interpretive signage** in vegetated dunes that explains the value of dune vegetation. See Avalon Boro's Beach & Dune Trail for an excellent example of interpretive signage.

Coastal shrubs can be very bright and attractive in the summer and fall seasons.

Photo: Stacy Small-Lorenz

Ecological Solutions in Action:

Coastal Forest and Shrublands

Historically, coastal forests and shrublands covered New Jersey's barrier islands, typically positioned behind secondary dunes. They also grew in swaths along the shores of our bays and along the coastline of our oceanfront mainland. Since these areas overlap with coastal upland areas desirable for development, coastal forests and shrublands are now among the rarest of New Jersey's coastal ecosystems. However there remain a few very large examples: at Sandy Hook; Island Beach State Park; in Berkeley Township and Forked River, between the marshes and Route 9; in the federal and state lands in and around Stafford Township; and in the western and northern sections of Cape May County. Other smaller but worthy examples can be found in Brigantine, Corson's Inlet, Avalon, Stone Harbor, Diamond Beach, and around the tip of Cape May, between the ends of the Cape May Canal.

Cape May County

Avalon Boro has created and implemented a very sophisticated Community Forestry Management Plan that has been used as a model for other communities in both New Jersey and Delaware. The plan, which has been approved by NJDEP and is carried out by the Boro's Tree Management Committee, contains a Dune Vegetation Management Plan. It encompasses anything from street trees to residential yards to the Boro's extensive dune system. Its actions include inventory and assessment, enhancement, invasive species control, staff and volunteer training, and a "pilot demonstration project to test standards and techniques." One of the plan's outcomes was the restoration of 15 blocks of protective native maritime forest behind its oceanfront dunes, removing invasive non-native trees in the process.

Among the plan's goals are to create an environmental ethic in the community, which is supported by public outreach, recommending suitable native tree and shrub species for private property owners. The species recommendations are aimed at plant survival, minimal maintenance, and water conservation. Having appropriate species used throughout the community helps to ensure that a ready seed source is present to re-plant damaged habitat.

Avalon's plan and actions are a wonderful example of how a coastal community can proactively manage native trees and shrubs for community-wide habitat diversity and storm protection. The Boro credits its extensive dune system, much of which is forested, for protecting the community during Hurricane Sandy.

South Cape May Meadows is a model restored natural area that sits at the site of the former town of **South Cape May,** which was destroyed by storms in the 1950s. The land that hadn't already washed into the Atlantic Ocean was acquired by The Nature Conservancy and restored in the early 2000s in partnership with surrounding communities, Cape May County, U.S. Army Corps of Engineers and NJDEP. The purpose of the restoration project was to create wildlife habitat while protecting the communities of **Cape May City, West Cape May** and **Cape May Point,** which had been flooded by previous storms.

Contiguous with Cape May Point State Park, the Meadows now contains beach and dune, non-tidal freshwater wetlands, and coastal forest and shrubland habitats that support an incredible diversity of wildlife, and it brings in an estimated 313 million dollars in eco-tourism revenue each year from birders who flock to this hotspot. In addition, it succeeded in protecting surrounding neighborhoods from Hurricane Sandy flooding. The restoration project intentionally preserved acres of coastal forest and shrubland, which serve not only as bird nesting and feeding areas, but also as a wind buffer and debris trap for surrounding communities.

Cape May City, among its many ecological resilience practices, hosts a demonstration water conservation garden to teach residents about native drought-tolerant plants that are excellent options for landscaping with less water. Cape Resorts, a local upscale resort chain,

Restoration planting at Fletcher Lake in Bradley Beach, New Jersey.

Photo: Stacy Small-Lorenz

has landscaped their oceanfront properties with native hedgerows that shelter and protect outdoor recreation areas while providing migratory bird and butterfly habitat. They have also conserved farmland inland, protecting open space while producing fresh produce for their local restaurants.

Monmouth County

Bradley Beach hosts a wonderful example of a recently reclaimed area that is being restored to native coastal shrub and forest plantings. Situated near its northern border with Ocean Grove, between the boardwalk and Fletcher Lake, was once a 0.4-acre hard-packed dirt lot. It has been turned into a demonstration planting for residents and visitors to enjoy, complete with interpretive signage.

The project is the result of a unique partnership between government and private entities. It was spearheaded by the American Littoral Society on land owned by the Borough, which adopted the New Jersey Wildlife Action plan pledge just for this project. Monmouth County Department of Public Works and Engineering contributed the heavy construction work. Rutgers Master Gardeners maintains the plantings. The Bradley Beach Arts Council designed the interpretive signs. Several other entities provided technical assistance, labor, and funding.

Although small, this demonstration project provides sorely needed habitat in a densely developed area, reduces stormwater runoff (430,125 gallons of runoff per year), and will trap blown-in debris and sand, reducing the need to dredge Fletcher Lake.

Middletown's Bayshore Waterfront Park (part of the Monmouth County Park System, located on Raritan Bay in Middletown Township) is comprised of coastal forest, dunes, and beach. The park runs parallel to the shoreline, forming a buffer between the bay and a residential neighborhood. The Monmouth County Park System has initiated restoration and enhancement of the existing coastal maritime forest, as well as its dune and beach system, as part of a larger effort for coastal resiliency, in partnership with the Army Corps of Engineers. This intentional management, both protection and restoration, of the coastal forest and other ecosystems, helps protect the neighborhood from hazards such as strong winds, waves, and nor'easters.

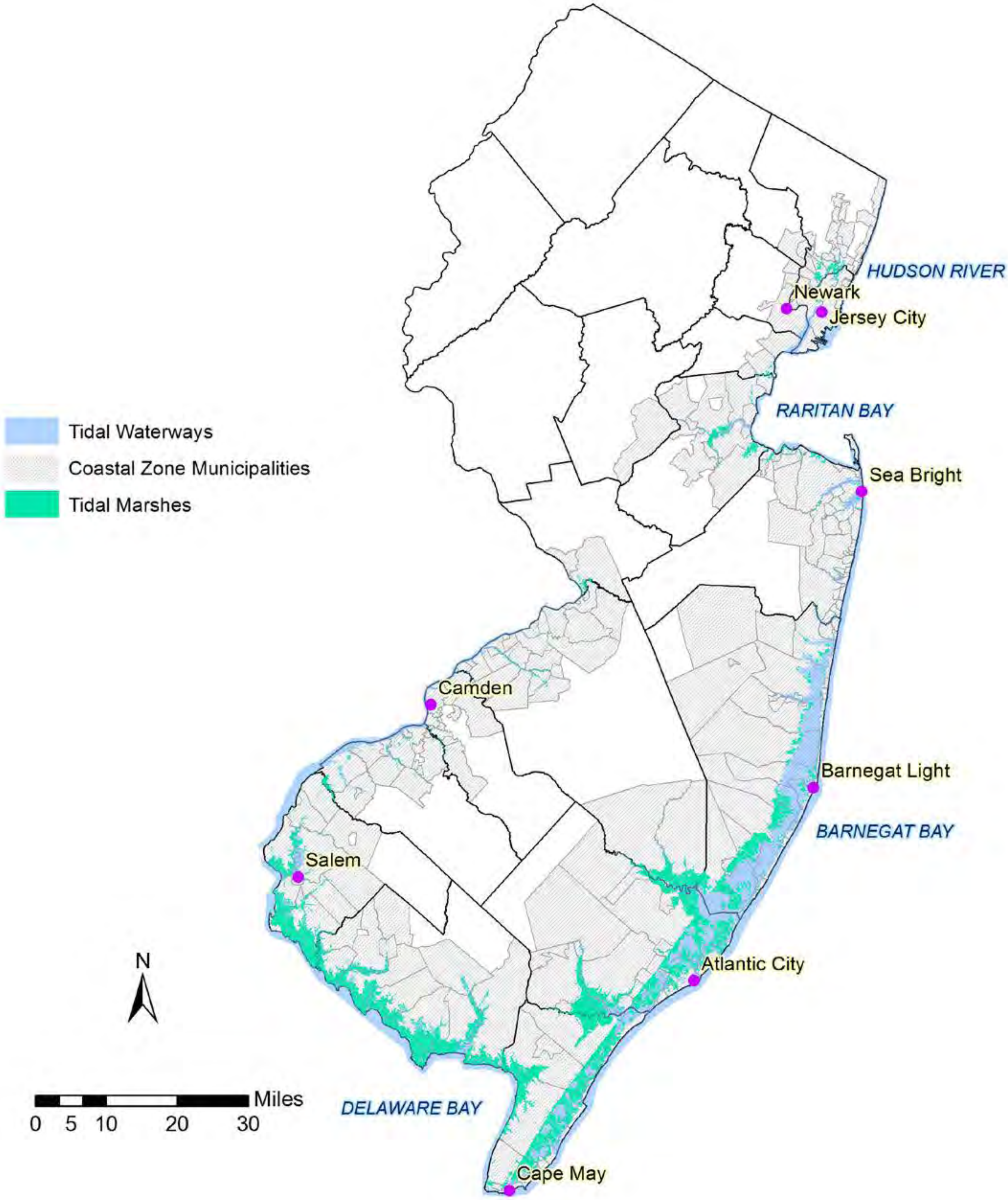


Figure 13. New Jersey tidal marshes.

Feature data source NJDEP LULC 2012. This map is for informational purposes only.

Tidal Marshes

Overview of New Jersey Tidal Marshes

Tidal marshes are one of New Jersey's defining coastal features (Fig. 13). They are the mostly grassy expanses that define iconic places like the Meadowlands, Barnegat Bay, and the Delaware Bayshore. These wetland features occur as far north as Alpine, New Jersey, and continue south in the Atlantic coast bays around Cape May and then north on the Delaware River to Trenton (Tiner 1985).

When Bruce Springsteen sings that his car is "stuck in the mud somewhere in the swamps of Jersey," he might have actually driven into a tidal marsh (Springsteen 1973). While people use various common names – saltmarshes, marshes, coastal wetlands, meadows, and yes, even swamps, which are actually forested wetlands – we will be referring to them here as tidal marshes.

Tidal marshes are highly valuable. They buffer back-bay communities against erosion and inundation by dissipating wave energy and reducing storm surge height. Tidal marshes helped to avoid hundreds of millions of dollars in flood damages from Superstorm Sandy and it has been estimated that the conservation of tidal marshes has the potential to reduce yearly flood losses by 20% in Ocean County (Narayan et al. 2016).

Tidal marshes are also very rich habitat, serving as nurseries for marine fish (EPA 2004) and nesting areas for birds and other coastal wildlife (Mitsch and Gosselink 1994, NJDEP 2008). However, increased coastal development and shoreline modification, along with a changing climate and rising seas, are threatening the future of tidal marshes.

The good news is that practices that protect and restore the ecological integrity of tidal marshes can also buffer communities from coastal hazards, helping them prepare for a resilient future (MADEP 2017). This is one reason it is so important to monitor and manage this coastal ecosystem.

Winter tidal marshes at Stone Harbor, New Jersey.

Photo: Stacy Small-Lorenz

An Ecosystem Defined by Tides

In contrast to sandy beaches, tidal marshes occur in relatively sheltered waters (bays, river mouths, harbors, and sounds), typically between mean sea-level and mean high water (Haaf et al. 2015). This shallow-water habitat, being protected from large oceanic waves and strong currents, is where fine sediments settle out of the water and accumulate, allowing the establishment of a few specialized plant species that can handle such conditions (Mitsch and Gosselink 1994). Although they are often referred to as salt marshes, New Jersey actually has tidal marshes in salty, brackish, and fresh water.

Tidal marshes are coastal wetlands that can be considered part land and part water, being submerged at high tide and fully open to the air during low tide (NOAA 2008). A full tidal marsh complex contains areas of low marsh and high marsh. Low marsh sits physically lower in elevation than high marsh. Generally in New Jersey, low marsh is flooded twice per day and the high marsh is flooded twice per month when the tides are at their highest, during full and new moons, often referred to as "spring tides" (NOAA 2016b). The highest of spring tides -- perigean or "king" tides -- occur when "the orbits and alignment of the Earth, moon, and sun combine to produce the greatest tidal effects (EPA 2016a)."

> ## Check the Regulations
>
> See Coastal Zone Management Rules N.J.S.A. 7:7 for information.
>
> ✔ N.J.S.A. 7:7-9.27 Wetlands
> ✔ N.J.S.A. 7:7-9.28 Wetlands Buffers

In some coastal communities, spring and king tides block roadways and damage buildings with what is euphemistically known as "nuisance flooding," disrupting daily life and threatening the ability to live safely near the coast. With sea-level rise, high tides are getting even higher and reaching even further inland to more roads, more homes, and more businesses. The combined consequences of stronger coastal storms, geological subsidence of the state's coastal plain (Sun et al. 1999), and marsh loss, could be devastating. Maintaining healthy marshes and restoring those that are damaged or in decline is a priority for coastal resilience along the Atlantic coast, for the dual benefits of community protection and fish and wildlife habitat.

Tidal Marshes are a Valuable Coastal Asset

Historically, tidal marshes were perceived as having little value. They were filled in to provide fast land to accommodate housing, roads, and landfills, dug out to create open water areas for marinas and lagoons, diked for agriculture and largely unsuccessful efforts to reduce mosquitoes (Tiner 1985). Ditching marshes significantly impacted this habitat, by shredding the root mat, decomposing the peat, altering tidal flow, and increasing erosion and scour. As a result, New Jersey has lost a large portion of its tidal marshes. Although no comprehensive data is available for losses since European settlement, we do know that in just one 20 year period (1953 to 1973), nearly one quarter of New Jersey's tidal marshes were destroyed (Tiner 1985). Once their many values were recognized, laws were enacted to protect the state's remaining tidal marshes, and efforts began to properly manage and restore them.

We now know that healthy marshes are extremely valuable for their environmental resources, buffering coastal communities, protecting valuable assets and bringing dollars to coastal communities from eco-tourism and commercial and recreational fishing.
Photo: Stacy Small-Lorenz

We now know that healthy marshes are extremely valuable for their environmental resources, buffering coastal communities, protecting valuable assets and bringing dollars to coastal communities from eco-tourism and commercial and recreational fishing. In fact, most salt-water fish rely on tidal marshes, so without this habitat, we would not have most of the fish we eat (EPA 2004).

Protective Values of Tidal Marshes

Tidal marshes provide a host of valuable services to communities. In particular, a growing body of evidence shows that tidal marshes protect communities from some of the forces of coastal storms (Wamsley et al. 2010, Gedan et al. 2011, Bridges et al. 2015, Narayan et al. 2016). Tidal marshes act as a front-line buffer to the impacts of waves, wakes, and storm surges, reducing their height and force. As water surges through the relatively shallow marsh during coastal storms, it loses some of its force from the reduced depth and the drag created by vegetation. To think about storm surge moving through a marsh, imagine rolling a ball up a ramp from a smooth floor to carpeting. In this way, tidal marshes can at least partially dissipate destructive energy before it reaches properties and structures along the shoreline.

A post-Hurricane Sandy damage assessment found that communities upland of wetlands were buffered from storm surge and winds, and these communities appeared to have sustained less damage, but there was evidence of storm damage to infrastructure like docks, piers,

Narrow tidal marshes may provide more buffer than having none at all.
Photo: Stacy Small-Lorenz

and bulkheads, which were directly impacted by the storm's intensity (Bilinski et al. 2015). The assessment determined that the impact of ongoing recreational activities, including boat traffic, wakes, and landings in the marsh, have had a greater adverse impact on shoreline stability, vegetation, and wildlife habitat than the impacts attributed to the storm in a number of areas where wetland vegetation recovered. The same study reported that marshes in areas previously compromised by ditching, open marsh water management, and diking appeared to have sustained more damage and were slower to recover than other more intact marsh areas (Bilinski et al. 2015). Another study found that tidal marshes in North Carolina survived Hurricane Irene better than bulkheads (Gittman et al. 2014), similar to the post-Hurricane Sandy results.

While narrow marshes provide more buffer than none at all, in some cases, large expanses of intact tidal marsh can provide even more protection from erosion and storm surges (Gedan et al. 2011). Tidal marshes also have some ability to withstand and recover from coastal storms. This is often not the case with rigid shoreline armoring, which sometimes must be repaired at great expense (Seachange Consulting 2011).

Tidal marshes dissipate wave energy, thereby calming the water. In contrast, waves bounce off sea walls and bulkheads, sometimes with high impact. This can cause erosion and significant property damage (Council 2007, Swann 2008). While such structures might be necessary where critical infrastructure is at risk, their use should be limited.

While erosion is a natural process that can benefit the aquatic environment, it can threaten nearby manmade structures. In these situations, ecologically enhanced protection should be the first consideration. However, there are limits to the amount of protection that either tidal marshes or built structures can provide against extreme events, as a very high surge can submerge all shoreline features, natural or manmade.

Another benefit that tidal marshes provide is the storage of carbon (a.k.a. "**blue carbon**"), a component of carbon dioxide, a powerful greenhouse gas that contributes to global warming and sea level rise (Mcleod et al. 2011, Howard et al. 2017, NOAA 2017b). As all plants do, wetland plants take up carbon dioxide from the air and use it to grow: to make more stems and leaves, roots and rhizomes, flowers and seeds (NOAA 2017a). As these plant parts die, they are slowly and continually buried. This plant matter remains underground as peat, which is comprised of the carbon that the living plant removed from carbon dioxide. As long as the peat remains saturated -- as it is in a tidal wetland -- the carbon remains stored, or "sequestered," underground. Because tidal marshes store more carbon than they emit, protecting and restoring them are important tools for mitigating global warming and, by extension, slowing sea-level rise. New evidence has emerged that even living shorelines projects created primarily to reduce erosion, using native marsh plants, have carbon storage benefits (Davis et al. 2015).

Northern harrier, *Circus cyaneus*, over marsh.

Photo: Tom Koerner

Fish and Wildlife Depend on Tidal Marshes

Tidal marshes are celebrated for providing vital habitat (e.g., food and shelter, nesting and rearing sites) for numerous fish and wildlife. One of the main drivers of such abundance and diversity of wildlife is the tide cycle. In New Jersey, the low marsh is submerged twice per day during high tides, and twice it is fully exposed to air during low tide. Because of this, the marsh accommodates animals that spend their life in water, on land, and in between. For example, when the tide is high, small fish arrive eating algae off plant stems, shellfish open and feed, and wading birds arrive to hunt for fish. When the tide is low, the wetland surface is exposed, at which point fiddler crabs come out of their burrows and bivalve shellfish close up.

One of the most prominent group of animals that benefit from tidal marshes is birds (Mitsch and Gosselink 1994). Marsh birds, waterfowl, and shorebirds are found in and at the edges of these wetlands throughout the tidal cycle and are particularly abundant during their northward and southward migrations. Many are also year-round residents of New Jersey, such as the great egret. Others use tidal marshes temporarily, such as the glossy ibis, which raises its young here in summer, or the American oystercatcher, which nests in New Jersey tidal marshes and on beaches. The northern harrier, a hawk, flies low

Diamondback terrapins, *Malaclemys terrapin*, use both tidal marshes and beach habitat.

Photo: Robin Baranowski

over the marsh grasses as it hunts for prey. When inland freshwater lakes freeze in winter, rafts of waterfowl move in to the unfrozen sheltered waters within and adjacent to tidal marshes.

However, the group of animals most dependent on tidal marshes are fish, such as mummichogs, silversides, winter flounder, and striped bass. It is estimated that 95% of commercial fish and 85% of recreational fish use coastal wetlands and estuarine habitats for feeding, breeding, and shelter (EPA 2004). Some fish species use this habitat for part of their day, part of their life cycle, or for their entire lifetime. Like other shallow-water areas, tidal marshes provide small fish refuge from larger predatory fish. Some fish lay eggs while others feed here when they are young and small. Most of the saltwater fish we humans eat depend on tidal marshes for some part of their lives. If we remove a tidal marsh, we have removed a portion of our food source and the coastal economy.

New Jersey tidal marshes are facing threats from accelerated sea-level rise, erosion, human alterations, and more intense coastal storms.

Photo: Stacy Small-Lorenz

Other species that inhabit tidal marshes include diamondback terrapins, muskrats, ribbed mussels, and a variety of insects. Some marsh species are officially recognized by the state and federal government as endangered, threatened, or a species of concern (NJDEP 2008; Appendix 2).

Key Vulnerabilities of Tidal Marshes

Coastal Hazards that Affect Tidal Marshes

Tidal marshes have long been at risk from activities such as filling, dumping, excavating, road and utility crossings, boat wakes, diking, ditching, water pollution, and the spread of invasive plants (Tiner 1985). These things have been and, in some cases, still are the cause of degradation and even complete loss of thousands of acres of tidal marshes in New Jersey alone. With climate change, tidal marshes have the added threats of accelerated sea-level rise (Titus et al. 2009), more pollution from increased precipitation, and more intense coastal storms (Scavia et al. 2002).

Accelerated Sea-Level Rise

Tidal marsh vegetation grows at a specific elevation in relation to the tides. For instance, as you approach a tidal marsh from the water, the first grass (smooth cordgrass or *Spartina alterniflora*) starts growing midway between the

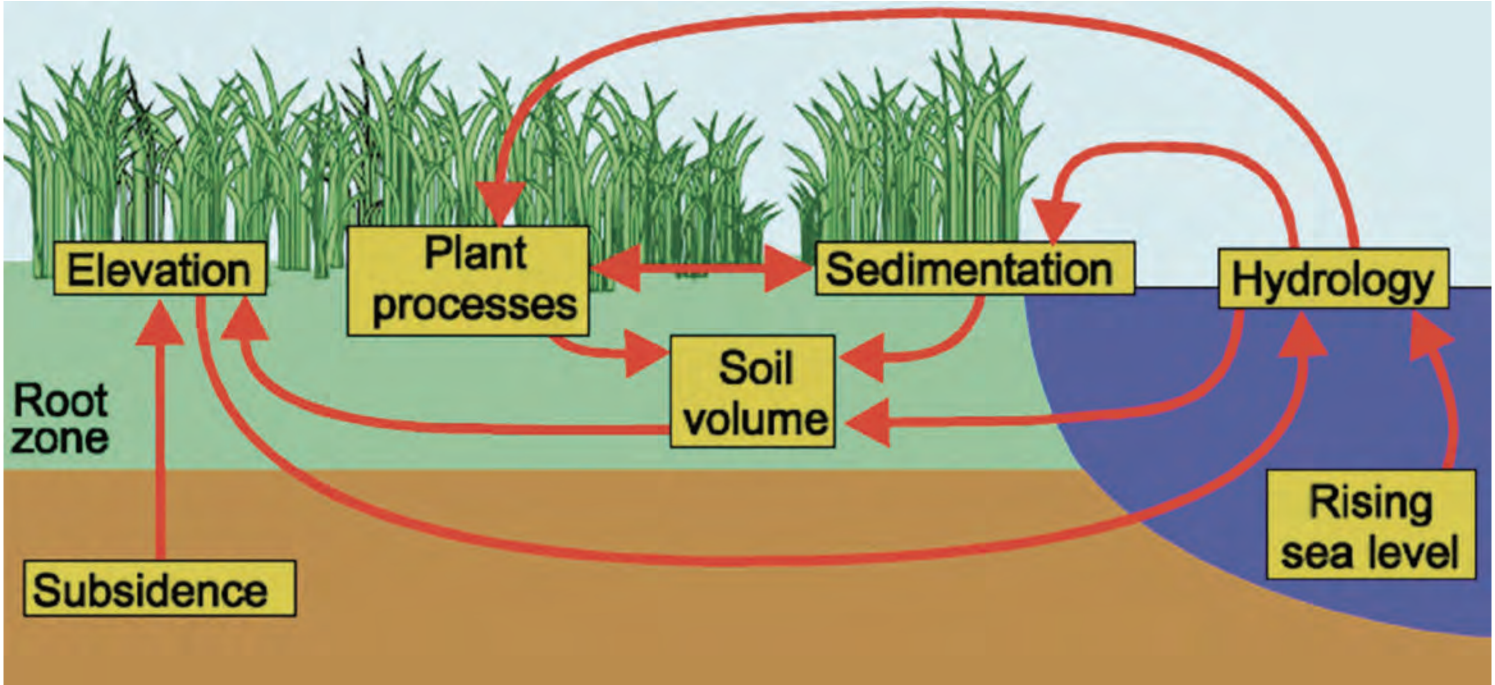


Figure 14. An accelerated rate of sea-level rise, combined with subsidence and human alteration of marshes, can outpace the vertical growth of a tidal marsh.

Graphic: USGS

average low and high tides and continue uphill until the height of the average high tide. In general, this "low marsh" is submerged twice per day by the tide. At that upper edge, you would see a distinct change in the texture of the vegetation. This area, the "high marsh," is submerged twice per month during spring tides and is dominated by a mix of salt hay *(Spartina patens)* and salt grass *(Disticlis spicata)*. At the upper edge of the high marsh, shrubs and other plants take over (Mitsch and Gosselink 1994).

Tidal marshes are no stranger to sea-level rise. Indeed, sea-level has been rising longer than marshes have existed. The reason rising seas did not simply overcome and drown tidal marshes historically is because they increased vertically at the same rate as the sea was rising, where there was an abundant sediment supply. The vertical increase of marsh elevation is mainly the result of sediment capture and organic matter accumulation from plant production (Haaf et al. 2015). These and other processes had continuously increased the height of marshes by incremental amounts over time and allowed them to keep pace with sea-level rise for thousands of years (Mitsch and Gosselink 1994) (Fig. 14).

However, compared to the global rate, sea-level has been rising much faster in New Jersey and the whole mid-Atlantic region, due to sediment compaction and land subsidence. Furthermore, the **rate of sea-level rise** is accelerating in the 21st century (Miller et al. 2014). An accelerated rate of sea-level rise can outpace the vertical growth of a marsh (Fig. 15, p. 69). This can lead to what is referred to as "drowning" marshes, where vegetation dies off and both mudflats and ponds expand in the interior of tidal marshes (Cahoon and Guntenspergen 2010). The situation is further exacerbated by both the breakdown of the marsh "soil" (peat) caused by excessive nitrogen pollution (NYSDEC 2014) and a legacy of ditching and ponding for mosquito control, as discussed below.

An accelerated rate of sea-level rise can outpace the vertical growth of a marsh. This can lead to what is referred to as "drowning" marshes, where vegetation dies off and both mudflats and ponds expand in the interior of tidal marshes.

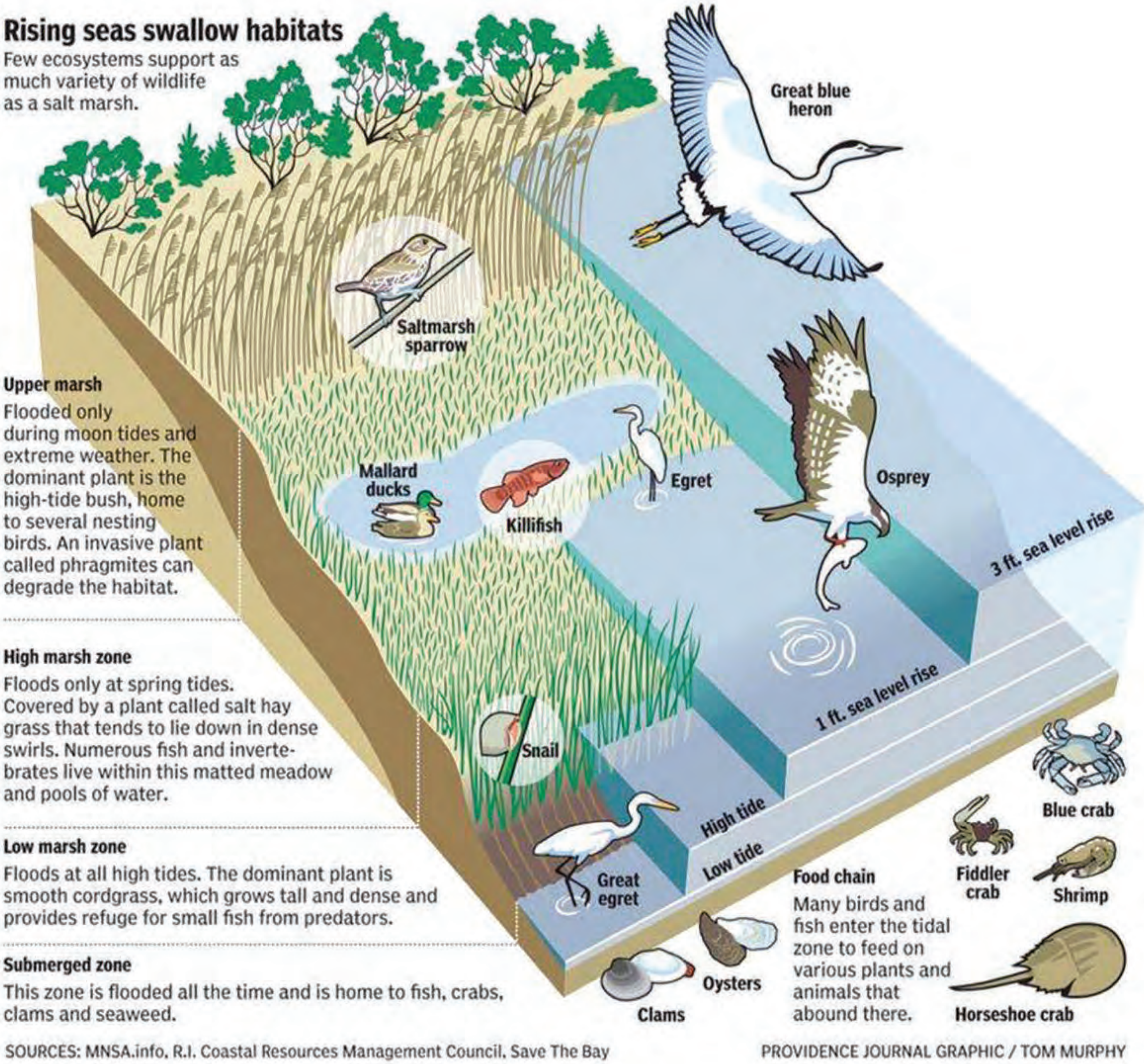


Figure 15. Sea-level rise contributes to "drowning" marshes and habitat loss.

Graphic adapted from: Tom Murphy, Providence Journal

More Polluted Runoff

The predicted increase in heavy precipitation will increase runoff, which may bring more pollutants like nitrogen (Scavia et al. 2002). It has been discovered that tidal marshes are shrinking and dying off, partly in response to excessive nitrogen pollution (NYSDEC 2014).

Nitrogen enters the water from upland sources, such as water-soluble fertilizers, pet waste, septic systems, and combined sewer systems (EPA 2003). This water-borne nitrogen supports above-ground plant growth at the expense of bank stabilizing roots, increasing the breakdown of marsh peat. Fewer roots mean that the marsh is not held together as well, which is a particular problem at the water's edge, where waves crash and large clumps of marsh break off. It also means that the marsh may not be creating enough peat to keep pace with sea-level rise.

Man-made Mosquito Control Ditches and Pools

Like most states in the northeast, New Jersey's tidal marshes were ditched extensively in the 1930s and 1940s in an attempt to control mosquitoes. Not only did this method not work for its intended purpose, it also damaged tidal marshes, shredding the root mat, decomposing the peat, and causing scour and erosion. By the 1960s, it was clear that this method was ineffective, as mosquitoes made it nearly impossible to live in coastal areas (NJDEP 2009). At that time, a new method was developed that focused on reducing mosquitoes by improving habitat for fish and other mosquito predators. This method, known as Open Marsh Water Management, can be effective at reducing that breed in tidal marshes (Wolfe 1996). However, it comes at a cost to marsh conditions and doesn't control mosquitoes that breed in non-tidal environments, such as **container-breeding mosquitoes** that can carry serious diseases (CDC 2016a). This method also keeps the marsh surface wetter longer, which can inhibit plant growth, accelerate erosion and lead to a breakdown of marsh peat (Vincent et al. 2014). The result is compromised marsh integrity, saltwater intrusion inland, and a legacy of unneeded ditches.

Man-made ditches and pools can compromise tidal marsh integrity, inhibiting plant growth and leading to breakdown of marsh peat, accelerated erosion and saltwater intrusion.

Photo: Steven Jacobus

More Intense and More Frequent Storms

Increasingly intense storms are another looming threat to our tidal marshes (Scavia et al. 2002). Strong winds from coastal storms create damaging waves, which can severely erode the waterward edges of tidal marshes. While storm erosion is common, as long as marshes build vertically and no landward obstruction exists, they can migrate inland as sea-level rises and sometimes even expand on their waterward edge. Through this process, marshes can maintain their size and, in some cases, even expand if sediment supply is sufficient (Titus et al. 2009). More frequent and intense storms (NYCPCC 2015), combined with larger boat wakes, accelerated sea-level rise, and development at the marsh's landward edge, on the other hand, can hasten the loss of tidal marshes.

Boat Wake Erosion

Historically, wetlands had a window of opportunity to recover from winter storms during the calmer summer months. With an increase in personal watercraft and larger boats, wetlands are subject to increased wakes in summer (S. Farrell pers. comm.). Boat wakes can erode shorelines even more than waves or storm surges (T. Bridges pers. comm.), so marshes are exposed to erosive forces year-round. Therefore, New Jersey's marshes have been shrinking as they continually erode from their edges and fall into the water. This also adds to navigation problems because the sediment settles in channels, making them shallower. **Wake limits** are critical to preventing marsh erosion and wildlife disturbance (NJDEP 2012). If we are to retain our remaining tidal marshes, wake limits and wetland buffers should be updated and strictly enforced. Abiding by wake limits, rather than speed limits, is one of the most direct ways boaters can increase coastal community resiliency.

The combination of boat wakes, stronger coastal storms, accelerated sea-level rise, and additional polluted run-off from increasing precipitation poses a combined threat to the very survival of tidal marshes, especially where they have already been damaged or fragmented from ditching, infrastructure, and development (Scavia et al. 2002).

Boat wakes can erode tidal marsh edges even more than waves or storm surge in places, so marshes are exposed to erosive forces year-round.

Photo: Steven Jacobus

Ecological Solutions Involving Tidal Marshes

There is growing acceptance that tidal marshes play a significant role in buffering communities from coastal storms (Wamsley et al. 2010, Gedan et al. 2011, Gittman et al. 2014, Bridges et al. 2015, Narayan et al. 2016). Therefore, their protection, management, and restoration are high priorities. To optimize the many societal benefits provided by tidal marshes, municipalities can take a number of actions.

Land-Use Planning and Zoning

- **Incorporate sea-level rise and projected migrations in land use zoning and open space planning.** Consider accelerated sea-level rise in all aspects of open space planning and municipal zoning. Tidal marshes naturally shift or "migrate" inland and upland as sea-level rises, in the absence of barriers (Hussein 2009, Gedan et al. 2011). Development and hard infrastructure right up to the edge of marshes prevents this process and results in wetland loss and the inevitable conversion to open water, in a process known as "coastal squeeze." Identify where the built environment blocks projected migration of tidal marshes and tidal waters and consider re-zoning these areas as well as voluntary buy-outs or other community-relocation options.

- **Designate conservation zones to allow for marsh migration through zoning, development setbacks, conservation easements, and targeted buy-outs to allow for the migration of marshes inland with sea-level rise.** As tidal waters encroach upon undeveloped uplands, tidal marshes may form on these newly submerged lands. As the coastline creeps steadily inland, neighborhoods closer to open water will be increasingly exposed to coastal hazards, while those farther inland will remain somewhat more buffered by intact ecosystems. New Jersey Flood Mapper is a useful, free, visualization tool that can help its users map projected sea-level rise, storm surge, and marsh migration (Rutgers 2017).

- **Establish ample development setbacks** from tidal marshes and open tidal waters to accommodate projected marsh migration.

- **Promote enrollment in** NJDEP's Blue Acres program for residences in the path of projected marsh migration (NJDEP 2017).

- **Discourage re-building** after disasters on sand overwash fans over wetlands and in places that will block projected marsh migration.

- **Establish a local policy of zero loss of tidal marshes** in your community. While state and federal laws protect all wetlands, a municipality can, and likely should, go beyond existing regulations with its own resilient future as the goal. No loss of wetlands means that all existing wetlands are protected and have room to move or even expand. Zero loss differs from the federal policy of no net loss, which allows some wetlands to be taken if new ones are created or restored to replace those lost.

  Creation and restoration of marshes is not only far more expensive than protection, restoration outcomes can be less certain than efforts to protect existing wetlands. Furthermore, wetland loss releases a significant amount of carbon dioxide into the atmosphere, contributing to global warming and accelerated sea-level rise (Howard et al. 2017).

Better management of tidal marshes starts with knowing their condition and extent.

Photo: Stacy Small-Lorenz

Conservation Practices

- **Inventory all tidal marshes** within your municipality on both public and private lands. Management of any natural resource, such as tidal marshes, starts with knowing their location and extent (ecologists refer to this as distribution and abundance).

- **Protect all existing tidal marshes** (see zero loss policy, previous page).

- **Assess tidal marsh conditions in your community, working with scientists from local universities or non-profit conservation organizations.** An assessment may include the makeup, density, and height of the vegetation; soil composition and density; the presence of open water; stability of the wetland at the water's edge; the flow or stagnation of tidal waters; and the presence of wildlife, such as fiddler crabs and ribbed mussels, diamondback terrapins and marsh birds, among other species.

- **Develop plans to restore tidal marshes that your assessment shows are impaired,** working closely with state and federal agencies, scientists, and community groups (RIHI 2017). Indications of degradation may include:
  - Legacy manmade ditches, pools, or dikes
  - Eroding edges
  - Signs of significant subsidence or drowning,
  - Roads (or other infrastructure) crossing a marsh in such a way that restricts water and sediment flow or the free passage of fish and wildlife.

Restoration should also include connecting patches of tidal marsh to form a larger intact wetland where human activities have fragmented marshes, as larger expanses are more resilient to damage and other drivers of change. If permanent structures prevent connecting adjacent marshes, look for opportunities to connect them hydrologically by such actions as raising roads or installing culverts of adequate size. Not only does this improve the function of tidal marshes, it relieves the pressure on the road (or other infrastructure) when a significant tidal force bears down on it. Adequately sized culverts reduces these hydrological "pinch points" that increase tidal velocity, causing erosion near both ends of the culvert, resulting in a loss of tidal marshes there.

A useful reference for restoring tidal marshes is NOAA's *Planning for Sea-level Rise in the Northeast: Considerations for the Implementation of Tidal Wetland Habitat Restoration Projects* (NOAA 2011).

- **Consider and prioritize "living shorelines" practices** instead of automatically defaulting to rigid armoring such as bulkheads for shoreline stabilization (NOAA 2017c). Living shorelines are a broad suite of erosion control practices that, unlike rigid armoring, are designed to absorb wave energy while still maintaining some of the natural processes and ecological integrity of the shore zone (NJDEP 2016c). Certain types of living shorelines have been shown to survive a Category 1 hurricane better than bulkheads (Gittman et al. 2014). Some of the design considerations include fetch, boat wakes, nearshore gradient, substrate consistency, tide range, and sun exposure. Materials and configurations can vary based on site conditions, but can include coconut-fiber logs, rock sills and breakwaters, clean sediment, fill, plants, and shellfish.

Engineering and ecological expertise are necessary to plan and execute this technology. Stevens Institute has developed useful Living Shorelines Engineering Guidelines (Miller et al. 2015). NOAA has developed Guidance for Considering the Use of Living Shorelines (NOAA 2015). Partnership for the Delaware Estuary has developed a host of resources, including practitioner's guidance for living shorelines using shellfish and other site-appropriate biological materials (Whalen et al. 2011, PDE 2012). In addition, VIMS has online teaching modules about living shorelines (VIMS 2016).

> Check the Regulations

See Coastal Zone Management Rules N.J.S.A. 7:7 for more information.

- ✔ N.J.S.A. 7:7-6.17 General Permit 17 – Stabilization of eroded shorelines
- ✔ N.J.S.A. 7:7-6.24 General Permit 24 – Habitat creation, restoration, enhancement and living shoreline activities
- ✔ N.J.S.A. 7:7-9.15 – Intertidal and subtidal shallows
- ✔ N.J.S.A. 7:7-9.19 – Erosion hazard areas
- ✔ N.J.S.A. 7:7-12.23 – Living shorelines

- **Consider using clean dredged sediments to restore marshes.** Thin layer placement of dredged sediments can raise the elevation of tidal marshes that are sinking or not keeping up with sea-level rise (USACE 2017). Currently, dredged sediment typically is sent to a landfill or other upland site. If done correctly, using clean sediment to raise the marsh surface could be a viable and productive use of an otherwise wasted resource, and such methods are currently being tested in New Jersey. Some of the considerations include texture, contamination, and acidity of the source sediment, as well as methods and depth of placement. This technique is not well established in New Jersey and few local examples exist. Therefore, it should be approached with caution and in coordination with well-qualified ecologists, engineers, and the appropriate state and federal agencies.

- **Reduce, soften (naturalize), or even eliminate rigid vertical structures abutting marshes.**

- **Reduce threats to tidal marshes from mosquito control practices that damage wetland integrity.** Where feasible, work with mosquito control agencies to restore marsh structure and function. Tidal marshes were damaged by the widespread ditching of the early 20th century (LeMay 2007, Vincent et al. 2014) with little impact on mosquito populations (NJDEP 2009). Selectively fill manmade pools and ditches (Rochlin et al. 2012a, Rochlin et al. 2012b) especially in areas far from neighborhoods where mosquitoes are not a public nuisance. This can facilitate sediment accretion, helping marshes to better keep pace with sea-level rise and continuing to provide storm-buffering benefits (LeMay 2007). Avoid creating new channels, ditches, or pools in marshes unless justified by a thorough alternatives analysis with public review. In addition to mosquito control agencies, such activities should be planned in consultation with ecosystem restoration practitioners.

Ensure that your community's mosquito control activities focus attention on:

- Actions individual residents can take to manage container-breeding, disease-bearing mosquitoes, thereby reducing disease-bearing mosquitoes and reducing public pressure to further manipulate marshes.
- Targeted control in select, densely populated areas only where mosquito-borne disease and disease-bearing mosquitoes are known to be present.
- Supporting natural mosquito predators, such as dragonflies, birds, bats, and fish by following the Xerces Society's best practices for ecologically sound mosquito management in wetlands, which will reduce the need for pesticide application in these sensitive habitats (Mazzacano and Black 2013).
- Encouraging citizen scientists to support mosquito-monitoring activities, such as those of county agencies and Rutgers University.
- Obtaining the appropriate expertise to identify mosquito species, which will help you determine whether a disease-bearing species is present (Mazzacano and Black 2013).

- **Protect marsh-dwelling wildlife.**
  - Control feral domestic cats, which prey on birds and other marsh-dwelling wildlife.
  - Protect sandy areas within and adjacent to marshes, for terrapin nesting.

- **Review and revise wake limits/zones to reduce shoreline and tidal marsh erosion.** Wake limits are critical to preventing marsh erosion and wildlife disturbance (NJDEP 2012). If we are to retain our remaining tidal marshes, wake limits and wetland buffers should be updated and strictly enforced. Abiding by wake limits, rather than speed limits, is one of the most direct ways boaters can help community resiliency. Offer boater education to promote understanding of wake management and why it matters to marsh habitat and coastal communities.
  - Fully enforce existing no-wake zones.
  - Review no-wake laws to ensure they effectively reduce wakes, especially in and around marshes.
  - Use wake size instead of speed limits, which don't prevent wakes from all types of boats.
  - Establish no-wake zones adjacent to all tidal marshes.
  - Expand no-wake zones so that "deceleration" wakes occur away from tidal marshes.

> Check the Regulations

See Coastal Zone Management Rules N.J.S.A. 7:7 for more information.

✔ N.J.S.A. 7:7-12.20 - Vertical wake or wave-attenuation structures

- **Restore tidal flow** where it has been severed within and between marshes and other tidal areas.

- **Protect intact vegetation,** which provides cover for various species. Even temporary human disturbance can disrupt wildlife in a way that reduces their populations.

- Prohibit personal watercraft from crossing over tidal marshes or in narrow tidal creeks.
- Prohibit motor vehicles from entering high marsh areas.

- **Reduce Polluted Runoff**
  - Additional nutrients in tidal waters, from fertilizers and other sources, can damage wetland vegetation and other aquatic plants, impairing these ecosystems. Promote the use of native plants in landscaping and leaf mulching, which improves soil condition, permeability, and needs less water and synthetic fertilizer. For guidance on native plants appropriate to your site, visit Jersey-Friendly Yards (BBP 2017).
  - Promote a culture shift away from grass turf, using it only where lawn-dependent activities occur and replacing it wherever possible with attractive native vegetation.
  - Reduce impervious surfaces and promote Low Impact Development and green stormwater management practices, in particular capturing and using rainwater where it falls (EPA 2016c).

  Some resources for reducing polluted runoff include Jersey Friendly Yards and Barnegat Bay Comprehensive Plan of Action Item #3 (NJDEP 2016b, BBP 2017).

Public Education and Outreach

- **Publicly declare the importance of tidal marshes** to community resilience and commit to becoming exemplary tidal marsh stewards.

- **Recognize and reward private landowners** who demonstrate excellent stewardship of tidal marshes.

Birders, anglers, kayakers, and hunters can be engaged in citizen science to monitor marsh conditions.

Photo: Stacy Small-Lorenz

- **Engage hunters, anglers, kayakers, birders** and others to monitor and report changes in tidal marshes and adjacent open spaces.

- **Follow** ecological mosquito control practices to reduce pressure on marshes (Mazzacano and Black 2013):
  - Disseminate information about the vital role residents have in controlling container-breeding mosquitoes on their properties and CDC-recommended personal protective measures (EPA 2016b, CDC 2017).
  - Make clear distinctions between mosquitoes that inhabit tidal marshes and the most problematic disease bearing mosquitoes, which are primarily freshwater, container-breeding mosquitoes.
  - To reduce nuisance biting, emphasize the value of natural mosquito predators over spraying around marshes in natural areas.
  - If pesticide use is fully justified, target spraying only where most necessary in proximity to populated areas.

Ecological Solutions in Action:

Tidal Marshes

Ocean County

Mordecai Island in Beach Haven was purchased by the Mordecai Land Trust (MLT) for the express purpose of protecting this tidal marsh for its wildlife and community-protection benefits. The marsh, which buffers 30 percent of the town's bay shoreline, is home to a rather large breeding population of state-endangered black skimmers, as well as several other bird species.

The western shoreline of Mordecai Island had severely eroded over decades from storms and boat wakes (the Intracoastal Waterway was relocated closer to the island in 1945). In the mid-1980s, the erosion created a cut that split the island fully in two. Its deteriorating condition prompted the formation of MLT, which purchased the island in 2001.

Under MLT's management, the island has become somewhat of a demonstration site for various marsh protection and restoration actions, which have been employed in different sections. These actions include temporary bio-logs, sand-filled geotextile tubes, and a ribbed-mussel-and-oyster breakwater to protect the geo-tubes. In addition, the Army Corps of Engineers reconnected the two islands using dredged sediments and native marsh plants, and MLT is planning to install an Oyster Castle breakwater. These efforts have involved a host of partners, including American Littoral Society, NOAA Fisheries Restoration Center, US Army Corps of Engineers, ReClam the Bay, Long Beach Island Foundation, and Rutgers University.

Brick Township's ordinance on Landscaping and Buffer Requirements protects water quality by prohibiting the use of fertilizers, pesticides, other chemicals, hazardous waste activities, junkyards, and industrial storage facilities within 300 feet of waterbodies. By protecting water quality in this way, the township also protects the health of the tidal marshes in Brick and those of its neighboring communities.

In **Berkeley Township,** the Sedge Islands Marine Conservation Zone (MCZ) is a state-created and -managed area which offers a good example of protection and education about tidal marshes and other habitats. The MCZ prohibits such things as commercial fishing and clamming, personal watercraft, wakes within 300 feet of bird nesting and resting areas, and approaching bird nests. The Barnegat Bay Partnership and The Partnership for the Delaware Estuary, working with NJDEP, have designed a living shoreline at the Sedge Island Natural Resource Education Center to restore and enhance shorelines eroded during Superstorm Sandy. There is a large educational component at Sedge Islands, which reached more than 3,000 people in 2016, and Save Barnegat Bay created water-trail maps for paddlers. These public-private partnerships are helping protect this tidal marsh ecosystem which shelters the northern side of Barnegat Inlet and protects the southwestern end of the barrier island that is home to Island Beach State Park.

Cape May County

Cape May City's Floodplain Management Plan recognizes the importance of tidal marshes, floodplains and wetlands and sets a goal of preserving, protecting, and acquiring these "environmentally sensitive lands." While it acknowledges that tidal marshes are currently protected by state law, it seeks acquisition to further protect this resource, which the City knows is critical for the wildlife that make Cape May attractive to residents and tourists alike. Ownership will give the City the ability to add further protections for its marshes and allow it more control when it needs to conduct any management activities in the future.

Sea Isle City, which is north of Cape May City, owns approximately 300 acres of tidal marshes. Although it currently leaves their management to the Cape May County Department of Mosquito Control, ownership does give the City a big advantage when the time comes to conduct any needed restoration or other management activities.

High school students from Cape May County Technical School District taking tide measurements in a local salt marsh.

Photo: Hanna Toft

The **Strathmere community of Upper Township** is home to one of the latest New Jersey "living shorelines" projects adjacent to the reconstructed Bayview Drive boat ramp. The project is designed to restore a section of eroded shoreline and reduce future erosion while enhancing fish and wildlife habitat. The design consists of debris removal and the placement of two rows of terraced coconut-fiber logs along the western side of the boat ramp and a single row of coconut-fiber logs on the eastern side, with the area behind the logs filled with sediment and planted.

Middlesex County

Woodbridge Township has created an ordinance to protect the natural habitats of Woodbridge Waterfront Park, which contains recently restored tidal marshes as well as non-tidal wetlands and coastal forest and shrublands. This ordinance, *Habitat Protection Within Woodbridge Waterfront Park,* codifies the conservation easements on the site. This is a great example of how a municipality can formally protect ecosystems in perpetuity. In addition, as the site was once a NJDEP-designated Brownfield Development Area, this park is also an example of ecosystem restoration.

Cumberland County

In **Maurice River Township**, a "living shorelines" project transformed a riprap shoreline into a stable tidal marsh at Matts Landing, a marina in the Heislerville Fish and Wildlife Management Area in Maurice River Township.

This project was designed, implemented, and monitored by the Partnership for the Delaware Estuary and Rutgers University, which have pioneered a living shoreline technique tailored to the unique conditions of tidal marshes. Their approach relies on a mutualistic relationship between ribbed mussels *(Geukensia demissa)* and smooth cordgrass *(Spartina alterniflora),* whereby mussels provide oxygen and nutrients to the plant roots and the plants provide a stable place for mussels to live. Their Matt's Landing project is just one example of a successful living shoreline installed by the Partnership for the Delaware Estuary. Other installations can be found in both New Jersey and Delaware.

Maritime forest in autumn. Stone Harbor, New Jersey.

Photo: Stacy Small-Lorenz

Conclusions

New Jersey coastal communities know extreme weather and hazardous flooding first-hand. Undoubtedly, life in coastal regions is becoming increasingly risky. Sea-level rise, erosion, torrential downpours, and massive storms are taking a combined toll on coastal populations. Hurricane Sandy exceeded what many previously considered a worst-case scenario, and subsequent damaging storms have occurred throughout the state's coastal areas.

Residents of coastal areas are well acquainted with the consequences of accelerating sea level rise as they witness the high-tide line inching toward their homes and encounter frequent disruptive flooding at high tides. Some communities are already dealing with saltwater intrusion as it contaminates drinking water sources and creates ever expanding "ghost forests."

We can achieve a more resilient future by committing to excellent stewardship of ecosystems in coastal landscapes, managing natural features in a way that maximizes protection and habitat value, incorporating natural and green infrastructure into urban areas, and developing modern land use plans updated to account for sea-level rise and other growing coastal hazards.

If managed with an eye toward resilience, coastal ecosystems– beaches and dunes, forests, shrublands, and tidal marshes– can afford communities significant protection against mounting hazards.

Dunes of Cape May Point, New Jersey.

Photo: Stacy Small-Lorenz

If managed with an eye toward resilience, coastal ecosystems–beaches and dunes, forests, shrublands, and tidal marshes–can afford communities significant protection against mounting hazards.

Photo: Stacy Small-Lorenz

If managed with an eye toward resilience, coastal ecosystems–beaches and dunes, forests, shrublands, and tidal marshes–can afford communities significant protection against mounting hazards. These natural features offer an array of benefits, such as maintaining elevation, attenuating storm surges and waves, buffering strong winds, and protecting against erosion and land loss. In addition to these valuable protective services, they are also vital to local economies through abundant fisheries, wildlife habitat, and natural beauty, all of which attract millions of visitors for recreation and eco-tourism.

We encourage coastal communities to maximize their resilience through ecological solutions, such as:

- Encouraging and incentivizing native landscaping;
- Incorporating sea-level rise into land use plans;
- Restoring or creating vegetated dune complexes, using native vegetation;
- Seeking ways to protect and restore coastal forests and shrublands;
- Protecting and restoring intact tidal marshes and allowing room for marshes to migrate inland with sea-level rise, through open space planning;
- Controlling shoreline erosion using "living shorelines" or hybrid green-gray techniques and, where appropriate, softening armored shorelines;
- Capturing rainwater where it falls, to reduce flooding and to recharge groundwater;
- Conserving groundwater to avoid overdraft, saltwater intrusion, and local land subsidence;
- Reducing impervious surface cover and landscaping with native vegetation; and
- Keeping new development out of low-lying, flood-prone areas.

Furthermore, when planning any coastal community project, consider the following:

- Sea-level rise and precipitation trends;
- Relevant site conditions, such as tides, wave energy, sediment transport, erosion, plant communities, wildlife, flood risk, etc.
- Is the project is beneficial, neutral, or detrimental to fish and wildlife?
- Does the project conserve groundwater, use native plants, reduce impervious cover, allow room for nature to move, and/or maximize eco-tourism potential?
- Can the project be implemented using natural materials?
- Can the project sustain or even self-repair after storm damage or does it exacerbate storm damage (e.g., erosion)?
- Does the project avoid transferring damages or risks to neighbors or downstream?
- What is the project's life expectancy and long-term maintenance requirements?

Planning for sea-level rise while incorporating natural features and ecological processes into land use planning and urban design will improve the sustainability of coastal communities. This is especially true where coastal systems like dunes and wetlands are managed and maintained in ways that allow for elevation gain (e.g., dune-building and marsh accretion). Such practices are particularly effective when they incorporate site-appropriate native vegetation, which can be encouraged and accelerated with the right technical assistance, policies, and incentives. The first steps to implementing ecological solutions are getting to know the ecosystems in your landscape and conducting a clear-eyed climate vulnerability assessment of local resources and assets.

Consider a possible future for our coastal communities, in which:

- Coastal ecosystems keep pace with sea-level rise, buffering communities against erosion, land loss, and eventual inundation.
- Wide beaches and vegetated dune complexes protect beachfront communities from storm damages.
- Coastal forests, shrublands, and native landscaping buffer communities against storm winds, waves, and erosion, as well as sand and debris deposits.
- Vibrant, intact tidal marshes protect back-bay shorelines against erosion.
- Permeable, native landscaping and green infrastructure features like bio-swales, rain barrels, and retrofitted stormwater basins capture stormwater in place, before it contributes to coastal flooding.
- Floodwaters cause minimal economic damage in low-lying areas, as they inundate thoughtfully planned open spaces, and not buildings or infrastructure.

This vision of thriving, resilient coasts is only possible through a broad shift in how coastal communities plan and intentionally manage open space, natural features, and developed areas, with a changing future in mind.

Monmouth Beach, New Jersey, is popular with beachgoers and nesting Least Terns.

Photo: Stacy Small-Lorenz

Migrating monarch butterflies depend on the nectar of Seaside Goldenrod. Cape May Point, New Jersey.

Photo: Stacy Small-Lorenz

Waterfront open space at Paulus Hook, Jersey City, New Jersey.

Photo: Steven Jacobus

> Before Implementing Solutions, Check the Regulations

Within the New Jersey Department of Environmental Protection, Land Use Management regulates activities including development and restoration that can occur within coastal ecosystems.

The Coastal Zone Management Rules establish the rules regarding the use, development, and protection of New Jersey's coastal resources. These rules are used in reviewing applications for permits under the Coastal Area Facility Review Act (CAFRA), N.J.S.A. 13:19-1 et seq. (CAFRA permits), the Wetlands Act of 1970, N.J.S.A. 13:9A-1 et seq. (coastal wetlands permits), and the Waterfront Development Law, N.J.S.A. 12:5-3 (waterfront development permits). The rules are used in the review of water quality certificates subject to Section 401 of the Federal Clean Water Act. The rules also provide a basis for making recommendations to the Tidelands Resource Council on applications for riparian grants, leases and licenses.

- ✔ Coastal Area Facility Review Act (N.J.S.A. 13:19)
- ✔ Wetlands Act of 1970 (N.J.S.A. 13:9A)
- ✔ Waterfront Development Law (N.J.S.A. 12:5-3)
- ✔ Tidelands Act (N.J.S.A. 12:3)

In addition, the following portions of the CZM Rules N.J.S.A. 7:7 – may be of interest:

- ✔ N.J.A.C. 7:7-1.5 – Definitions
- ✔ N.J.A.C. 7:7-2.3 – Coastal Wetlands
- ✔ N.J.A.C. 7:7-4.3 Permit-by Rule 3 – Placement of public safety or beach/dune ordinance signs on beaches or dunes and placement of signs on the beaches and dunes at public parks
- ✔ N.J.A.C. 7:7-4.15 Permit-by Rule 15 – Placement of sand fencing to create or sustain a dune
- ✔ N.J.A.C. 7:7-6.2 General Permit 2 – Beach and dune maintenance
- ✔ N.J.A.C. 7:7-6.17 General Permit 17 – Stabilization of eroded shorelines
- ✔ N.J.A.C. 7:7-6.24 General Permit 24 – Habitat creation, restoration, enhancement and living shoreline activities
- ✔ N.J.A.C. 7:7-9.1 – Special Areas
- ✔ N.J.A.C. 7:7-9.1 – (Special Areas) Purpose and Scope
- ✔ N.J.A.C. 7:7-9.15 – Intertidal and subtidal shallows
- ✔ N.J.A.C. 7:7-9.16 – Dunes
- ✔ N.J.A.C. 7:7-9.19 – Erosion hazard areas
- ✔ N.J.A.C. 7:7-9.22 – Beaches
- ✔ N.J.A.C. 7:7-9.27 – Wetlands
- ✔ N.J.A.C. 7:7-9.28 – Wetlands buffers
- ✔ N.J.A.C. 7:7-9.36 – Endangered or threatened wildlife or plant species habitats
- ✔ N.J.A.C. 7:7-9.37 – Critical wildlife habitats
- ✔ N.J.A.C 7:7-10 – Standards for Beach and Dune Activities
- ✔ N.J.A.C. 7:7-12.20 – Vertical wake or wave-attenuation structures
- ✔ N.J.A.C. 7:7-12.23 – Living shorelines

For the most up-to-date information, see NJ DEP Coastal Management Program website.

Delegable and Non-Delegable Waters

On March 2, 1994, the Department of Environmental Protection assumed responsibility for administering the Federal wetlands program (also known as the 404 Program) in delegable waters. In non-delegable waters, the USACE retains jurisdiction under Federal Law, and both Federal and State requirements apply. Accordingly, a project in non-delegable waters requires two permits. "Delegable waters" means all waters of the United States within New Jersey, as defined in the Freshwater Wetlands Protection Act Rules, N.J.A.C. 7:7A, except waters which are presently used, or are susceptible to use in their natural condition or by reasonable improvement, as a means to transport interstate or foreign commerce, shoreward to their ordinary high water mark. This term includes all waters which are subject to the ebb and flow of the tide, shoreward to their mean high water mark, including wetlands that are partially or entirely located within 1000 feet of their ordinary high water mark or mean high tide. Non-delegable waters include, but are not limited to:

1. The entire length of the Delaware River within the State of New Jersey;

2. Waters of the United States under the jurisdiction of the Hackensack Meadowlands Development Commission; and

3. Greenwood Lake.

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Appendix 1:

Checklist of Ecological Solutions for New Jersey Coastal Communities

The following checklist briefly summarizes recommendations presented in the guide Building Ecological Solutions to Coastal Community Hazards. These are nature-oriented solutions to various coastal hazards that may be actionable at the municipal level, and applicability may vary based upon the ecological landscape and conditions in your community. Selection of actions may depend upon community planning goals, work already underway, and specific coastal hazards experienced or anticipated in your community. No solutions provide 100% protection against extreme hazards; please seek professional ecological, engineering and regulatory guidance regarding implementation of practices you may be considering.

General Recommendations

1. Land Use Planning and Zoning

- ❑ Conduct a climate vulnerability assessment of your community
- ❑ Map existing open space and projected inland migration of coastal ecosystems
- ❑ Identify and map existing barriers to marsh migration
- ❑ Survey and assess coastal ecosystem and vegetation condition
- ❑ Incorporate sea-level rise and coastal ecosystem migration projections into land use planning and zoning
- ❑ Establish local development setbacks for coastal ecosystem migration or expansion
- ❑ Prioritize natural infrastructure over hard infrastructure to improve ecosystem function

2. Conservation Practices

- ❑ Protect or restore coastal ecosystems for community protection
- ❑ Apply best management practices for wildlife when restoring or managing natural areas
- ❑ Adopt practices that reduce runoff to help address flooding and water pollution
- ❑ Promote groundwater conservation and recharge to minimize land subsidence and saltwater intrusion into freshwater sources
  - ❑ Establish groundwater conservation programs
  - ❑ Reduce impervious surface and turf cover
  - ❑ Enhance groundwater recharge with native landscaping
  - ❑ Incentivize native rain gardens and bio-swales
- ❑ Promote use of native vegetation in public and private landscaping
- ❑ Conserve, restore, and protect intact native vegetation for community resilience and wildlife value
- ❑ Reduce sale and transport of non-native, invasive plant species
- ❑ Keep loose pets out of coastal ecosystems
- ❑ Reduce reliance on engineered hard structures to reduce erosion impacts and improve ecosystem function
- ❑ Re-design or retrofit hard infrastructure to allow for sediment and water flows

3. Public Education and Outreach

- ❑ Recognize and reward property owners who practice excellent ecological stewardship
- ❑ Establish ecological literacy as a community goal
  - ❑ Provide educational signage and outdoor learning opportunities to advance understanding of coastal ecosystem benefits
  - ❑ Consider ecosystems in all land use planning and local governance decisions
  - ❑ Incorporate ecological resilience into school curriculums and outdoor education programming
- ❑ Promote understanding of native vegetation benefits
  - ❑ Engage community groups to inventory natural systems
  - ❑ Work with community groups to map natural systems
  - ❑ Develop native species planting lists
  - ❑ Pursue funding and partnership opportunities for ecological stewardship
  - ❑ Promote citizen science to monitor ecosystems in your community

Developed/Coastal Urban Areas

1. Land Use Planning and Zoning

- ❑ Develop municipal open space plans that incorporate climate change, sea-level rise and marsh migration projections
- ❑ Develop overlay zoning to acquire and manage land as open space to buffer against coastal hazards and make room for marsh migration

- ❏ Develop and implement watershed management plans that consider increasing precipitation trends and coastal flooding projections
- ❏ Establish/enhance minimum requirements for municipal design features to prepare for future climate change impacts
- ❏ Consider moving, elevating or removing property and infrastructure in hazard-prone areas
  - ❏ Support community buy-out programs in these areas
  - ❏ Prioritize habitat restoration to enhance ecosystem benefits, such as flood attenuation, groundwater recharge and wildlife habitat
- ❏ Incorporate wildlife movements and road crossings into infrastructure design and land use planning

2. Conservation Practices

- ❏ Restore natural features or install nature-based features for protection against coastal hazards
- ❏ Increase native landscaping in your community
- ❏ Reduce impervious surface cover to decrease stormwater runoff and flooding
- ❏ Promote groundwater conservation and recharge to reduce saltwater intrusion into freshwater resources
- ❏ Encourage use of Low Impact Development (LID) strategies in municipalities
  - ❏ Establish buffer zones around waterways
  - ❏ Promote rain barrels
  - ❏ Promote the use of green roofs
  - ❏ Increase native tree canopy
  - ❏ Inventory, inspect and test storm water basins
  - ❏ Improve function of existing storm water basins
  - ❏ Reduce impervious surfaces: turf cover, asphalt, stone

3. Public Education and Outreach

- ❏ Encourage residents to adopt native demonstration gardens to improve water infiltration and create habitat
- ❏ Promote understanding of native vegetation benefits
  - ❏ Engage community groups to inventory natural systems
  - ❏ Work with community groups to map natural systems
  - ❏ Develop native species planting lists
  - ❏ Pursue funding and partnership opportunities for ecological stewardship
- ❏ Reduce threats to tidal marshes from mosquito control practices that damage wetland integrity without reducing disease risk; educate public about CDC-approved, personal protection measures against container-breeding mosquitoes that bear disease
- ❏ Raise awareness and stewardship of wildlife crossings and consider wildlife migration in infrastructure retrofits, especially as wildlife must migrate to seek out suitable habitat
- ❏ Recognize and reward property owners who demonstrate excellent ecological stewardship of ecosystems

Beaches and Dunes

1. Land Use Planning and Zoning

- ❏ Incorporate sea-level rise and coastal dynamics into beach management plans
- ❏ Establish development setbacks behind secondary dunes in land use zoning and local building codes
- ❏ Survey beach and dune complexes to identify points of vulnerability, such as:
  - ❏ Active erosion
  - ❏ Sediment depletion
  - ❏ Gaps in landward dunes
  - ❏ Low dunes
  - ❏ Footpaths cutting through dunes
  - ❏ Absence of vegetation
  - ❏ Narrow beaches

2. Conservation Practices

- ❏ Protect dunes, dune-building processes, and dune vegetation
- ❏ Promote ecologically-sound beach nourishment and dune restoration
  - ❏ Apply best management practices for wildlife habitat in dune design and management
  - ❏ Use native vegetation in dunes restoration projects
  - ❏ Design for continuous secondary, landward dunes
  - ❏ Utilize elevated walkovers
  - ❏ Plug gaps in secondary dunes

- ❏ Promote the use of native dune vegetation in local landscaping
    - ❏ Establish and protect the full range of native dune vegetation
    - ❏ Protect maritime shrub and forest vegetation typical of older secondary and tertiary dunes
    - ❏ Plant native herbaceous, shrub and tree species
    - ❏ Use native dune vegetation as protective hedgerows around properties to capture sand and storm deposits and provide windbreaks
    - ❏ Consider the source and genetic diversity of plant material used in beach and dune restoration projects
- ❏ Replace cut-through footpaths with elevated dune walkovers to reduce dune erosion and vulnerabilities to storm surge
- ❏ Incorporate wildlife best management practices into beach and dune management to protect beach-dwelling wildlife
- ❏ Re-design or retrofit hard infrastructure in beach and barrier island environments to help address erosion and habitat loss

3. Public Education and Outreach

- ❏ Establish and enforce local ordinances that protect dunes, including native dune plants and beach-dwelling wildlife
- ❏ Participate in coastal community networks to share lessons from beach and dune management
- ❏ Establish ecological literacy as a community goal to educate the public about beach and dune benefits
    - ❏ Provide educational signage and outdoor learning opportunities to advance understanding of beach and dune benefits
    - ❏ Consider beaches and dunes in land use planning and local governance decisions
- ❏ Promote understanding of native beach and dune vegetation benefits
    - ❏ Engage community groups to inventory and map beach and dune systems
    - ❏ Develop local native species planting lists for beaches and dunes
    - ❏ Pursue funding and partnership opportunities for ecological stewardship of beaches and dunes
- ❏ Recognize and reward residents and landowners who are excellent dune and beach stewards

Coastal Forest and Shrublands

1. Land Use Planning and Zoning

- ❏ Establish restrictions on coastal forest and shrub clearing
- ❏ Incorporate sea-level rise and coastal ecosystem migration projections into coastal forest and shrub management plans
- ❏ Survey and map existing coastal forest and shrubland habitat
- ❏ Map existing upland open space in relation to projected marsh migration
- ❏ Conduct inventories of native trees and shrubs in your community
- ❏ Develop native vegetation planting lists based on this inventory
- ❏ Develop a local seed bank of local native species for native landscaping and restoration
- ❏ Establish or protect dune vegetation communities, from beach grass to maritime forest
- ❏ Train landscape architects and contractors in native landscaping and ecological solutions to coastal hazards

2. Conservation Practices

- ❏ Protect intact coastal forest and shrub stands
- ❏ Establish ordinances and practices supporting maritime forest and shrub protection and restoration
- ❏ Promote landscaping with native coastal forest and shrub vegetation
- ❏ Identify and protect all existing native vegetation
- ❏ Incorporate coastal forest and shrub species into stormwater management features
- ❏ Establish groundwater conservation and ecological recharge practices to minimize saltwater intrusion into plant root zones
- ❏ Discourage the use, sale or transport of invasive, non-native species that impair coastal forest and shrub communities.
- ❏ Keep loose pets and predators out of coastal forest and areas to protect habitat and wildlife

3. Public Education and Outreach

- ❏ Educate the public about the protective and habitat value of coastal forest and shrub vegetation
    - ❏ Provide educational signage and outdoor learning opportunities to advance understanding of coastal forest and shrubland benefits
    - ❏ Consider coastal forest and shrub conservation in land use planning and local governance decisions
- ❏ Promote understanding of native coastal forest and shrub vegetation benefits
    - ❏ Engage community groups in citizen science to inventory and map coastal forest and shrub vegetation in the community and surrounding landscape
    - ❏ Develop native species planting lists for coastal shrub and forests
    - ❏ Require use of native plants in public landscaping and any ecologically sensitive areas.
    - ❏ Encourage and incentivize native landscaping on private properties.
    - ❏ Pursue funding and partnership opportunities for ecological stewardship of coastal forests and shrublands
- ❏ Design and build public demonstration gardens and native landscaping exhibits with interpretive signage

Tidal Marshes

1. Land Use Planning and Zoning

- ❑ Incorporate sea-level rise and coastal ecosystem migration projections into tidal marsh management plans
- ❑ Map tidal marsh migration zones and barriers to marsh migration, such as hard infrastructure
- ❑ Discourage new development or infrastructure designs that would block marsh migration
- ❑ Establish development setbacks from tidal marshes
- ❑ Establish ordinances ensuring zero loss of tidal marshes
- ❑ Promote enrollment in NJDEP's Blue Acres program for residents in low lying areas and in the path of projected marsh migration

2. Conservation Practices

- ❑ Inventory all tidal marshes in your municipality
- ❑ Establish practices that protect existing tidal marshes
- ❑ Assess tidal marshes in your municipality to understand their condition
- ❑ Develop plans to restore impaired tidal marshes with state and federal agencies, scientists, and community groups. Possible signs of damage include:
    - ❑ Legacy manmade ditches, pools, or dikes that interfere with tidal flows or hasten erosion, and saltwater intrusion
    - ❑ Eroding edges
    - ❑ Signs of significant subsidence or drowning
    - ❑ Roads or other infrastructure crossing a marsh that will restrict water and sediment flow or the free passage of fish and wildlife
- ❑ Prioritize living shoreline practices over hard infrastructure, where feasible
- ❑ Reduce, soften or eliminate rigid vertical structures adjacent to tidal marshes
- ❑ Apply ecological best practices when considering re-using dredge materials to restore marshes
- ❑ Adopt ecologically sound mosquito control practices, as opposed to those that damage marsh condition and water quality. Such practices include:
    - ❑ Promote actions residents and property owners can take to manage container-breeding, disease-bearing mosquitoes around homes, schools, and businesses
    - ❑ Target mosquito control in select areas where disease-bearing mosquitoes are known to be present
    - ❑ Support natural mosquito predators, such as dragonflies, birds, bats and fish
    - ❑ Encourage citizen science monitoring of mosquitoes and predators
    - ❑ Obtain the appropriate expertise to identify mosquito species
- ❑ Review and revise local wake limits to reduce erosion of shorelines and tidal marshes
    - ❑ Use wake size limits instead of speed limits
    - ❑ Review current no-wake laws to ensure they provide adequate protection against tidal marsh erosion
    - ❑ Enforce existing no-wake zones
    - ❑ Establish or expand no-wake zones adjacent to all tidal marshes
- ❑ Restore tidal flow where it has been severed within and between marshes and other tidal areas
- ❑ Advance efforts to reduce polluted runoff into marshes, bays, and waterways
    - ❑ Promote use of native plants to reduce need for synthetic inputs, such as pesticides and fertilizers
    - ❑ Promote a culture shift away from grass turf and replace with native vegetation
    - ❑ Reduce impervious surface cover
    - ❑ Adopt low-impact development and green storm water management practices

3. Public Education and Outreach

- ❑ Publicly declare the importance of tidal marshes for community resilience
- ❑ Engage the public as citizen scientists in tidal marsh monitoring and reporting
- ❑ Recognize and reward private landowners who demonstrate excellent ecological stewardship of tidal marshes
- ❑ Follow ecological mosquito control practices to reduce pressure on marshes from mosquito control activities
    - ❑ Educate public about the distinction between mosquitoes that inhabit tidal marshes and disease-bearing, container-breeding mosquitoes
    - ❑ Disseminate information about the vital role residents have in mosquito control efforts by preventing against standing water on their properties that attracts container-breeding mosquitoes
    - ❑ Promote CDC-recommended personal protective measures
    - ❑ Emphasize the value of natural mosquito predators over pesticide spraying
    - ❑ Target mosquito spraying only where most necessary, in proximity to populated areas where actual disease risk has been detected

Appendix 2:

Threatened and Endangered Species of New Jersey Coastal Areas

Common Name	Scientific Name	Coastal Urban Areas	Beaches and Dunes	Coastal Forest & Shrubland	Tidal Marshes	Nearshore
Fish						
Shortnose Sturgeon [1,2]	*Acipenser brevirostrum*				X	
Reptiles						
Atlantic green turtle [1,2]	*Chelonia mydas*					X
Atlantic hawksbill turtle [1,2]	*Eretmochelys imbricata*					X
Atlantic leatherback turtle [1,2]	*Dermochelys coriacea*					X
Atlantic loggerhead turtle [1,2]	*Caretta caretta*					X
Kemp's ridley turtle [1,2]	*Lepidochelys kempi*					X
Birds						
American Bittern [1]	*Botaurus lentiginosu*				X	
Bald Eagle [1]	*Haliaeetus leucocephalus*		X	X	X	
Black Rail [1]	*Laterallus jamaicensis*				X	
Black Skimmer [1]	*Rynchops niger*		X		X	
Black-crowned Night Heron [1]	*Nycticorax nycticorax*			X	X	
Bobolink [1]	*Dolichonyx oryzivorus*				X	
Cattle Egret [1]	*Bubulcus ibis*				X	
Least Tern [1]	*Sternula antillarum*		X			
Northern Harrier [1]	*Circus cyaneus*				X	
Osprey [1]	*Pandion haliaetus*				X	
Peregrine Falcon [1]	*Falco peregrinus*	X	X	X	X	
Piping Plover [1,2]	*Charadrius melodus*		X			
Red Knot [1]	*Calidris canutus*		X			
Roseate Tern [1,2]	*Sterna dougallii*		X		X	
Savannah Sparrow [1]	*Passerculus sandwichensis*		X		X	
Sedge Wren [1]	*Cistothorus platensis*				X	
Short-eared Owl [1]	*Asio flammeus*				X	
Yellow-crowned Night Heron [1]	*Nyctanassa violacea*	X		X	X	
Invertebrates						
Banner Clubtail [1]	*Gomphus apomyius*				X	
Bronze Copper [1]	*Lycaena hyllus*				X	
Northeastern Beach Tiger Beetle [1,2]	*Cicindela d. dorsalis*		X			
Robust Baskettail [1]	*Epitheca spinosa*				X	

[1] State Endangered; [2] Federally Endangered

Avalon Dune and Beach Trail at Avalon, NJ.

Photo: Stacy Small-Lorenz

Maritime forest at Cape May Point State Park. *Photo: Stacy Small-Lorenz*