




STATE
OF THE
COAST

Photo: Above Summit

FUTURE CLIMATE-DRIVEN RISKS—AND
THEIR SOLUTIONS—ON MASSACHUSETTS'
NORTH SHORE



Proudly sponsored by
Breckinridge Capital Advisors



The collision between our natural world and the significant—and accelerating—impacts of climate change is a reckoning for ourselves and our environment.

As the largest nonprofit steward of Massachusetts coastline, protecting 120 miles of shoreline, The Trustees recognizes that we stand at an inflection point in 2020, much as our founder Charles Eliot did in 1891. Eliot and his generation faced the major threats of rapid development and privatization. In response, The Trustees commissioned a Province Lands Report, laying the foundation for what would become Cape Cod National Seashore, a conserved landscape of immense beauty.

Today, too, we must not hesitate to secure our coast for future generations. Over the next four years, The Trustees will release an annual State of the Coast report to spark dialogue and action across Massachusetts' diverse coastal regions. While uncertainty is inherent in projecting future risk, this report pinpoints climate-based threats and highlights solutions—many of which could serve as national models.

Our debut report features 13 North Shore communities, six of which have Trustees-owned properties that are beloved to nearly a half million visitors each year, from Crane Beach in Ipswich to Crowninshield Island in Marblehead. We highlight potential impacts from town to shore, spotlight current strategies, and propose future opportunities.

For us, protecting the coast is not only a priority—it's part of who we are. We shoulder a responsibility to champion for these iconic landscapes of extraordinary ecological and recreational value, all vulnerable to change and critical to the environment. We also understand and appreciate their significance to those who live, work, and play among them, and to New England's rare habitats and species within.

Achieving our goals requires leadership, collaboration, and innovation to an unprecedented degree. Climate change will call on us to adapt to a “new normal,” so we invite you to explore these findings, and to engage with us on this important work of discovery, protection, restoration, and care for a coast that needs our help more than ever.



Barbara Erickson

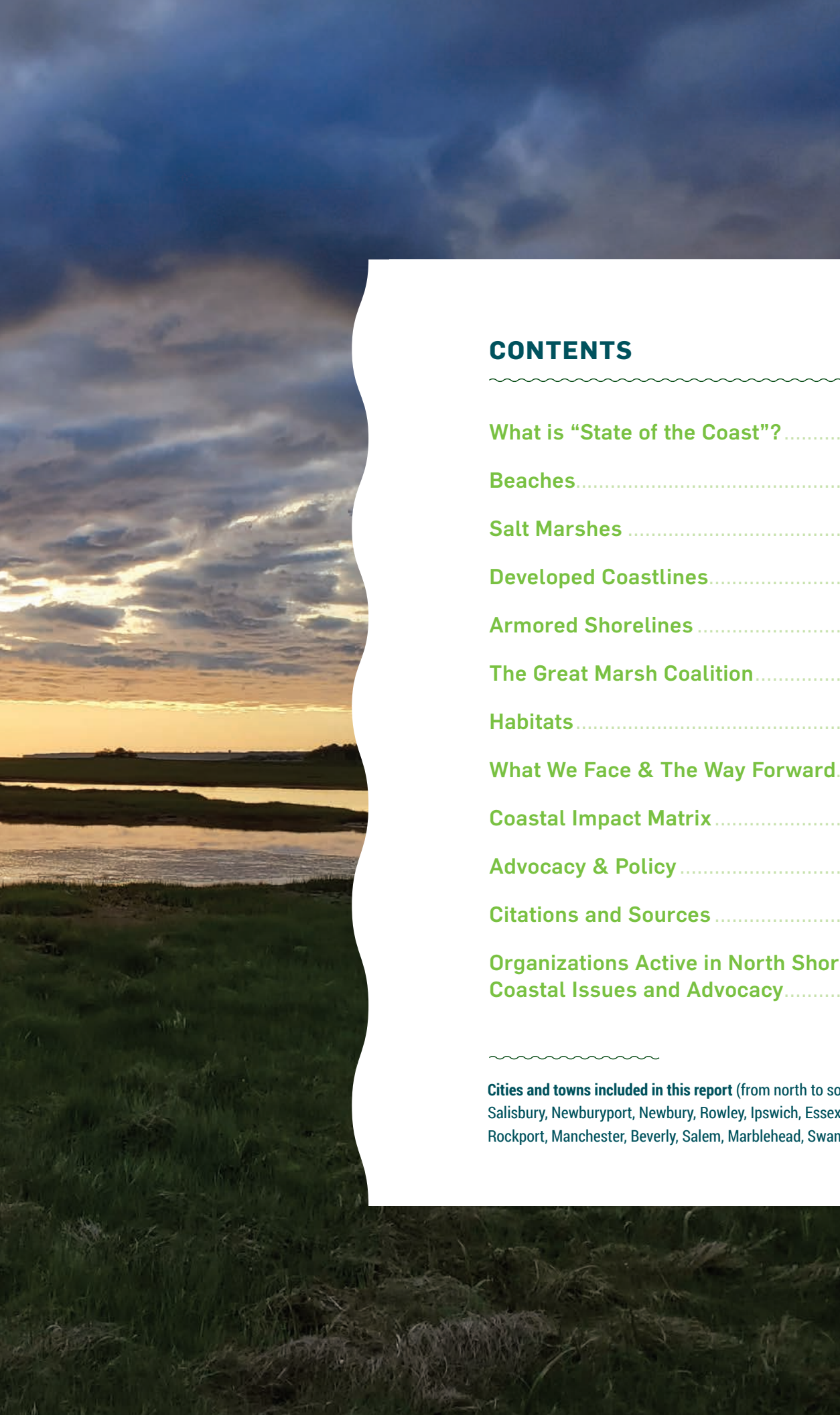
President & CEO
Trustees of Reservations



Tom O'Shea

Director of Coast & Natural Resources
Trustees of Reservations





CONTENTS

What is “State of the Coast”?	4
Beaches	8
Salt Marshes	10
Developed Coastlines	18
Armored Shorelines	20
The Great Marsh Coalition	29
Habitats	30
What We Face & The Way Forward	32
Coastal Impact Matrix	36
Advocacy & Policy	37
Citations and Sources	38
Organizations Active in North Shore Coastal Issues and Advocacy	39

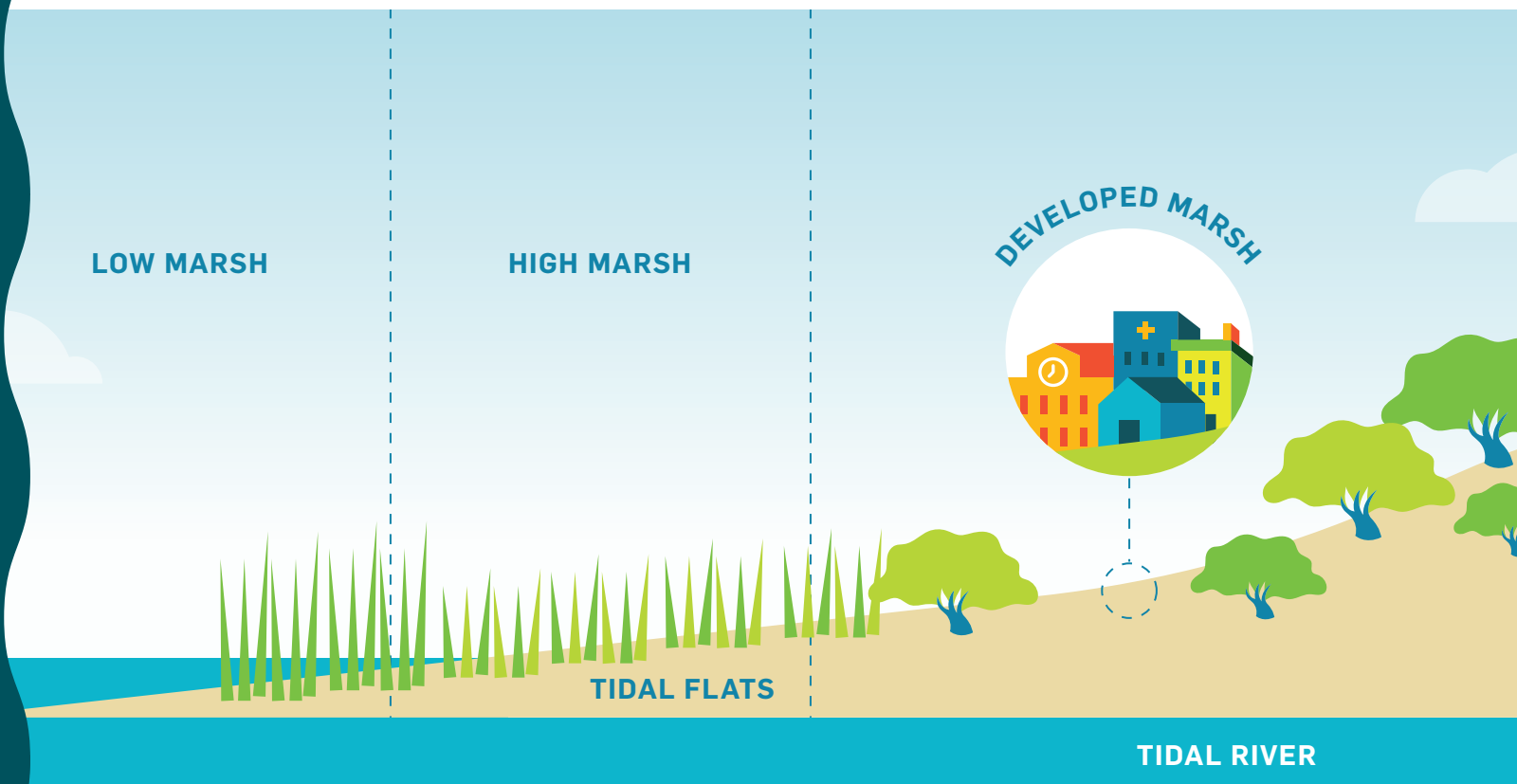
Cities and towns included in this report (from north to south):
Salisbury, Newburyport, Newbury, Rowley, Ipswich, Essex, Gloucester,
Rockport, Manchester, Beverly, Salem, Marblehead, Swampscott.

What is “State of the Coast”?

“State of the Coast” is an analytical assessment that uses the latest data to provide a snapshot of current coastal conditions, along with future-facing strategies and opportunities to create a more resilient and healthier coast on the North Shore of Massachusetts.

The report is designed to be a guiding resource that can stimulate discussion, action, and engagement among public officials, conservation partners, residents, and others. Sections include a *coastal impact matrix and flooding map* offering a visual of community impacts, and an *advocacy letter* detailing our specific proposals, as well as:

- *13 short town features* exploring possible climate change impacts and risks. In this section, we outline potential shoreline impacts, flood risks to developed areas, and innovative solutions that could serve as models elsewhere.
- *5 shoreline features* (salt marshes, beaches, developed coasts, armored coasts, and habitats) highlighting the main challenges that could be faced by different coastal areas on the North Shore. In this section, we also examine some current strategies and future opportunities for interventions and adaptation.



A digital version of the report at thetrustees.org/coast features interactive maps, additional data, and longer form content. We have broadened our scope beyond The Trustees to make this report as comprehensive and accessible as possible. Our editorial team included a North Shore-based coastal geologist and environmental consultant, mapping and flood risk modeling experts from Woods Hole Group, a creative director with experience designing complex reports, and an award-winning journalist.

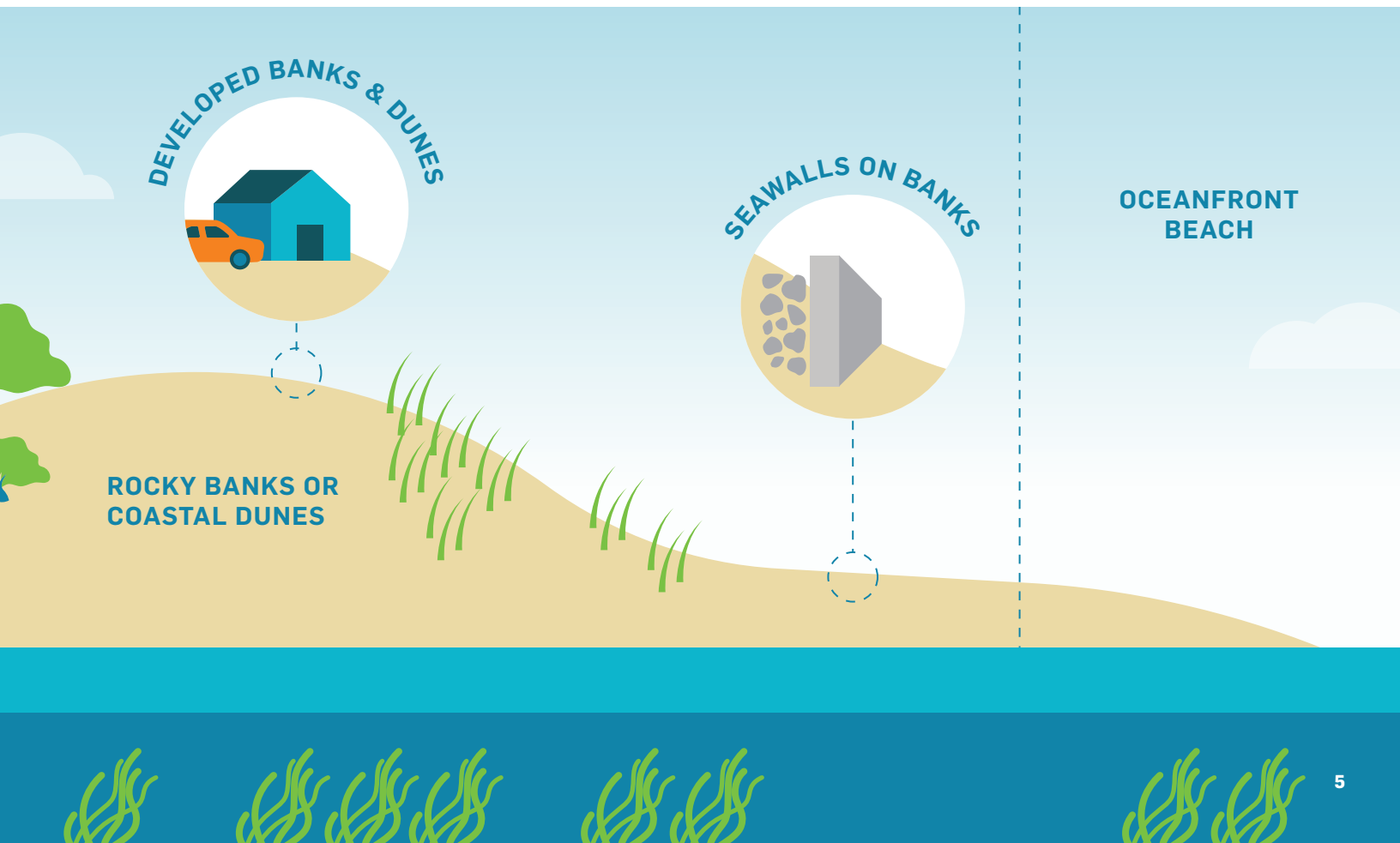
WHY US?

As the first conservation nonprofit and the largest private coastal landowner in Massachusetts, The Trustees has witnessed firsthand the accelerating and widespread impacts of climate change to our properties, which are located within 6 of the 13 communities in this report. Recognizing that it's

time for regional and statewide approaches to adapting and preparing our coast for the future, we embrace this opportunity to help lead and build consensus for meaningful change. We are in a unique position to share a long-term perspective that speaks to our mission, values, and philosophy—and underscores the urgent need for new coastal strategies.

WHY NOW?

We recognize the many pressures facing our shorelines and coastal habitats, such as development and pollution, and understand how many communities are already experiencing climate change-driven impacts to their coastal areas. These impacts include ocean warming and acidification, flooding from sea level rise, and stronger storm surge (which often features more intense wave energy) that can destroy structures and severely erode beaches and shorelines.



For this report, we have focused on two significant future impacts from climate change—*sea level rise* and *storm surge*. Both are anticipated to significantly increase after the year 2050 and have widespread impacts to coastal areas. Which means we have until then to make smart choices for interventions to adapt, but we need to start now.

Community strategies to adapt to climate change have primarily concentrated on critical infrastructure needs, ranging from municipal vulnerability planning to raising roads, protecting wastewater treatment facilities from flooding, and considering oyster reefs as protective breakwaters. This is encouraging, but most projects are still in the planning phase.

Among the issues to be addressed are, risks to coastal properties, including those owned privately, and significant threats to the conservation of important natural resources, wildlife, and ecosystems. The time to adapt and make smart intervention choices is limited, and we need to start now if we are to bring new approaches effectively and successfully to scale both on a regional and a statewide basis.

WHAT ARE THE MAIN CHALLENGES?

BEACHES We're losing extensive areas of beach, data shows. Some of our largest beaches are experiencing the greatest rate of shoreline loss, while sea level rise means smaller beaches hemmed in by seawalls, groins, and development may be increasingly sand-starved with nowhere to go.

SALT MARSHES Keeping pace with sea level rise is necessary for salt marshes to continue to act as important buffers against coastal flooding and storm surge, among their other valuable functions. Critical to this effort is building marsh elevation, along with removing tidal restrictions such as dams and culverts that disrupt natural water flow.

DEVELOPED COASTS Many of our communities are already affected by intense storms and severe flooding, which have led to road closures, damaged homes and businesses, and public safety risks. Though no one can predict the future for certain, thousands of buildings and many more miles of road have the potential to be impacted in the not-so-distant future, data shows. Communities and individual landowners may face a difficult choice: adapt or relocate.

DATA SCENARIOS AND ASSUMPTIONS

SEA LEVEL RISE (SLR) AND CHRONIC FLOODING

The Trustees and the Woods Hole Group, Inc. (WHG) utilized results from the Massachusetts Coastal Flood Risk Model (MC-FRM) to determine future projected chronic and storm-based flooding. MC-FRM includes SLR associated with the “high” projections as recommended by the Massachusetts Office of Coastal Zone Management (CZM), MassDOT, and the University of Massachusetts, and developed specifically for the Commonwealth of Massachusetts by DeConto and Kopp (2017). This “high” scenario of SLR assumes that global greenhouse gas (GHG) emissions continue in a similar fashion as today. This report's data is consistent with the Massachusetts coast-wide analysis conducted for MassDOT using the MC-FRM, which was developed to encompass all risk levels and assess critical infrastructure.

The actual elevations (in NAVD88) used to represent these SLR values vary slightly from town to town, and can be found on thetrustees.org/coast, under “data.”

Impacts to buildings and roads from storm flooding were determined using results from the MC-FRM developed by

WHG. MC-FRM considers the probability of severe coastal storms and evaluates impacts of those events in terms of coastal inundation. The storm effects consider assumed sea levels in the future given the SLR projections.

Marsh and coastal habitat changes were derived from Sea Level Affecting Marshes Model (SLAMM) results developed for CZM by WHG (details on thetrustees.org/coast, under “data”). The SLAMM results were also developed with SLR projections that assumed the global GHG emissions continue at the current rate; however, this was completed with older SLR projections (~2015) representative of a high rate of SLR at the time, but is more comparable to an intermediate-high scenario under the more recent projections of DeConto and Kopp (2017). Current marsh accretion rates were determined by applying the Marsh Equilibrium Model (Morris, 2015) applied at the Great Marsh System for the North Shore. More information on potential marsh accretion rates can be found in the link above.

Beach erosion rates were derived from the DRAFT Massachusetts Coastal Erosion Viewer.

ARMORED SHORELINES The North Shore has 54.4 miles of hard coastal barriers such as seawalls [CIT. 4] intended to hold back the sea, but they're aging and not designed to adapt to climate impacts. Not only are they costly to repair and replace, but these structures can wreak damage of their own on nearby natural shorelines. More resilient options are necessary for our coastal communities to be prepared for the challenges to come.

COASTAL HABITATS Only about 25% of our coastal habitats are permanently protected from development [CIT. 9], and they face increasing peril from climate-driven changes. A regional land protection strategy will help enhance the resiliency of both coastal and upland areas and relieve pressures from development and pollution.

WHAT GENERAL TRENDS DO WE SEE?

From a regional perspective, we see important differences in our northern and southern tiers that will require targeted approaches. Larger, less developed coastal beaches and marshes in communities such as Ipswich and Salisbury may experience more impacts but also provide more resiliency options due to the size of their natural coastal resources.

Although areas south of Gloucester are higher in elevation and generally less affected by flooding, their natural resource areas are likely to be *more vulnerable* and *less resilient* because they are smaller with little room for inland migration.

WHAT CAN YOU DO TO HELP?

We are asking you—our conservation partners, government officials, and communities—to engage in coastal land protection measures by advocating for larger investments in funding and new policies for coastal resiliency and conservation. We're also calling on you—our members, visitors, and coastal residents—to collaborate on effective responses and innovative strategies to confront climate-driven impacts to our most beloved, vulnerable places. Together, we can support adaptations that respond to coastal change.

We cannot wait to act. We're at a pivotal moment when working together can make a real difference on our dramatically changing landscape, and all that it contains.

GLOSSARY OF COMMONLY USED TERMS

MUNICIPAL VULNERABILITY PREPAREDNESS PROGRAM

An evaluation and planning process coordinated, funded, and led by the Commonwealth of Massachusetts Executive Office of Energy and Environmental Affairs, that allows communities to define climate-related hazards, understand how they may be impacted by climate change based on the latest science and data, identify existing and future climate vulnerabilities and strengths, and target opportunities to reduce risk and build resilience. Based on this information, communities can implement priority actions. *Source: MVP program website*

CLIMATE RESILIENCE The ability to anticipate, prepare for, and respond to hazardous events, trends, or problems related to climate. Improving climate resilience involves assessing climate-related risks, and taking steps to better cope with these risks. Coastal resilience means the ability of a community to "bounce back" after hazardous events such as hurricanes, coastal storms, and flooding. *Sources: NOAA, Center for Climate and Energy Solutions*

STORM SURGE The abnormal rise in seawater level during a storm, measured as the height of the water above the normal predicted astronomical tide. The surge is caused primarily by a storm's winds pushing water onshore. The rise can cause extreme flooding in coastal areas, especially when it coincides with normal high tide. Its strength depends on the orientation of the coast and intensity of storm, among other factors. *Source: NOAA*

WAVE ENERGY Waves are created by energy passing through water, causing it to move in a circular motion. Waves also transmit energy, not water, across the ocean. Because water weighs approximately 1,700 pounds per cubic yard, extended pounding by frequent waves can severely damage or destroy coastal structures and erode natural elements such as sand. Wave energy and storm surge work together to impact coastal areas. *Source: NOAA*

SEA LEVEL RISE An increase in the level of the world's oceans due to the effects of global warming, which is caused primarily by two factors: the added water from melting ice sheets and glaciers and the expansion of seawater as it warms. Sea level rise poses a serious threat to coasts around the world, with consequences including intensified storm surges, flooding, and damage to coastal zones, particularly low-lying areas. *Sources: NOAA, National Geographic*

MEAN HIGHER HIGH WATER (MHHW) The average of the higher high water height of each tidal day observed over a 19-year tidal cycle referred to as the National Tidal Datum Epoch. *Source: NOAA*

Beaches

Beaches are fragile, dynamic environments that respond to wind, currents, waves, tides, changing seasons, and manmade shoreline changes. While resilient beaches, especially barrier beach systems, have coastal dunes and beach grass to soften the impacts, climate-driven sea level rise and storm surge accelerate erosion and threaten these precious natural resources.

Erosion also threatens wildlife habitat and damages properties and infrastructure. Data shows we need to plan now for how to protect our beaches and safely accommodate change.

CLIMATE CHANGE IMPACTS

It can be difficult to distinguish between natural shifts and climate-driven changes, but what's clear is that we're experiencing a dramatic loss of shoreline at some of our most beloved beaches. The eastern tip of Trustees-owned Crane Beach has narrowed by 5 feet per year since the 1950s [CIT. 5] for a total loss of 112 acres—the equivalent of 84 football fields—and it has lost about 2,000 feet in length since 1995 [CIT. 4]. Future impacts include:

- **WEAKENED STORM PROTECTION** Intensifying storms will pose greater risks to beaches and private and public properties—about half of which are protected by some sort of armoring on the North Shore. In Essex County, more than \$100 billion of coastal real estate is at risk, according to a 2015 MA Coastal Erosion Commission report [CIT. 4].
- **INCREASED POLLUTION** When it floods, stormwater runoff triggers increased sewage overflows. For example, Swampscott's waterfront along Eastern Avenue led the state in 2019 with 39 potentially unsafe beach days, according to news reports.
- **LOSS OF WILDLIFE HABITAT** Beach and dune erosion poses risks to fish, shellfish, and migratory birds such as the federally threatened piping plovers.
- **REDUCED SEDIMENT** The northern section of Plum Island, for instance, has suffered nearly 300 feet of shoreline loss [CIT. 5] due to storm damage and erosion. Most recently, Newburyport requested sand deployment assistance after a severe storm.
- **LIMITED PUBLIC ACCESS** Flooding is likely to make public beach access by car, bike, and foot even more challenging, hurting communities that rely on summer visitors and tourism. Crane Beach alone accounts for more than 350,000 visitors annually.

FUTURE OPPORTUNITIES

Beach nourishment and dune reconstruction efforts can be effective short- to medium-term measures to address erosion on beaches. These measures can require significant investments in dredged sand—which can be costly, and sometimes controversial. Sand, which drifts over time, is considered a "soft" solution and is often more compatible with a natural system.

Beach managers and coastal landowners may be faced with the question of values, time horizon, and return on investment for choosing when to intervene and when to accept loss as erosion accelerates in places. Based on our latest findings, we propose:

EXPANDING DUNE AND BEACH RESTORATION to protect public access, habitat, and property from erosion and flood risk. While not a universal solution, it can have a real short- to medium-term impact in some cases.

TRANSITIONING EXISTING DEVELOPMENT by employing strategies such as expanded buyout options, rolling easements (combined with policies to prevent coastal armoring) to ease relocation, and incentives for residents and developers to develop adaptive, floodproof designs.

INCREASING RESILIENT PUBLIC ACCESS It's time to take a renewed look at how we will ensure future beach access. Crane Beach boardwalks, for instance, adjust in length and height to reflect changing dune conditions. The Trustees also is working with Ipswich to raise Argilla Road to reduce flooding impacts and preserve public access for the next 50 years.

INVOLVING THE PUBLIC AS COASTAL AMBASSADORS IN BEACH PROJECTS such as beach grass planting or the citizen-science profiling effort at Crane Beach. Volunteers collect monthly data on beach conditions and educate visitors about changes in the beach shoreline. The Trustees, with the support of CZM, has also developed a series of videos, podcasts, and whitepapers that include local stakeholder perspectives and preferences on adaptation measures to protect publicly accessible shorelines and coastal beaches from flooding and erosion.

More action, and more action now, is needed to preserve and protect our natural coast. Learn more and get involved at thetrustees.org/coast



Aerial of Crane Beach, Ipswich, MA

CURRENT COASTAL STRATEGIES

BEACH NOURISHMENT/DUNE RECONSTRUCTION which generally refers to building up a beach or dune by replacing sand lost to longshore drift or erosion with sand from another source. Sand dunes protect communities during storms, while vegetation stabilizes and builds dunes and provides wildlife habitat. Activities in recent years include:

- Salisbury Beach was replenished with 10,000 cubic yards of sand to fortify storm-damaged dunes [CIT. 4]. New snow fencing was installed to trap snow and sand and prevent erosion.
- Newbury used native vegetation methods and installed sand fencing to nourish and stabilize eroding dunes.
- As part of its repairs to Long Beach, Rockport added sand to strengthen the buffer and protect homes.

COASTAL WAVE AND SEDIMENT STUDIES to assess how climate-driven change could impact our most at-risk beaches. The Trustees, Town of Essex, and Boston University, for instance, are conducting a study exploring the future integrity of Crane Beach and Essex Bay/Estuary.

Salt Marshes



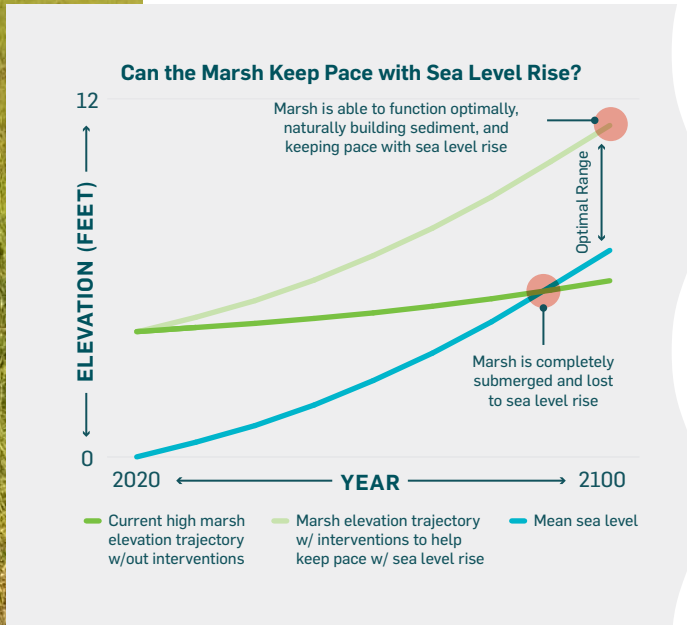
With wide open views, natural beauty, and diverse wildlife, salt marshes are one of the most productive ecosystems on the planet. Their grasses, flooded and drained by tides, accumulate captured sediment and decomposing plant matter to form peat and provide growing space for roots, allowing marsh to rise and keep pace with sea levels.

Marshes are divided into two distinct zones, with a minor difference in elevation: low marsh, which floods daily at high tide, and the predominant high marsh, known for fine low grasses that flood only a few times each month. These wetland areas are especially vulnerable to projected climate change effects due to a legacy of widespread ditches and tidal restrictions that disrupt natural water flow.

CLIMATE CHANGE IMPACTS

The Great Marsh, the largest salt marsh in New England at more than 20,000 acres, is considered one of the East Coast's most resilient marsh systems. Yet our latest data shows potentially dramatic shifts by 2070. Nearly 14,000 acres could flood daily, compared to 1,500 now, with at least 400 acres of Great Marsh completely lost [CIT. 2]. Impacts include:

- **SEA-LEVEL RISE OUTPACING MARSH ACCRETION** Without intervention, high marsh is likely to convert to low marsh, tidal flats, or be completely submerged [CIT. 2].
- **WEAKENED MARSH SHORELINE RESISTANCE** to waves, possibly causing erosion and endangering homes, businesses, and roads.
- **LOSS OF REFUGE, FEEDING, AND BREEDING AREAS**, posing risks to fish, shellfish, plants, and migratory birds such as the salt-marsh sparrow, whose population is declining by 9% per year [CIT. 12].
- **LOSS OF A NATURAL CLIMATE SOLUTION** Coastal ecosystems such as salt marshes improve water quality and absorb carbon at rates up to 50 times greater than forests.
- **LOSS OF RECREATIONAL AND ECONOMIC ACTIVITIES** such as bird watching, fishing, shellfishing, boating, and hiking. The shellfish harvest in Great Marsh communities alone was valued at more than \$5 million in 2018 [CIT. 8].



CURRENT COASTAL STRATEGIES

It's not too late to save our marshes, large sections of which are owned by conservation nonprofits and public agencies. Ongoing strategies include:

REMIEDIATING THE LEGACY OF DITCHING With few exceptions, the marshes throughout Essex County are home to the remnants of ditches once used for increasing agricultural production and controlling mosquitoes. The result was altered hydrology and marsh loss. To reverse this trend and restore marsh health, The Trustees is "healing" old agricultural ditches across more than 300 acres in Newbury, Essex, and Ipswich, by cutting marsh vegetation and securing it in low ditches to trap tidal sediment, allowing peat to rebuild.

REDUCING THE IMPACT OF AGED AQUATIC BARRIERS The Ipswich River Watershed Association is working with communities to reduce the impact of aquatic barriers such as dams, culverts, and bridges on natural salt tidal flow.

CREATING LIVING SHORELINES Salem, among other places, is restoring fringing salt marsh. The city is using biodegradable coir rolls and salt marsh vegetation to help naturally protect its popular Collins Cove recreational pathway and nearby homes from wave action and flooding.

PROTECTING COASTAL LAND Mass Audubon and Greenbelt, Essex County's Land Trust, manage Rough Meadows Wildlife Sanctuary in Rowley on more than 265 acres of saltmarsh and adjacent upland once slated for development. The sanctuary protects land suitable for accommodating sea level rise and encompasses coastal woodlands, salt marshes, tidal creeks, and salt pannes with diverse wildlife.

FUTURE OPPORTUNITIES

We need cost-effective, marsh-wide restoration projects that sustainably target areas with the best chance of resiliency and ability to adapt. And we need them now since full restoration frequently takes a decade or more. Based on our latest findings, we propose:

IMPLEMENT RESTORATION AND RESILIENCY

AT-SCALE Restoring thousands of acres of marsh requires close partnership with communities, land-owners, regulators, and organizations up and down the coast. It means making investments in low-risk, nature-based techniques such as removing tidal restrictions, ditch remediation, and runneling to improve tidal flow and help marsh keep pace with sea level rise.

REBUILD MARSHES THROUGH INNOVATION It's time to test new approaches such as Mud Motors, which involve strategically placing dredged sediment in tidal channels, so it can naturally, continuously disperse to nearby salt marshes.

ENACTING EFFECTIVE PUBLIC POLICY State and local wetland laws and regulations must go beyond existing impacts to also consider future resiliency benefits when permitting for actions such as pilot marsh restoration.

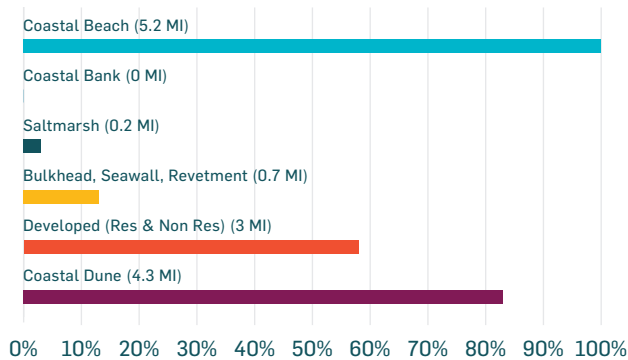
MITIGATING DEVELOPMENT AND CONSERVING SALT MARSH MIGRATION PATHWAYS If new salt marsh is to migrate onto higher ground, land must be permanently and sustainably protected from development. Tools can include coastal buyouts, rolling easements, conservation and deed restrictions, and in-lieu fee programs once we identify what is protected and what is not.

More action, and more action now, is needed to preserve and protect our natural coast. Learn more and get involved at thetrustees.org/coast

Salisbury

OCEAN-FACING SHORELINE (5.2 MILES) [CIT. 4]

Shoreline types below can overlap, not cumulative



FUTURE STORM AND TIDAL FLOODING [CIT. 1,3]



- Current Shoreline
- 2050 Chronic Tidal Flooding (MHHW)
- 2050 1% (1 in 100 year) storm flooding

THE MAIN IMPACTS:

EROSION Roughly 4,500 acres (40%) are vulnerable to coastal inundation [CIT. 3], with a public beach that has short term erosion rates of more than 2 feet per year [CIT. 4].

MARSH LOSS More than half of Salisbury's coastal area is salt marsh, and up to 978 acres (38%) of high marsh could be lost by 2050 [CIT. 4].

HABITAT CONCERNS At risk are migrating shorebirds, waterfowl, wintering harbor seals, and even foxes.

DEVELOPED COAST Buildings behind Salisbury Beach, especially near marsh, could be at-risk of daily tidal and storm flooding in 2050. Rt. 1 (Bridge Road) and buildings near the Merrimack River may be flooded from daily tides [CIT. 1,3].

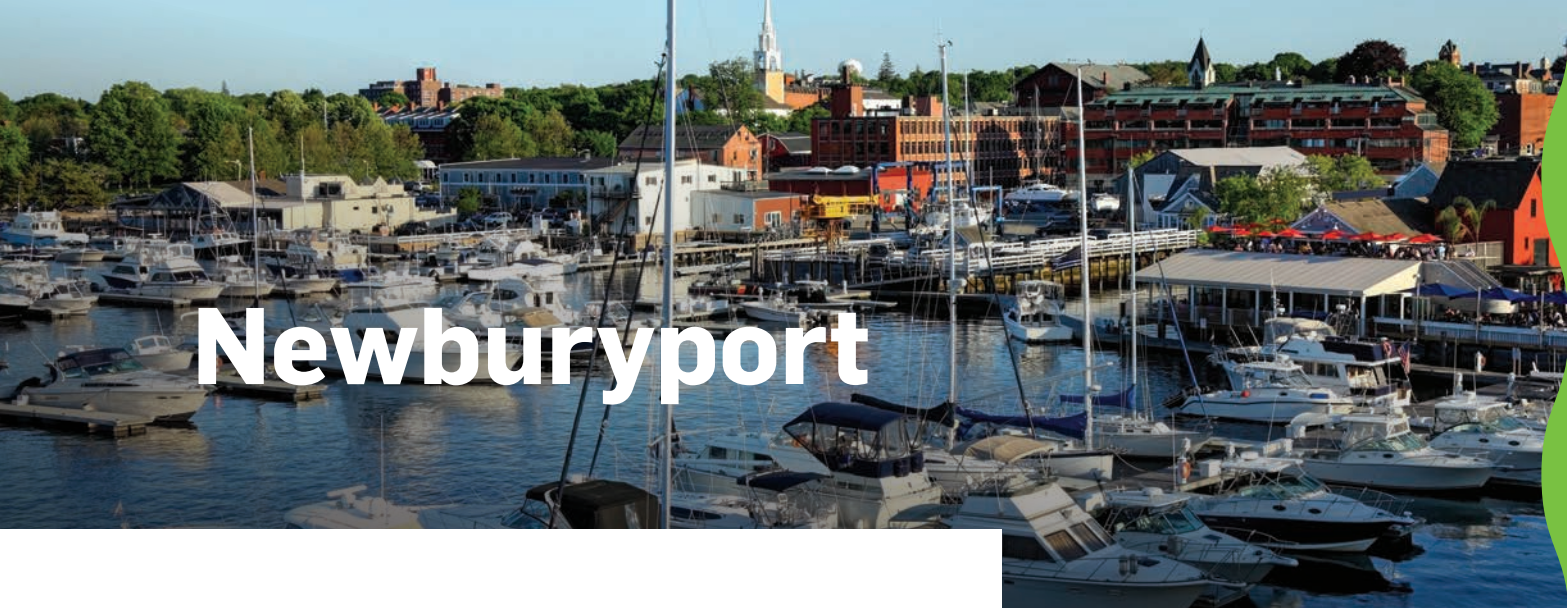
OTHER RISKS INCLUDE:

PROPERTY DAMAGE A 10-year storm may flood almost 1,646 buildings (30.3%) in 2050 [CIT. 3]. Chronic daily tidal flooding could impact 512 buildings (9.4%) in 2050 [CIT. 1].

ROAD FLOODING Daily high tides may flood about 2.8 miles (3.4%) of roads in 2050 [CIT. 1]. An estimated 22 miles (26.1%) of roadway could flood in the event of a 100-year storm in 2050 [CIT. 3].

STRATEGY SNAPSHOT: ELEVATING ROADS

Salisbury is considering raising two Ring's Island roads—March and Ferry Roads—to reduce chronic flooding impacts and ensure public safety. Similarly, The Trustees is working with Ipswich to raise Argilla Road near Crane Beach, while communities elsewhere are turning to so-called “floating roads” (with supports or pontoons) to mitigate climate impacts.



Newburyport

THE MAIN IMPACTS:

EROSION Plum Island's severe erosion, with a short-term erosion rate of up to 7.5 feet per year [CIT. 5], continues to threaten beaches and homes.

MARSH LOSS By 2050, 17% of the city's 257 acres of total marsh may be lost—the highest percentage on the North Shore [CIT. 2].

HABITAT CONCERNS By 2050, about 537 (71%) of 755 acres of Newburyport's estuarine beach/tidal flats could become open water [CIT. 2].

DEVELOPED COAST Downtown riverfront areas could be susceptible to 10-year storm flooding events in 2050 as well as areas at the end of Old Point Road in Plum Island. Some daily tidal flooding may occur in 2050 in these areas [CIT. 1, 3].

OTHER RISKS INCLUDE:

PROPERTY DAMAGE A 10-year storm in Newburyport may flood almost 419 buildings (5.7%) in 2050 [CIT. 3]. Chronic daily tidal flooding could impact 30 buildings (0.4%) in 2050 [CIT. 1].

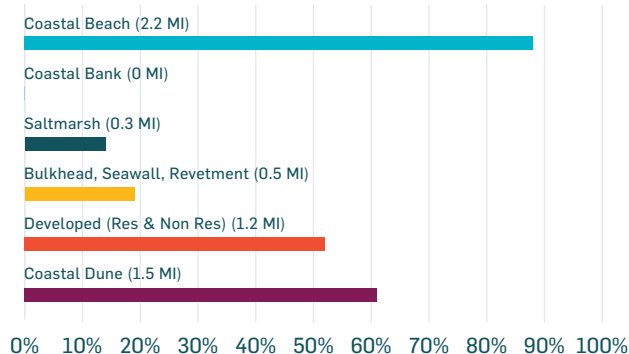
ROAD FLOODING Daily high tides may flood 0.2 miles (0.2%) of roads in 2050 [CIT. 1]. An estimated 7.4 miles (7.3%) of roadway could flood in the event of a 100-year storm in 2050 [CIT. 3].

STRATEGY SNAPSHOT: WASTEWATER TREATMENT PLANT

Newburyport is developing ways to protect its low-lying wastewater treatment plant from flooding, storm surge, and sea level rise—climate-driven impacts that could eventually force its relocation from Water Street along the Merrimack River. Saltwater from storm surges can damage wastewater plants, while flooding carries contamination and public health risks. Short-term solutions under consideration include a berm, flood wall, and temporary hydraulic barriers for building entrances and critical infrastructure. Gloucester, too, is taking mitigation actions to protect five of its most vulnerable sewer pumping stations.

OCEAN-FACING SHORELINE (2.4 MILES) [CIT. 4]

Shoreline types below can overlap, not cumulative



FUTURE STORM AND TIDAL FLOODING [CIT. 1,3]

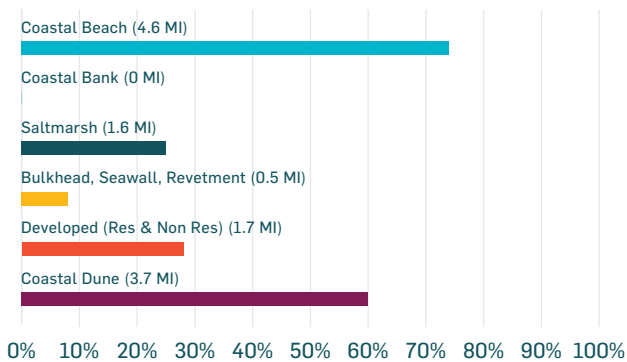


- Current Shoreline
- 2050 Chronic Tidal Flooding (MHHW)
- 2050 1% (1 in 100 year) storm flooding

Newbury

OCEAN-FACING SHORELINE (6.2 MILES) [CIT. 4]

Shoreline types below can overlap, not cumulative



FUTURE STORM AND TIDAL FLOODING [CIT. 1,3]



- Current Shoreline
- 2050 Chronic Tidal Flooding (MHHW)
- 2050 1% (1 in 100 year) storm flooding

THE MAIN IMPACTS:

EROSION on the developed portion of Newbury Beach, north of Parker River National Wildlife Sanctuary, threatens ocean-front neighborhoods, with up to 4.6 feet of beach already lost per year [CIT. 5].

MARSH LOSS By 2050, the town's low marsh may increase by 61% as high marsh transitions to low marsh [CIT. 2].

HABITAT CONCERNS By 2050, about 115 (18%) of the town's 637 acres of estuarine beach/tidal flats could become open water [CIT. 2].

DEVELOPED COAST Daily tidal flooding of Newman and Pine Island Road may occur in 2050. Ten-year storm flooding of roads and buildings on Plum Island, Northern Boulevard, and Plum Island Turnpike is likely in 2050, with some daily tidal flooding [CIT. 1,3].

OTHER RISKS INCLUDE:

PROPERTY DAMAGE A 10-year storm in Newbury may flood more than 609 buildings (14.6%) in 2050 [CIT. 3]. Chronic daily tidal flooding could impact 44 buildings (1.1%) in 2050 [CIT. 1].

ROAD FLOODING Daily high tides may flood almost 1.7 miles (1.9%) of roads in 2050 [CIT. 1]. An estimated 18.5 miles (20.5%) of roadway could flood in the event of a 100-year storm in 2050 [CIT. 3].

STRATEGY SNAPSHOT: DUNE NOURISHMENT

Sand dunes serve as a critical natural barrier for protecting coastlines from storms and flooding. After losing several homes to the sea, Newbury restored a stretch of coastal dunes several years ago by planting native vegetation, installing sand fencing, and removing invasive species with technical assistance from the University of New Hampshire. The project team, and community volunteers, also collected data to inform future restoration efforts.

Rowley

THE MAIN IMPACTS:

EROSION While Plum Island erosion is likely to worsen, no specific threat exists for Rowley residents, who do not live on the island.

MARSH LOSS High marsh, which makes up most of Rowley's 2,000 acres of marsh, may start transitioning to regularly flooded marsh and open water by 2050, with 100 acres of high marsh possibly lost [CIT. 2].

HABITAT CONCERNS By 2050, about 200 acres (46%) of the town's 437 acres of estuarine beach/tidal flats could become open water [CIT. 2].

DEVELOPED COAST Daily tidal flooding of Stackyard and Patmos Roads is likely in 2050 [CIT. 1].

OTHER RISKS INCLUDE:

PROPERTY DAMAGE A 10-year storm in Rowley may flood more than 73 buildings (about 2.3%) in 2050 [CIT. 3]. Chronic daily tidal flooding could impact 25 buildings (0.8%) in 2050 [CIT. 1].

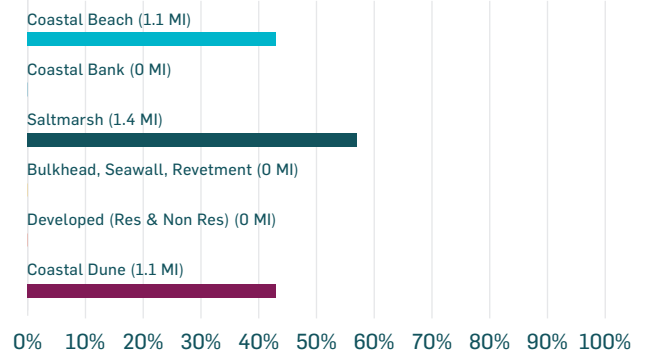
ROAD FLOODING Daily high tides may flood almost 1.5 miles (2.0%) of roads in 2050 [CIT. 1]. An estimated 9.2 miles (12.2%) of roadway could flood in the event of a 100-year storm in 2050 [CIT. 3].

STRATEGY SNAPSHOT: MVP PLAN

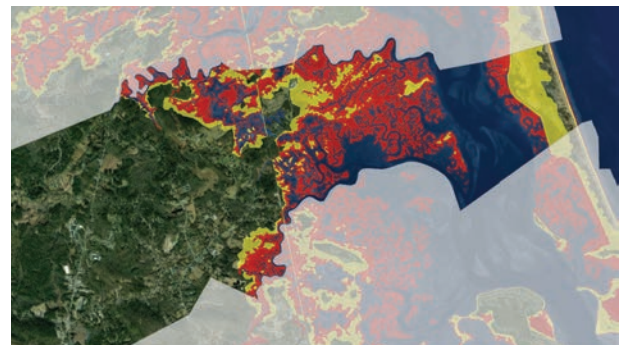
Rowley received a Municipal Vulnerability Preparedness (MVP) grant earlier this year for community-led planning around climate-related risks. The MVP program provides funding and technical support for cities and towns to identify climate hazards and develop strategies to improve resilience. When its plan is complete, Rowley will be eligible for MVP Action Grants to implement priority projects. Communities use grants for on-the-ground actions such as adapting infrastructure, stormwater upgrades, dam retrofits and removals, and nature-based solutions such as wetland restoration.

OCEAN-FACING SHORELINE (2.5 MILES) [CIT. 4]

Shoreline types below can overlap, not cumulative



FUTURE STORM AND TIDAL FLOODING [CIT. 1,3]

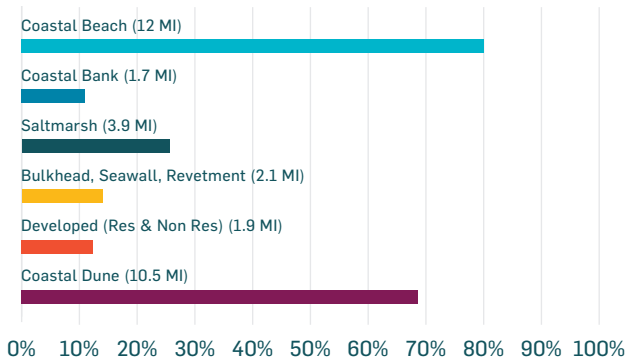


- Current Shoreline
- 2050 Chronic Tidal Flooding (MHHW)
- 2050 1% (1 in 100 year) storm flooding

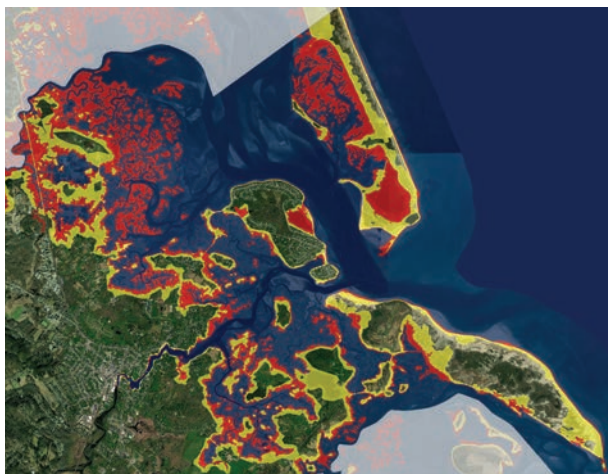
Ipswich

OCEAN-FACING SHORELINE (15.3 MILES) [CIT. 4]

Shoreline types below can overlap, not cumulative



FUTURE STORM AND TIDAL FLOODING [CIT. 1,3]



- Current Shoreline
- 2050 Chronic Tidal Flooding (MHHW)
- 2050 1% (1 in 100 year) storm flooding

THE MAIN IMPACTS:

EROSION Crane Beach is expected to continue to experience the most dramatic erosion of public beaches along the North Shore, with 1,500 feet of sand and dunes already lost since 2000 [CIT. 8].

MARSH LOSS By 2050, about 10% of 3600 acres of high marsh may be regularly flooded [CIT. 2].

HABITAT CONCERNS About 445 of 1,679 acres (27%) of estuarine beach/tidal flats could be lost to open water by 2050 [CIT. 2].

DEVELOPED COAST Daily tidal flooding of Jeffrey's Neck, Argilla, and Labor in Vain roads as well as buildings in the center of town near the Ipswich River may occur in 2050 [CIT. 1].

OTHER RISKS INCLUDE:

PROPERTY DAMAGE A 10-year storm in Ipswich may flood more than 340 buildings (5.1%) in 2050 [CIT. 3]. Chronic daily tidal flooding could impact 50 buildings (0.8%) in 2050 [CIT. 1].

ROAD FLOODING Daily high tides may flood nearly 1.7 miles (1.2%) of roads in 2050 [CIT. 1]. An estimated 15.8 miles (11.5%) of roadway could flood in the event of a 100-year storm in 2050 [CIT. 3].

STRATEGY SNAPSHOT: ADAPTIVE DESIGN

Building in flood zones requires innovative design and adaptive construction. The Trustees' planned Coastal Education Center at Crane Beach contains several different resiliency strategies within one building and is part of an overall plan that involves raising a stretch of Argilla Road, the only public beach route. The new center will include a hardened, dry floodproofed core and three elevations with wet floodproofing features, such as breakaway walls for water to pass through. It is also designed for diverse uses based on changing climate conditions over time.

Essex

THE MAIN IMPACTS:

EROSION Continued marsh erosion could significantly impact structures along the Essex River and around Conomo Point [CIT. 15].

MARSH LOSS High marsh, which now covers about 1,800 acres in Essex, may be reduced by 260 acres in 2050 as it transitions to low marsh [CIT. 2].

HABITAT CONCERNS By 2050, 125 (17%) of the town's 747 acres estuarine beach/tidal flats may become open water [CIT. 2].

DEVELOPED COAST Daily tidal flooding will likely impact access on sections of Main Street, Island Road, Robins Island Road, and Conomo Point Road in 2050. Some daily flooding of nearby buildings may occur [CIT. 1].

OTHER RISKS INCLUDE:

PROPERTY DAMAGE A 10-year storm in Essex may flood more than 325 buildings (13.6%) in 2050 [CIT. 3]. Chronic daily tidal flooding could impact 84 buildings (3.5%) in 2050 [CIT. 1].

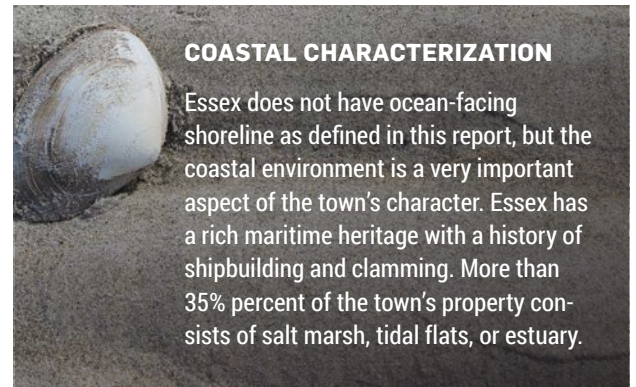
ROAD FLOODING Daily high tides may flood 0.7 miles of roads (1.6%) in 2050 [CIT. 1]. An estimated 5.2 miles (11.7%) of roadway could flood in the event of a 100-year storm in 2050 [CIT. 3].

STRATEGY SNAPSHOT: ARMORED STRUCTURES

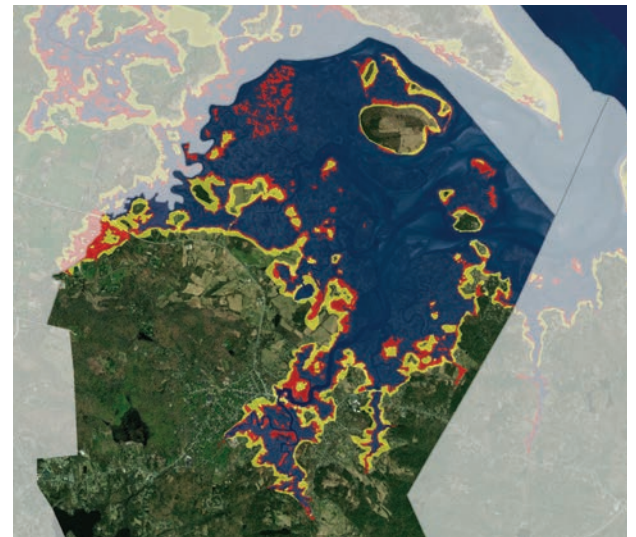
Essex is seeking to replace a critical seawall at Conomo Point, that sustained severe storm damage in 2018. The seawall protects properties and the road providing access to the primary boat launch used by emergency services and the Massachusetts Environmental Police. Other communities, too, are weighing whether to repair, replace or remove hard barriers, which increase risks to natural ecosystems.

COASTAL CHARACTERIZATION

Essex does not have ocean-facing shoreline as defined in this report, but the coastal environment is a very important aspect of the town's character. Essex has a rich maritime heritage with a history of shipbuilding and clamming. More than 35% percent of the town's property consists of salt marsh, tidal flats, or estuary.



FUTURE STORM AND TIDAL FLOODING [CIT. 1,3]



- Current Shoreline
- 2050 Chronic Tidal Flooding (MHW)
- 2050 1% (1 in 100 year) storm flooding

Developed Coastlines

Massachusetts coastal communities face significant risks from coastal storms, flooding, erosion, and sea level rise—challenges exacerbated by climate change. Adding to the threats is new and existing development, which can adversely impact sensitive coastal resources.

Many people here live, work, and play in close proximity to the seashore. If immediate action is not taken, The Trustees is concerned about the likelihood of substantial impacts to public road access, homes, businesses, and critical infrastructure in coastal areas.

While vulnerability varies considerably, some areas with extensive beaches (Salisbury to Essex) are relatively low-lying and more likely to experience negative impacts. The coast from Gloucester south to Swampscott is generally higher and more developed, yet even these areas may see over-topped seawalls and banks from storms and flooding of low areas. With most of the coastline privately held, thousands of property owners are likely to face the increasing challenges of climate change.

Examples of impacts include:

ROADS Flooding is projected to increasingly threaten property and public safety, particularly in Salisbury, Gloucester, Salem, Ipswich, and Essex. For example, the data shows more than 18 miles of roads in Newbury may flood in a 100-year storm in 2050 [CIT. 3]. Roads chronically flooded from daily tides after 2050 could include Argilla and Jeffrey's Neck Roads in Ipswich, the Plum Island Turnpike, and roads along the Great Marsh in Newbury, Rowley, and Essex [CIT. 1].

NEIGHBORHOODS Communities in recent years have experienced the devastation caused by repeated storm surges and flooding. Our 2050 projections show potential flooding on a regular basis on Plum Island and Salisbury Beach, near the Devereux Beach area in Marblehead and Long Beach in Gloucester, and in Essex neighborhoods near Conomo Point [CIT. 1].

BUSINESS DISTRICTS Flooding threatens downtown areas, new coastal developments, and critical infrastructure. In 2018, for instance, an intense winter storm sent high tides crashing over Front Street in Marblehead just two months after historic high tides led to road closures, Plum Island evacuations, and damage to businesses like Woodman's in Essex. Storms

(cont'd)



also may impact downtown Newburyport along the Merrimack River, including its wastewater treatment plant.

CURRENT COASTAL STRATEGIES

Cities and towns on the North Shore actively participate in two state-sponsored programs—the **Coastal Resilience Grant Program** and the **Municipal Vulnerability Preparedness program**—and have undertaken vulnerability assessments. The programs provide financial and technical support for local efforts to prepare for climate change resiliency, develop action-oriented adaptation plans, and implement priority projects.

FUTURE OPPORTUNITIES

What faces us now is a chance to transition our communities so that they are protected from climate-driven dangers and can recover from damage and loss. Projections indicate that North Shore residents and business owners must make hard choices now about ways to avoid or reduce

POTENTIAL FLOOD IMPACTS IN 2050



Salisbury, MA [CIT. 1,3]

- Roads potentially flooded by 100-year storm flooding
- Buildings potentially flooded by 100-year storm flooding
- Buildings and roads potentially affected by daily or frequent tidal flooding
- Areas potentially affected by 100-year storm flooding
- Areas potentially affected by daily or frequent tidal flooding (MHHW)
- Current Shoreline

flood risk and whether they will leave risk-prone developed coastlines—or stay and adapt.

To buy time and increase the odds of success, these responses and initiatives should focus on the most highly vulnerable areas and the best opportunities to improve resiliency. Based on our latest findings, we propose:

PROTECTING VULNERABLE ROADS With so many routes bringing residents and visitors to shorelines at high risk of chronic daily tidal flooding, it's up to our communities to innovate in sustainable ways. Options include raising roads, removing or altering tidal restrictions, restoring adjacent marsh, and creating natural vegetated slopes along places like Argilla Road in Ipswich. Parts of other threatened roads may need to be abandoned.

ADAPTING NEW DEVELOPMENT AND SHORING UP EXISTING HOMES AND BUSINESSES It is urgent that new or existing buildings in current and projected flood zones are designed for adaptive reuse, with features such as breakaway walls, wet and dry floodproofing, and multiple elevations. We must undertake creative planning and retrofitting to protect them against storm surges, and consider whether other buildings—including some critical infrastructure—should be relocated.

BUFFERING OCEAN-FACING ECONOMIES FROM CLIMATE IMPACTS With tourism, fishing, and other businesses expected to experience increased disruption, it makes sense to create opportunities for sustainable, regional growth. Gloucester, for instance, is working with partners on one such initiative called the North Shore Blue Economy.

IMPLEMENTING COASTAL BUYOUTS AND PROVIDING FINANCIAL RELIEF TO HOMEOWNERS, LESSEES, RENTERS, AND BUSINESSES AT-RISK OF SEVERE OR REPEATED FLOOD DAMAGE A FEMA report released earlier this year recommended expanding government programs to buy and raze houses in flood zones, relocating owners to higher ground and reducing costs to public disaster programs. Flood-prone areas could then be conserved as resilient, publicly accessible open space, offering protections into the future.

More action, and more action now, is needed to preserve and protect developed coastlines. Learn more and get involved at thetrustees.org/coast

Armored Shorelines

Travel along our coast, and you'll see any number of engineered shoreline defenses from seawalls and groins to jetties and riprap. These manmade, hard barriers are designed to hold back the sea—slowing erosion, reducing storm surge, tidal and wave impacts, and protecting oceanfront property and infrastructure.

Armored structures may be necessary or work as a “quick fix” in the absence of natural shorelines, but they are environmentally—and economically—costly, and lack resiliency to climate impacts. They also can flood or fail along the North Shore's 54.4 miles of armored oceanfront. Action must be taken now to transition towards more resilient options if our coastal communities are to be prepared for the challenges to come.

CLIMATE CHANGE IMPACTS

Climate change increases the damage to hard structures and intensifies their environmental impacts. Greater wave energy and water volume cause flooding by overtopping structures and scouring and undermining seawall banks. These natural forces also break and dislodge revetments, groins, and jetties. Hard barriers, meanwhile, accelerate erosion and flooding in adjacent areas, giving natural habitat nowhere to retreat.

Examples of potential impacts on hard barriers (and their effect on the coast) include:

LOSS AND DAMAGE TO HOMES AND STRUCTURES Most manmade barriers were not designed with climate change in mind. Shoreline rock armoring (riprap), for instance, has failed to protect portions of Plum Island, while an overtopped canal levee in Gloucester caused severe flooding.

ACCELERATED EROSION More intense storms and waves deflect off hard structures and erode neighboring shorelines. Hard barriers also block the flow of water, sand, and natural shoreline migration, starving areas of sand and sediments.

LOSS OF RECREATIONAL, ECONOMIC, AND PUBLIC SAFETY ACTIVITIES when hard barriers are damaged or deteriorate and impede critical public access to the coast. The Conomo Point seawall, for example, helps protect Essex properties and access to the primary boat launch used by emergency services and state Environmental Police.



LOSS OF REFUGE, FEEDING, AND BREEDING AREAS, endangering migratory birds, fish, and shellfish. Studies show habitat near these structures may be suitable only for certain fish and crab species.

GREATER EXPENSE AND INVESTMENT to maintain, repair or replace armored structures if properties, roads, and critical infrastructure are to be preserved and public safety assured. The vast majority of structures statewide are at least 50 years old and have gone without any major repairs.

CURRENT COASTAL STRATEGIES

The Trustees supports efforts to promote living shorelines and “green” over “gray” infrastructure, where possible. Communities on the North Shore recognize the need for:

PRIORITIZING THE ASSESSMENT OF CURRENT ARMORED STRUCTURES for removal, repair, and redesign. Public safety and key economic centers may be at risk due to aging, deteriorating structures—some of which no longer serve their purpose.

REDUCING THE IMPACT OF ARMORED STRUCTURES When possible, armored structures should be removed or adapted to allow floodwaters to recede and drain more easily.

CREATING LIVING SHORELINES that protect coastal communities while maintaining natural ecosystems with “soft” measures such as bank restoration,

beach nourishment or salt marsh restoration, such as the project at Collins Cove in Salem.

FUTURE OPPORTUNITIES

Resiliency and effective adaption requires leadership and innovation when it comes to armored structures on the coast. Based on our latest findings, we propose:

REDUCING FUTURE RISKS AND COSTS We must continue to weigh storm responses against more climate-adaptive approaches. We need forward-facing zoning and policies incorporating sea level rise scenarios, no-construction buffer zones, and setback lines to ensure buildings are not located in vulnerable areas.

CREATING AND PROTECTING FLOODABLE, RESILIENT OPEN SPACE The Trustees, for example, is helping to create a climate-resilient Boston by working to build a series of waterfront parks that could serve as a model for North Shore communities.

USING INNOVATIVE BARRIER APPROACHES to dissipate wave action and protect shorelines. The Alabama Nature Conservancy, for instance, is strengthening bulkheads with a stair-steps cage system containing marsh plants. Marblehead is part of an oyster restoration project, while Swampscott and Beverly are considering offshore “living reef” breakwaters and a portable floodwall/deployable barrier system, respectively, as part of their harbor and waterfront plans.

REDESIGNING HARD BARRIERS The Office of Coastal Zone Management’s StormSmart Coasts Program recommends the latest design practices for seawalls and revetments to reduce impacts, minimize maintenance costs, and improve structural longevity. For instance, seawalls can be built to better conform to the natural shoreline and provide habitat for marine animals.

INCREASING FUNDING AND INCENTIVIZING NEW COASTAL RESILIENCE MEASURES Long-term capital budget planning is needed to support investments in “climate-smart” infrastructure and conservation efforts.



Location of armored shorelines in Beverly, Salem, and Marblehead [CIT. 4]

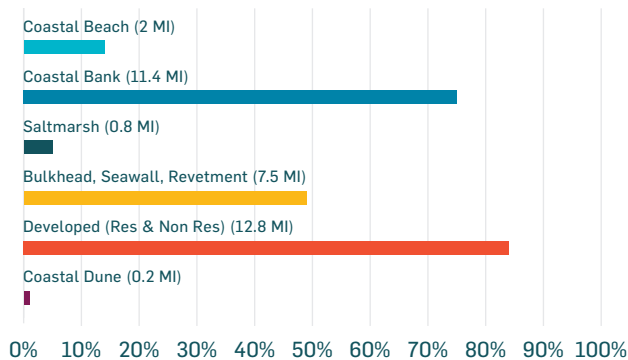
More action, and more action now, is needed to preserve and protect developed coastlines. Learn more and get involved at thetrustees.org/coast



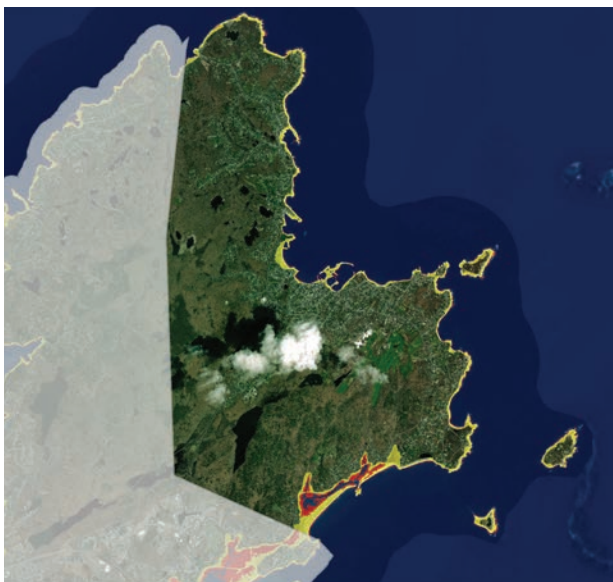
Rockport

OCEAN-FACING SHORELINE (15.2 MILES) [CIT. 4]

Shoreline types below can overlap, not cumulative



FUTURE STORM AND TIDAL FLOODING [CIT. 1,3]



- Current Shoreline
- 2050 Chronic Tidal Flooding (MHHW)
- 2050 1% (1 in 100 year) storm flooding

THE MAIN IMPACTS:

EROSION While most of the town's coast is rocky headlands, beach erosion is likely to continue to significantly threaten oceanfront homes and neighborhoods, with more than 2 feet of Cape Hedge Beach already lost per year [CIT. 5].

MARSH LOSS About three of Rockport's 39 acres of high marsh could transition to low marsh by 2050, with increases in both low marsh and tidal flats [CIT. 2]. In the decades after 2050, most high marsh may be lost [CIT. 2].

DEVELOPED COAST Ten-year storm flooding of buildings and homes is likely along Long Beach/Front Beach area and Rockport / Back Harbor areas in 2050. Some daily flooding of roads may occur near Front Beach [CIT. 1,3].

OTHER RISKS INCLUDE:

PROPERTY DAMAGE A 10-year storm in Rockport may flood more than 392 buildings (8.2%) in 2050 [CIT. 3]. Chronic daily tidal flooding could impact 45 buildings (0.9%) in 2050 [CIT. 1].

ROAD FLOODING Daily high tides may flood 0.3 miles (0.4%) of roads in 2050 [CIT. 1]. More than 4.1 miles (6.3%) of roadway could flood in the event of a 100-year storm in 2050 [CIT. 3].

STRATEGY SNAPSHOT: BEACH NOURISHMENT

Rockport used the "soft" structural strategy of beach nourishment as part of repairs to Long Beach. An aging seawall prevented shoreline migration, robbing the beach of sediment, and climate-driven storms and flooding caused significant erosion. Beach nourishment adds large amounts of sand or sediment so beaches can absorb wave energy, protect inland areas from flooding, and mitigate erosion. Rockport re-stabilized the seawall with boulders and added 8,000 yards of sand to strengthen the buffer and help protect homes [CIT. 14].

Gloucester

THE MAIN IMPACTS:

EROSION While most of Gloucester has a relatively high granite coast, beach erosion is likely to continue to significantly threaten oceanfront homes and neighborhoods, with as much as 1.4 feet per year lost at Good Harbor Beach [CIT. 5].

MARSH LOSS About 394 (41%) of 950 acres in Gloucester may be mostly flooded by 2050 [CIT. 2].

HABITAT CONCERNS By 2050, 225 acres (26%) of the city's 856 acres of estuarine beach/tidal flats could become open water [CIT. 2].

DEVELOPED COAST Ten-year storm flooding of homes and buildings is likely in 2050 on sections of Wingersheek Road, River Road (Lobster Cove), areas near Route 127 (Goose Cove), areas near the river on Wheeler Point, and areas near marshes off of Route 127. Daily tidal flooding possible in some sections [CIT. 3].

OTHER RISKS INCLUDE:

PROPERTY DAMAGE A 10-year storm in Gloucester may flood more than 1443 buildings (10.4%) in 2050 [CIT. 3]. Chronic daily tidal flooding could impact 305 buildings (2.2%) in 2050 [CIT. 1].

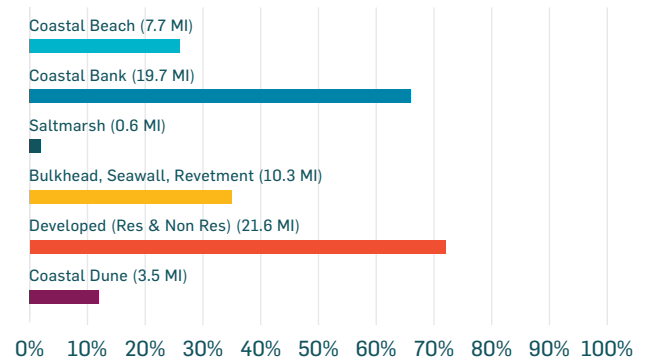
ROAD FLOODING Daily high tides may flood almost 1.7 miles of roads in 2050 (0.8%) [CIT. 1]. An estimated 26.9 miles (12.5%) of roadway could flood in the event of a 100-year storm in 2050 [CIT. 3].

STRATEGY SNAPSHOT: BLUE ECONOMY INCUBATOR

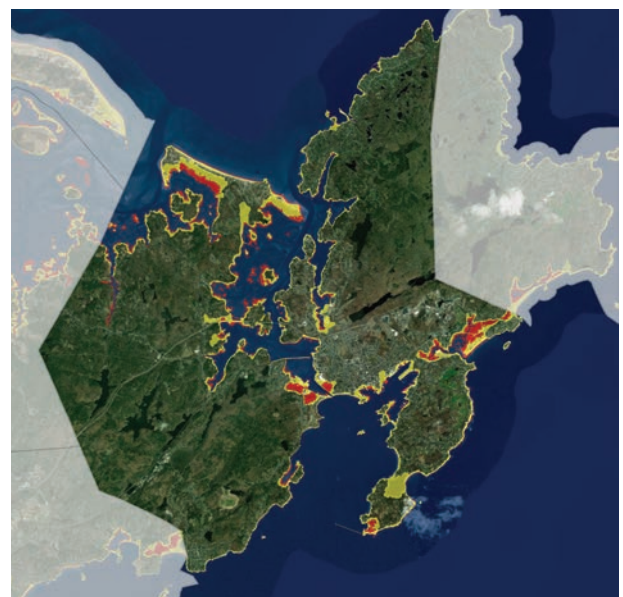
Gloucester is working with the University of Massachusetts, among other partners, on a 10-year North Shore Blue Economy initiative. The goal is to innovate and grow sustainable maritime industries that foster the sustainable use of ocean resources for economic growth, improved livelihoods and jobs, and ocean ecosystem health. The city also has completed preliminary designs to protect its water pollution control facility and has received funding for a flood barrier at Gloucester High School.

OCEAN-FACING SHORELINE (29.8 MILES) [CIT. 4]

Shoreline types below can overlap, not cumulative



FUTURE STORM AND TIDAL FLOODING [CIT. 1,3]



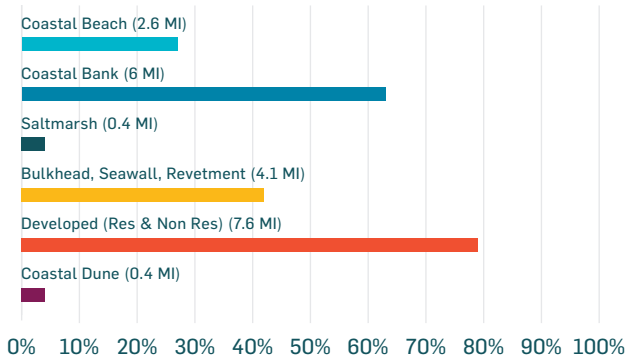
- Current Shoreline
- 2050 Chronic Tidal Flooding (MHHW)
- 2050 1% (1 in 100 year) storm flooding

Manchester-by-the-Sea



OCEAN-FACING SHORELINE (29.6 MILES) [CIT. 4]

Shoreline types below can overlap, not cumulative



FUTURE STORM AND TIDAL FLOODING [CIT. 1,3]



- Current Shoreline
- 2050 Chronic Tidal Flooding (MHHW)
- 2050 1% (1 in 100 year) storm flooding

THE MAIN IMPACTS:

EROSION While most of the coastline is rocky, beach erosion is likely to continue to significantly threaten oceanfront homes and neighborhoods.

MARSH LOSS About 11 (19%) of 56 acres of Manchester’s high marsh may be mostly flooded by 2050 [CIT. 2]. In the decades following 2050, most of the high marsh could be lost [CIT. 2].

DEVELOPED COAST Daily tidal and 10-year storm flooding may occur on roads and buildings near Magnolia Harbor, Kettle Cove, and Route 127 area between Pine Street and Central Pond in 2050 [CIT. 1,3].

OTHER RISKS INCLUDE:

PROPERTY DAMAGE A 10-year storm in Manchester may flood more than 207 buildings (7.3%) in 2050 [CIT. 3]. Chronic daily tidal flooding could impact 51 buildings (1.8%) in 2050 [CIT. 1].

ROAD FLOODING Daily high tides are not expected to significantly flood roads (0.3 miles, 0.4%) in 2050 [CIT. 1]. An estimated 3.6 miles (6.3%) of roadway may flood in the event of a 100-year storm in 2050 [CIT. 3].

STRATEGY SNAPSHOT: HABITAT RESTORATION

Manchester plans to remove a tide gate from the 1930s and ecologically restore natural habitats to the Central Pond area of Sawmill Brook, which provides spawning habitat for state-listed rainbow smelt and other diadromous fish species. Restoring the waterway’s natural flow will allow for fish passage, benefit other fish species and wildlife, and mitigate climate-driven flooding. The plan also involves replacing a bridge on Central Street at the mouth of Manchester Harbor and opening the culvert beneath.



Beverly

THE MAIN IMPACTS:

EROSION Beach erosion is likely to continue to significantly threaten oceanfront homes and neighborhoods.

MARSH LOSS High marsh, which makes up most of Beverly's 42 acres of marsh, may be reduced by about 2.5 acres by 2050 [CIT. 2].

HABITAT CONCERNS By 2050, 37 (44%) of the city's 84 acres of estuarine beach/tidal flats could become open water [CIT. 2].

DEVELOPED COAST Ten-year storm flooding may occur in areas near Water, River, and West Streets in 2050 [CIT. 1].

OTHER RISKS INCLUDE:

PROPERTY DAMAGE A 10-year storm in Beverly may flood more than 275 buildings (1.9%) in 2050 [CIT. 3]. Chronic daily tidal flooding could impact 49 buildings (0.3%) in 2050 [CIT. 1].

ROAD FLOODING Daily high tides may flood almost 0.4 miles (0.2%) of roads in 2050 [CIT. 1]. An estimated 5.2 miles (2.8%) of roadway could flood in the event of a 100-year storm in 2050 [CIT. 3].

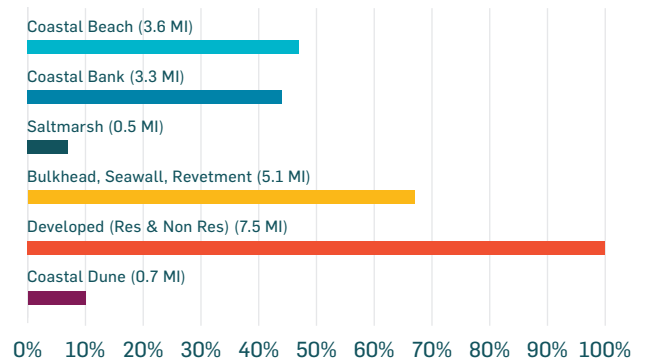
STRATEGY SNAPSHOT: INNOVATIVE APPROACHES

Beverly is exploring the possibility of using portable flood walls to block key flood pathways along the lower portion of the Bass River. Deployable barriers are relatively simple to use and may be cost-effective, making them increasingly popular in flood-prone communities nationwide. Earlier this year, Beverly was also awarded a \$100,000 MVP Action Grant to complete a comprehensive Climate Action Plan in collaboration with Salem. Both cities hope to identify and prioritize projects and create an actionable plan to reduce greenhouse gas emissions and mitigate climate change impacts.



OCEAN-FACING SHORELINE (7.6 MILES) [CIT. 4]

Shoreline types below can overlap, not cumulative



FUTURE STORM AND TIDAL FLOODING [CIT. 1,3]



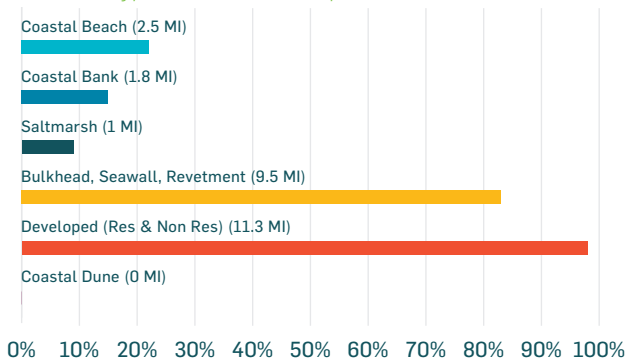
- Current Shoreline
- 2050 Chronic Tidal Flooding (MHHW)
- 2050 1% (1 in 100 year) storm flooding

Salem



OCEAN-FACING SHORELINE (11.6 MILES) [CIT. 4]

Shoreline types below can overlap, not cumulative



FUTURE STORM AND TIDAL FLOODING [CIT. 1, 3]



- Current Shoreline
- 2050 Chronic Tidal Flooding (MHHW)
- 2050 1% (1 in 100 year) storm flooding

THE MAIN IMPACTS:

EROSION While offshore islands help to protect Salem, beach erosion is likely to continue to significantly threaten ocean-front homes and neighborhoods.

MARSH LOSS About 12 (30%) of Salem's 38 acres of high marsh may be mostly flooded by 2050 [CIT. 2].

HABITAT CONCERNS By 2050, about 138 (54%) of the city's 246 acres of estuarine beach/tidal flats may become open water [CIT. 2].

DEVELOPED COAST Ten-year storm flooding is likely around Salem Neck, Juniper Cove, Collins Cove Park, Memorial Park, and near Bridget Street around 2050. Similar flooding may occur near the Salem State campus area. Some daily tidal flooding is projected in these areas as well [CIT. 1,3].

OTHER RISKS INCLUDE:

PROPERTY DAMAGE A 10-year storm in Salem may flood more than 1,095 buildings (9.5%) in 2050 [CIT. 3]. Chronic daily tidal flooding could impact 66 buildings (0.6%) in 2050 [CIT. 1].

ROAD FLOODING Daily high tides may flood about .07 miles (0.5%) of roadway in 2050 [CIT. 1]. An estimated 17.8 miles (13.5%) of roadway could flood in a 100-year storm in 2050 [CIT. 3].

STRATEGY SNAPSHOT: LIVING SHORELINES

Salem is restoring fringing salt marsh at Collins Cove to create a living shoreline, an increasingly popular "green" technique that uses natural elements to buffer coasts against climate-driven impacts. Living shorelines improve coastal resiliency, water quality, and biodiversity, among other benefits. Volunteers with Salem Sound Coastwatch last year planted more than 15,000 salt marsh plants. When they become established, the marsh will reduce flooding from extreme high tides and storm surge, helping to protect the city's popular recreational pathway and surrounding homes.

Marblehead

THE MAIN IMPACTS:

EROSION Coastal erosion has already impacted two major underground feeder power lines at Leads Mill Rail Trail. The exposed coast and northeast-facing harbor are also highly vulnerable to storm damage.

MARSH LOSS About 1.4 (10%) of Marblehead's 15 acres of high marsh may be mostly flooded by 2050 [CIT. 2].

HABITAT CONCERNS By 2050, about 15 (35%) of the town's 43 acres of estuarine beach/tidal flats may become open water [CIT. 2].

DEVELOPED COAST Buildings and homes adjacent to shoreline could be affected by either 10-year storms or daily tidal flooding in 2050 depending on elevation [CIT. 1,3].

OTHER RISKS INCLUDE:

PROPERTY DAMAGE A 10-year storm may flood more than 320 buildings (3.6%) in 2050 [CIT. 3]. Chronic daily tidal flooding could impact 48 buildings (0.5%) in 2050 [CIT. 1].

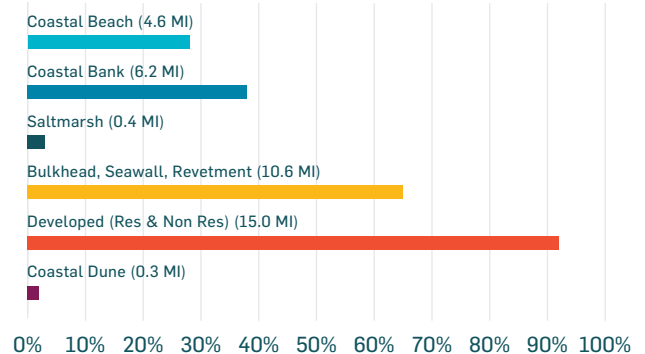
ROAD FLOODING Daily high tides may cause negligible flooding of roadways in 2050 [CIT. 1]. An estimated 3.8 miles (4.1%) of roadway could flood in the event of a 100-year storm in 2050 [CIT. 3].

STRATEGY SNAPSHOT: COASTAL EDUCATION

Marine science students from Marblehead Charter School's Shark Club help to maintain and operate an oyster upweller aimed at restoring native shellfish populations, strengthening the natural coastal environment, and mitigating the effects of climate change. Oyster reefs, which are making a comeback nationwide, can form natural barriers that protect shorelines from erosion, tides and storm surge. First piloted by the Massachusetts Oyster Project in Gloucester, the restoration program, which will not release oysters into the harbor, is also designed to improve water quality and increase the diversity of sea life.

OCEAN-FACING SHORELINE (16.3 MILES) [CIT. 4]

Shoreline types below can overlap, not cumulative



FUTURE STORM AND TIDAL FLOODING [CIT. 1,3]



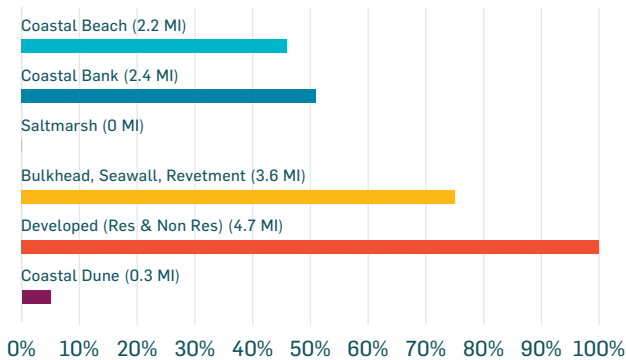
- Current Shoreline
- 2050 Chronic Tidal Flooding (MHHW)
- 2050 1% (1 in 100 year) storm flooding

Swampscott



OCEAN-FACING SHORELINE (4.8 MILES) [CIT. 4]

Shoreline types below can overlap, not cumulative



FUTURE STORM AND TIDAL FLOODING [CIT. 1,3]



- Current Shoreline
- 2050 Chronic Tidal Flooding (MHHW)
- 2050 1% (1 in 100 year) storm flooding

THE MAIN IMPACTS:

EROSION Beach erosion is likely to continue to significantly threaten oceanfront beach homes and neighborhoods, with Phillips Beach losing about 2 feet per year.

HABITAT CONCERNS About 11 (18%) of Swampscott’s 63 acres of ocean beaches may become open water by 2050 [CIT. 2]. Beaches and rocky intertidal areas could be threatened by rising sea level and future intense storms.

DEVELOPED COAST Ten-year storm flooding may affect buildings by Phillips Beach near Route 129/129A along with areas behind King’s Beach and near Puritan Road and Blodgett Avenue in 2050 [CIT. 1,3].

OTHER RISKS INCLUDE:

PROPERTY DAMAGE A 10-year storm in Swampscott could flood more than 357 buildings (6.3%) in 2050 [CIT. 3]. Chronic daily tidal flooding may impact four buildings (0.1%) in 2050 [CIT. 1].

ROAD FLOODING Daily high tides may have a minimal impact in 2050 [CIT. 1]. An estimated 4.0 miles (7.3%) of roadway could flood in a 100-year storm in 2050 [CIT. 3].

STRATEGY SNAPSHOT: PROTECTIVE LIVING REEF

Swampscott’s Harbor and Waterfront Plan proposes the development of a “protective living reef” breakwater system to ensure resiliency in the case of climate-driven intensified storm surge, flooding, and wave energy. The breakwater structures could attract sea life, create new habitat, and protect waterfront and harbor assets (piers, vessels, beach amenities, buildings) as well as beaches, buildings, and roads along Fisherman’s Beach and Lincoln House point. Used increasingly as a “green” solution to climate change by communities worldwide, living reefs also incorporate natural habitat and increase biodiversity.

The Great Marsh Coalition

The Trustees are pleased to be a part of the Great Marsh Coalition. With more than 20,000 acres stretching from Cape Ann to New Hampshire, the Great Marsh is the largest salt marsh in New England. Its vast landscape provides critical habitat for threatened species of flora and fauna and serves as an important source of climate resiliency for the region by capturing carbon and absorbing excess storm runoff.

Together, the group of organizations and agencies that banded together in 2000 to form the Great Marsh Coalition work to protect the marsh and surrounding watersheds and increase public awareness of its place as “a coastal treasure in our backyard.”

The coalition includes: Eight Towns and the Great Marsh, Essex National Heritage Area, Greenbelt, Ipswich River Watershed Association, Massachusetts Audubon Society, Massachusetts Office of Coastal Zone Management, Parker River Clean Water Association, Parker River National Wildlife Refuge, Plum Island Long Term Ecological Research project/MBL, and The Trustees.

Learn more at <https://www.greatmarsh.org>

Habitats



Coastal habitats on the North Shore provide extraordinary ecological value, with more than 53,000 acres that are home to some of New England's most beloved wildlife and many rare and threatened species. We have nearly 20% of the state's piping plovers, half of its saltmarsh sparrows, most of the region's seabeach needle grass, nurseries for commercial species, and tens of thousands of migrating shorebirds and waterfowl.

Despite this abundance of riches, only about 25% of our coastal habitats are permanently protected from development, and they face increasing peril from climate-driven changes. Such impacts go beyond intensified storms and sea level rise to include the ocean's warming temperatures and acidification. These effects—compounded by pollution, contamination, and sedimentation—could significantly degrade and destroy mudflats, eelgrass and shellfish beds, rocky coastlines, and cobble shores. If we fail to act now, we risk losing natural habitats and species not just today, but forever.

CLIMATE CHANGE IMPACTS AND OTHER THREATS

Our region features a mosaic of habitats facing powerful threats. Development, for instance, eliminates and degrades sensitive habitat and decreases the ability of shorelines to protect habitats by migrating landward. Tidal restrictions in the form of hundreds of culverts, bridges, and dams impede the full flow of water and migratory species such as river herring in our estuaries and salt marshes.

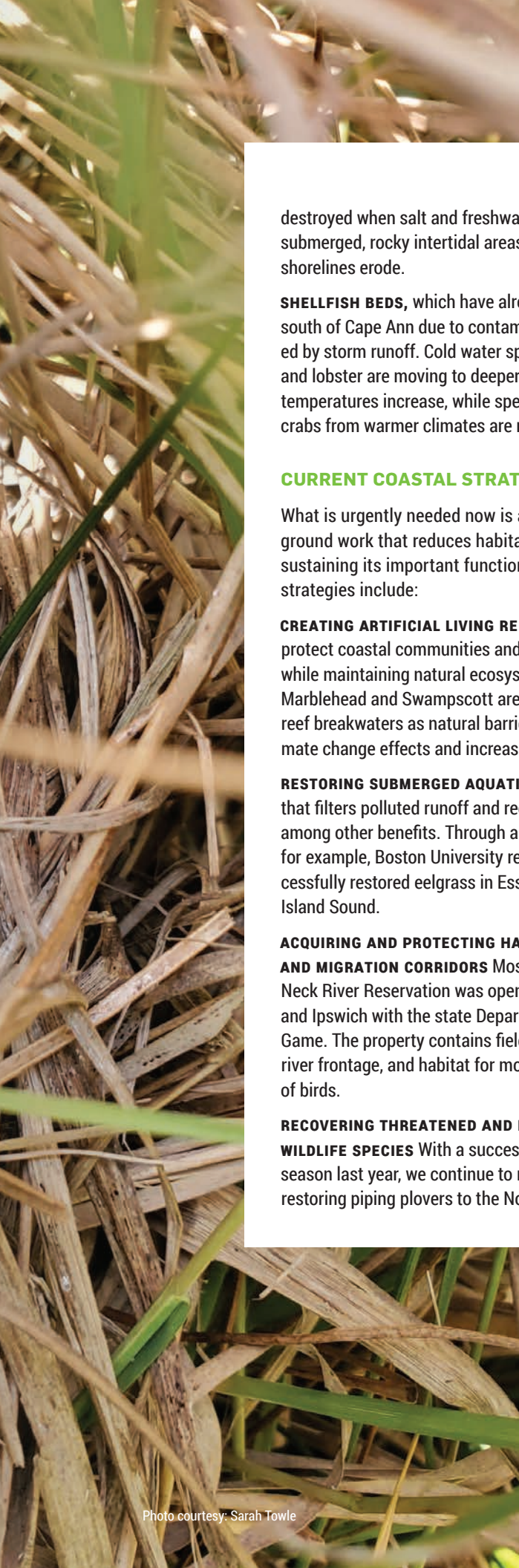
Climate change promises to worsen these devastating environmental impacts by causing the loss of:

INTERTIDAL ZONES Sea level rise may permanently inundate some clam flats in places like Essex and Ipswich, while pollution and contamination could lead to closures.

EELGRASS, which provides nursery habitat for commercially important shellfish and fisheries and also stabilizes sediments, removes pollutants, and sequesters carbon. Eelgrass may be affected by higher ocean temperatures, among other changes.

WILDLIFE, including migrating shorebirds and threatened species such as salt marsh sparrows. Habitats and nesting areas could be

(cont'd)



destroyed when salt and freshwater marsh is submerged, rocky intertidal areas flood, and sandy shorelines erode.

SHELLFISH BEDS, which have already been closed south of Cape Ann due to contaminants exacerbated by storm runoff. Cold water species such as cod and lobster are moving to deeper waters as ocean temperatures increase, while species like fiddler crabs from warmer climates are moving in.

CURRENT COASTAL STRATEGIES

What is urgently needed now is active, on-the-ground work that reduces habitat loss while sustaining its important functions. Ongoing strategies include:

CREATING ARTIFICIAL LIVING REEFS that protect coastal communities and private property while maintaining natural ecosystems and habitats. Marblehead and Swampscott are considering living reef breakwaters as natural barriers to mitigate climate change effects and increase sea life diversity.

RESTORING SUBMERGED AQUATIC VEGETATION that filters polluted runoff and reduces erosion, among other benefits. Through a pilot project, for example, Boston University researchers successfully restored eelgrass in Essex Bay and Plum Island Sound.

ACQUIRING AND PROTECTING HABITAT AREAS AND MIGRATION CORRIDORS Most recently, Castle Neck River Reservation was opened by Greenbelt and Ipswich with the state Department of Fish and Game. The property contains fields and farmland, river frontage, and habitat for more than 70 species of birds.

RECOVERING THREATENED AND ENDANGERED WILDLIFE SPECIES With a successful nesting season last year, we continue to make strides in restoring piping plovers to the North Shore.

REMOVING TIDAL RESTRICTIONS to enhance natural sediment and tidal flow to the Great Marsh. Together with Ipswich, The Trustees is installing a larger culvert under Argilla Road while Manchester plans to remove a tide gate and restore natural habitats to Sawmill Brook.

FUTURE OPPORTUNITIES

We need to focus on conserving and increasing the resiliency of coastal habitats, recognizing that The Great Marsh – the largest salt marsh habitat in New England – is one of the most ecologically intact areas worthy of protection statewide. Effective adaptation requires immediately developing and evaluating best practices and introducing innovative, at-scale solutions. Based on our findings, we propose:

CREATING BOLD, REGIONAL STRATEGIES FOR INCREASING FUNDING AND IMPLEMENTING PLANS to protect coastal habitats from the risks of existing and future flood-prone development.

EXPANDING RESTORATION AND REMEDIATION WORK to fortify diverse ecosystems and create the largest and most resilient salt marsh in New England – and the entire Northeast.

DEVELOPING FORWARD-LOOKING, ADAPTIVE REGULATIONS to provide incentives and pathways for innovative, sustainable solutions that protect and enhance coastal habitats regionwide.

CONTINUING LONG-TERM MONITORING AND RESEARCH WITH CLEAR METRICS AND COORDINATION to improve our understanding of coastal conditions and gauge whether interventions are working. We must enact climate-based practices and policies that protect our region's habitats and other natural resources.

More action, and more action now, is needed to preserve and protect our natural coast. Learn more and get involved at thetrustees.org/coast

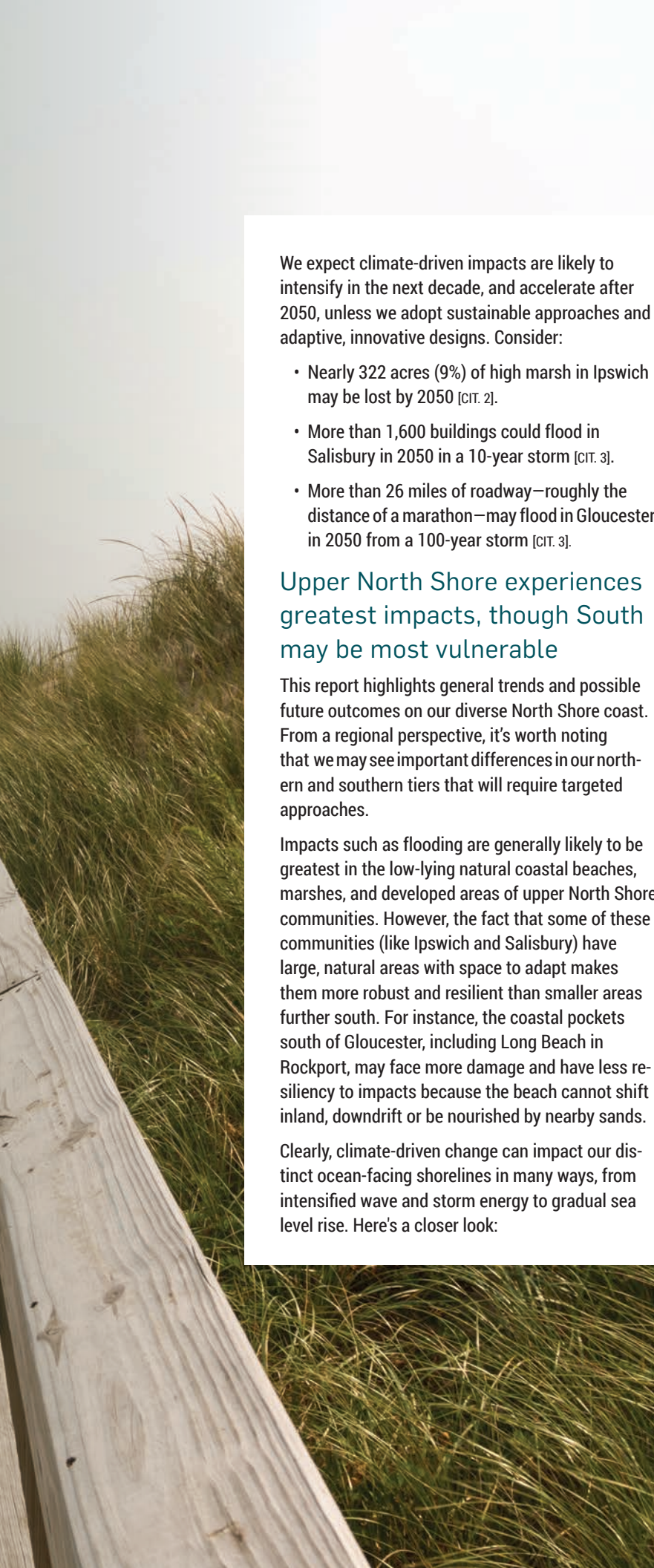


Protect. Adopt. Support. Collaborate.

What we face & the way forward

We already experience the disastrous impact of climate-driven storms, flooding, warmer ocean temperatures, and erosion on the places where we live, work, and play.

Time is running out to take steps that will protect our coast, and the latest data suggests that is not an exaggeration. We must act now.



We expect climate-driven impacts are likely to intensify in the next decade, and accelerate after 2050, unless we adopt sustainable approaches and adaptive, innovative designs. Consider:

- Nearly 322 acres (9%) of high marsh in Ipswich may be lost by 2050 [CIT. 2].
- More than 1,600 buildings could flood in Salisbury in 2050 in a 10-year storm [CIT. 3].
- More than 26 miles of roadway—roughly the distance of a marathon—may flood in Gloucester in 2050 from a 100-year storm [CIT. 3].

Upper North Shore experiences greatest impacts, though South may be most vulnerable

This report highlights general trends and possible future outcomes on our diverse North Shore coast. From a regional perspective, it's worth noting that we may see important differences in our northern and southern tiers that will require targeted approaches.

Impacts such as flooding are generally likely to be greatest in the low-lying natural coastal beaches, marshes, and developed areas of upper North Shore communities. However, the fact that some of these communities (like Ipswich and Salisbury) have large, natural areas with space to adapt makes them more robust and resilient than smaller areas further south. For instance, the coastal pockets south of Gloucester, including Long Beach in Rockport, may face more damage and have less resiliency to impacts because the beach cannot shift inland, downdrift or be nourished by nearby sands.

Clearly, climate-driven change can impact our distinct ocean-facing shorelines in many ways, from intensified wave and storm energy to gradual sea level rise. Here's a closer look:

CRANE BEACH HAS ALREADY LOST 112 ACRES, EQUAL TO 84 FOOTBALL FIELDS [CIT. 4]

BEACHES As the oceanfront shoreline continues to recede at Crane Beach and other beaches along the North Shore, we also face increased flood risks to the inland side of these barrier systems, including access to roads, homes, and businesses. Solutions are complex: Dune restoration and nourishment can be effective but costly and not always applicable, while sand supplies could be scarce and limited. We need to add resiliency with nature-based, sustainable techniques, while conducting studies to predict where problems are worsening and what solutions will work. Tough choices must be made about whether and where to allow retreat inland or let nature proceed without interventions.

“Coastal areas are undeniably impacted by the changing climate; however, this evolution also provides an opportunity to transform and reimagine our connection to the coast.”

**KIRK BOSMA,
SENIOR COASTAL ENGINEER,
WOODS HOLE GROUP**

BY 2050, ALMOST 2,200 ACRES OF HIGH MARSH IN THE GREAT MARSH MAY BE COMPLETELY LOST [CIT. 2]

SALT MARSHES The latest data indicates salt marshes may be unable to keep pace with sea-level rise and drown, transforming the coastal landscape and depriving us of a natural, carbon-capturing resource. Unless we take bold action immediately and over the next two decades, we can likely expect to see daily flooding of most high marsh to the extent that portions of the Great Marsh could be permanently submerged after 2050. Communities need to shift their overall focus from regulation to conservation, including restoring function and accelerating marsh building. We have to remove barriers to natural water flow and apply ditch remediation and other innovative, at-scale techniques to reverse this potentially devastating climate-driven trend.

FLOODING COULD THREATEN MORE THAN 7,500 BUILDINGS IN 2050 [CIT. 3]

DEVELOPED COASTLINES North Shore communities, leaders, and coastal landowners can no longer postpone climate-facing emergency planning and decision making. We have three choices: a) accept loss, damage, and disruption from intensified storms and increased flooding b) implement adaptive design and technologies to remain in place amid threats and/or c) relocate our lives and livelihoods inland, using buyouts, relocations, and other creative strategies to establish thriving safeholds away from the shore.

What is clear is that our sum is stronger than our parts, and this report's findings highlight the need to come together as a region to create at-scale, coordinated strategies and policies built on future conditions and benefits.

MOST ARMORED STRUCTURES ARE MORE THAN 50 YEARS OLD AND NEVER REPAIRED [CIT. 6]

ARMORED SHORELINES Coastal structures from seawalls to revetments and jetties were not designed with climate change in mind, and their inability to protect us from sea level rise and storm surge is increasingly apparent, from overtopped barriers to homes falling into the sea. Not only are these hard barriers damaged by strong storm impacts, but they also cause damage to our coastline, contributing to erosion, exacerbating property damage, and undermining resiliency by preventing migration inland. It's time to assess hundreds of aging armored structures on the North Shore for repair, renewal or redesign.

More than that, we need to move to living shorelines, artificial offshore reefs, and conversion of flood-prone areas to resilient and publicly accessible open space. Sand-starved beaches caused by seawalls and other protective armored structures will need to be nourished for the short-term with expensive sand. This may be increasingly challenging, and communities and residents are likely to face difficult choices in terms of weighing benefits and costs.

ONLY 25% OF OUR COASTAL HABITAT IS PERMANENTLY PROTECTED [CIT. 13]

COASTAL HABITATS Climate-driven impacts add to current development, recreational, and pollution pressures on our fisheries and regional habitats, particularly in the Great Marsh, an area of vital ecological significance. Meanwhile, state and federally listed species such as the saltmarsh sparrow are under threat, our migratory shorebirds and waterfowl may lose habitats and nesting places, and fish populations are expected to shift and become unstable due to warmer temperatures. With limited funding, and a traditional focus on infrastructure, options are narrow to protect areas that are critically important to the economy and recreation of coastal communities.

Our natural shorelines are not only valuable in themselves but also buffer and offer storm protection to critical infrastructure. We must pivot toward opportunities to enhance protections in key areas for natural resource investments with land protections, permitting reforms, leading-edge restoration techniques, and science and education efforts that involve community members, young and old. We need to work with nature and natural processes for more effective solutions.

Regional coordination, future-facing strategies can save our coast

At The Trustees, we see communities engaging in vulnerability planning to assess threats and seeking grants to implement diverse protection strategies, along with conservation groups working to raise awareness and implement resiliency measures. Less visible are the measures being taken by private landowners on the coast who need to adapt to the risks of sea-level rise and other impacts and should be encouraged to work with the public on “green infrastructure” and nature based solutions.

What is clear is that our sum is stronger than our parts, and this report’s findings highlight the need to come together as a region to create at-scale, coordinated strategies and policies built on future conditions and benefits. Communities are taking individual actions and weighing innovation options such as floating roads and offshore reefs, yet the question remains: How do they all fit together? And, is it enough? At the moment, our answer is no.

We ask our conservation partners, local and state officials, community residents, and visitors to:

- **PROTECT** natural areas along our coast, developing strategies to help these areas keep pace with accelerating sea level rise and storms
- **ADOPT** new policies and regulatory pathways and increase funding to bring coastal resiliency and conservation to scale
- **SUPPORT** adaptations and sustainable innovations such as living shorelines and green infrastructure that help our coast respond to climate change and contribute to decisions about where to accept change
- **COLLABORATE** regionwide on innovative models and designs that offer more sustainable solutions for the future

By taking action, we can conserve our coast and adapt to climate impacts over the next several decades, buying time and options for the next generation. We must prepare now with future-thinking scenarios and climate-based evidence to safely and effectively adapt our communities, and our shores, to the dynamic and beautiful natural world around us.

FUNDING RESILIENCE: HOW, AND WHO?

To date, much of the funding that addresses coastal resiliency on the North Shore has come from state sources, including CZM and MassBays. EEA and CZM provided \$4.5 million for 50 North Shore projects focused on coastal resiliency, coastal pollution remediation, healthy estuaries, and climate planning and action over the last five years.

Going forward, how much more will it cost us to prepare for sea-level rise and storm impacts? We don’t know for sure, and it depends on how much we do. It can be difficult to weigh long-term needs against short-term exigencies, and cities, towns and coastal property owners are often challenged by upfront mitigation costs. But it’s apparent that funding needs to match the potential magnitude of the threat. Once past a tipping point, recovery and repair can far exceed mitigation costs, if recovery remains an option. Consider a statistic from the National Institute of Building Sciences, which found that every \$1 spent on federally funded mitigation grants saves the nation \$6 in future disaster costs.

The price of doing nothing is clear—and it will particularly affect our most threatened wildlife species, beloved landscapes, and vulnerable human populations. The Trustees proposes that we need to look beyond our traditional community coffers and grants, and develop radical new ways of funding and incentivizing resiliency and conservation on a consistent, regional basis. Programs such as emissions trading systems, green/blue/resiliency bonds, and climate funds and derivatives are just the tip of the iceberg. So are mechanisms like insurance policies that offer lower premiums for taking steps to reduce climate risks and banks (e.g. Rhode Island Infrastructure Bank, New Jersey’s Energy Resilience Bank) that focus on investing in infrastructure, services, risk management, and sustainability. Capital investment is only part of the equation. As important, we need to support social science research that will help us find ways to make the rapid, significant psychological shifts as a society that are required to adapt to climate change. We need to understand better what it is that holds us back from investing more in climate solutions now and conserving our coast for generations to come.

Coastal Impact Matrix

Towns (North to South)

	Salisbury	Newburyport	Newbury	Rowley	Ipswich	Essex	Gloucester	Rockport	Manchester	Beverly	Salem	Marblehead	Swampscott
Beach Erosion (Short-term Rate) Ft/Yr from 1970-2014 [CIT. 4]	2.2	7.5	4.6	NA	52.4	NA	0.9	2.8	0.9	1.4	3.6	1.6	2
Beach Erosion (Long-term Rate) Ft/Yr from 1800s-2014 [CIT. 4]	1.8	0.4	2.2	1.3	5	NA	1.4	2.3	0.7	0.7	1.3	0.9	0.7
Acres Total High Marsh Loss in 2050* [CIT. 2]	978	17	108	98	322	263	393	3	11	2	12	1	0
Number of Buildings Flooded from Daily Tidal Flooding in 2050** [CIT. 1]	512	30	44	25	50	84	305	45	51	49	66	48	4
Number of Buildings Flooded from 10 Yr Storm in 2050** [CIT. 3]	1646	419	609	73	340	325	1443	392	207	275	1095	320	357
Miles of Road Flooded From Daily Tidal Flooding in 2050** [CIT. 1]	2.8	0.2	1.7	1.5	1.7	0.7	1.7	0.3	0.3	0.4	0.7	0.0	0.0
Miles of Road Flooded from a 100 Yr Storm in 2050** [CIT. 3]	22.0	7.4	18.5	9.2	15.8	5.2	26.9	4.1	3.6	5.2	17.8	3.8	4.0

* projected

** projected, and indicates when projected flooding touches the structure, but does not necessarily mean that water enters the structure

We are providing this chart so that communities can gauge their specific risks and vulnerabilities in relation to each other and the region as a whole. On the left are some of the climate-driven impacts—beach erosion, marsh loss, and flooding of buildings and roads—that are projected for 2050 from storms and sea level rise. The chart also shows rates of short- and long-term beach erosion, an impact that has already been experienced by most communities. For beaches in more developed areas, even

small rates of erosion can be problematic because their migration may be restricted by development or armored shorelines. You can see, for example, that Salisbury is likely to have more buildings flooded in a 10-year storm (1,646) compared to Essex (325) or Salem (1,095). At the same time, Salisbury appears to have had a relatively moderate long-term rate of beach erosion compared to some other communities shown. Visit thetrustees.org/coast for additional information.

Advocacy & Policy

The Trustees owns and protects 120 miles of Massachusetts shoreline for recreation and conservation. We've preserved this sensitive landscape by working with landowners, land trusts, and philanthropists as well as government officials and agency experts.



Together with our public and private partners, The Trustees leverages public funds, creates and advocates for public programs and policies, leads coalitions, spearheads education, and negotiates passage of legislative and regulatory reforms.

Going forward, investments in climate mitigation, adaptation, and resiliency are at the core of our coastal projects, which also help to provide some storm protection for our communities. Key to that is leveraging private resources and bringing conservation and restoration projects to scale—and we cannot accomplish this important work alone. We need you, our public partners. And today, we're asking you to do more.

We applaud the Massachusetts legislature for passing measures designed to spare communities from the impacts of climate change, from a climate and environmental bond bill to the State Hazard Mitigation and Climate Adaptation Plan, and Municipal Vulnerability Preparedness grant program. However, these actions are not enough.

Lawmakers need to prioritize climate-facing policies, increase investments in land conservation and restoration through traditional bond bills, and identify and pursue additional, creative funding sources to implement coastal protections and strategies.

Among other initiatives, The Trustees supports the permanent dedication of a new Sporting Goods Sales Tax to fund habitat conservation and outdoor recreation. We're advocating for a new Flood Risk Recovery Program designed to buy coastal properties and relocate homeowners and businesses from current and future flood-prone zones. We're contributing to pending legislation that incorporates nature-based, "green" solutions into new housing and transportation developments. We're urging Congress to make significant investments

in green infrastructure. And we're pushing for innovative ways to incentivize communities, nonprofits, and private landowners to improve critical natural resource management and capture greenhouse gases fast enough to make a difference.

Public, nonprofit, and private sectors together need to set forth a bold vision for the future of our coast that goes beyond a traditional understanding of land conservation. That means:

- **Transformative climate strategies** to heal and enhance our coastal resources
- **Legislative imagination and regulatory flexibility** in support of future-thinking pilot projects
- **A comprehensive, collaborative assessment** of coastal conditions and identification of strategies that work
- **And consistent, robust streams of dedicated local, state, and federal revenues** for climate mitigation, adaptation, and resiliency

The Trustees has made progress toward our collective goal of protecting coastal habitats and resources, not only for the benefit of nature and outdoor recreation but also for the welfare of individuals, families, and communities confronted by the potentially devastating impacts of climate change. We continue to rely on our lawmakers and agency partners to help us accomplish conservation projects and restoration work.

Success hinges upon our bearing the future in mind and on the strength of our public partnerships. Given the time that has already passed, we will likely not be able to save everything. But if we act now, with vision and decisiveness, we can protect our communities and preserve our scenic coasts as ecological gems and valuable buffers against irrevocable loss from the changes to come.

Citations and Sources

Data used in this report came from a variety of sources. Metrics such as marsh transitions, number of buildings flooded, or miles of roads impacted are based on assessments of model results done by The Trustees as part of this report. The models used are state-of-the-art, but models are based on a number of assumptions and various input conditions that come with inherent limitations. The Trustees used publicly available data for other metrics, including beach erosion rates, tidal restrictions, or miles of armored shoreline. Our sources include:

1. **Sea Level Rise** Details of state projections can be found in MA Climate Change Projections, March 2018, found at <https://resilientma.org/resources/resource::2152/massachusetts-climate-change-projections-statewide-and-for-major-drainage-basins>. The 'high' rate of SLR is what is used in our flood risk analyses using MC-FRM (Massachusetts Coast Flood Risk Model) as recommended by the Massachusetts Office of Coastal Zone Management (CZM), MassDOT, and UMass-Boston. Assumed sea level rise is 1.29 feet in 2030, 2.49 feet in 2050, and 4.29 feet in 2070.
2. **Marsh and coastal habitat changes** were provided by Woods Hole Group and derived from CZM's Massachusetts Sea Level Affecting Marshes Model (SLAMM) project. The sea level rise scenario from which SLAMM results are presented is 7.1 feet of rise from 2011-2100. Details on the SLAMM model can be found at www.mass.gov/service-details/report-on-modeling-the-effects-of-sea-level-rise-on-coastal-wetlands.
3. **Impact to buildings and roads from storm flooding.** Details on the Flood Risk Models, both the Boston Harbor Flood Risk Model (BH-FRM) and the Massachusetts Coast Flood Risk Model (MC-FRM), which was used for this study, can be found at *Bosma, K., E. Douglas, P. Kirshen, K. McArthur, S. Miller, and C. Watson. (2015), MassDOT-FWHA Pilot Project Report: Climate Change and Extreme Weather Vulnerability Assessments and Adaptation Options for the Central Artery. Report to MassDOT and FWHA, and for MC-FRM at Bosma, K., E. Douglas, P. Kirshen, K. McArthur, S. Miller, and C. Watson. (2020). Assessing the vulnerability of MassDOT's coastal transportation systems to future sea level rise and coastal storms, and developing conceptual adaptation strategies. In publication.*
4. **Shoreline Characterization** Layers from CZM were sourced from the Massachusetts Ocean Resources Information System (MORIS) at <https://www.mass.gov/service-details/massachusetts-ocean-resource-information-system-moris> and the Report of the Massachusetts Coastal Erosion Commission, Volume 1: Findings and Recommendations, and Volume 2: Working Group Reports, 2015. <https://www.mass.gov/service-details/massachusetts-coastal-erosion-commission>.
5. **Beach erosion rates** from *Shoreline Characterization and Change Analyses North Shore Region Regional Coastal Erosion Commission Workshop Gloucester - May 28, 2014*. Data sources included the 2011 USGS-CZM Shoreline Change Project's contemporary shoreline (MHHW) and transect data, CZM and DCR's Coastal Structures Inventory data, MassDEP's Wetlands map data, and MassGIS's 2005 Land Use data. Long and short term erosion rates in the impact matrix using data through 2014 were derived from DRAFT Massachusetts Coastal Erosion Viewer, found at <https://mass-eea.maps.arcgis.com/apps/MapSeries/index.html?appid=80fc0c7e-f5e443a8a5bc58096d2b3dc0>.
6. **Costs to repair seawalls and other structures** from Inventories of Seawalls and Other Coastal Structures, developed for the Massachusetts Office of Coastal Zone Management (CZM) and the Department of Conservation and Recreation (DCR) 2006-2015, multiple reports. See www.mass.gov/service-details/inventories-of-seawalls-and-other-coastal-structures.
7. **River herring counts** from MA Division of Fisheries and Wildlife; Ben Gahagan, Diadromous Fish Biologist (email communication, January 29, 2020).
8. **Tidal restrictions** from Tidal Restrictions, Version 3.0, North Atlantic U.S. Coast, McGarigal K, Compton BW, Plunkett EB, Deluca WV, and Grand J. 2017. Designing sustainable landscapes. Report to the North Atlantic Conservation Cooperative, US Fish and Wildlife Service, Northeast Region www.sciencebase.gov/catalog/item/5b-d89a1fe4b0b3fc5cea20bb.
9. Woods Hole Group, Inc. analysis of **MassGIS Data: NHESP Priority Habitats of Rare Species** (April 2017)
10. Woods Hole Group, Inc. analysis **MassGIS Data: MassDEP Wetlands Original** (1:12,000), (2009)
11. "2019 Massachusetts Beach Testing Results: Annual Report." Environmental Toxicology Program, Bureau of Environmental Health, Massachusetts Department of Public Health. <https://www.mass.gov/doc/2019-annual-beach-report/download>
12. **SHARP 2015. "Specialist-bird survey database: 1994-2012."** Saltmarsh Habitat and Avian Research Program. <https://www.tidalmarshbirds.org>.
13. Woods Hole Group, Inc. analysis of **MassGIS Data: Protected and Recreational OpenSpace** (February 2020)
14. **Cronin, M.** (2019, September 16). "Rockport: Long Beach seawall stabilization enters second phase." Gloucestertimes.com
15. **Peter Phippen**, Coastal Coordinator for Merrimack Valley Planning Commission and the MassBays Estuary Program (email communication, March 31, 2020)

Organizations Active in North Shore Coastal Issues and Advocacy

THE MASSACHUSETTS OFFICE OF COASTAL ZONE MANAGEMENT (CZM)

www.mass.gov/orgs/massachusetts-office-of-coastal-zone-management)

CZM is the lead policy, planning, and technical assistance agency on coastal and ocean issues within the Executive Office of Energy and Environmental Affairs. It implements the state's coastal program under the federal Coastal Zone Management Act.

SALEM SOUND COASTWATCH

www.salemsound.org/

Salem Sound Coastwatch is a non-profit coastal watershed organization that works with government agencies, businesses, other non-profit organizations and citizens, through municipal partnering, scientific investigation, education, and stewardship.

IPSWICH RIVER WATERSHED ASSOCIATION

www.ipswichriver.org/

The Ipswich River Watershed Association is a group of citizens, scientists, businesses and communities concerned about the health of the Ipswich River and its watershed.

MASS AUDUBON

www.massaudubon.org/

Mass Audubon is a leader and a catalyst for conservation, acting directly to protect the nature of Massachusetts and stimulating individual and institutional action through conservation, education, and advocacy.

GREENBELT

www.ecga.org/

As Essex County's Land Trust, Greenbelt works with landowners and the 34 cities and towns of Essex County to conserve open space, farmland, wildlife habitat and scenic landscapes.

THE GREAT MARSH COALITION

www.greatmarsh.org/

The Great Marsh Coalition is a group of organizations and agencies that began meeting in spring 2000 to discuss ways of building a regional awareness and identity for the Great Marsh.

PARKER RIVER NATIONAL WILDLIFE REFUGE

www.fws.gov/refuge/parker_river/

Located along the northeast coast of Massachusetts, Parker River National Wildlife Refuge was established in 1941 to provide feeding, resting, and nesting habitat for migratory birds.

MARINE BIOLOGICAL LABORATORY— THE PLUM ISLAND ECOSYSTEMS LTER (PIE LTER)

www.pie-lter.ecosystems.mbl.edu/

The MBL PIE LTER located in Rowley is an integrated research, education, and outreach program with the goal of developing a predictive understanding of the long-term response of watershed and estuarine ecosystems to changes in climate, land use, and sea level and to apply this knowledge to wise natural coastal resources management and policy development.

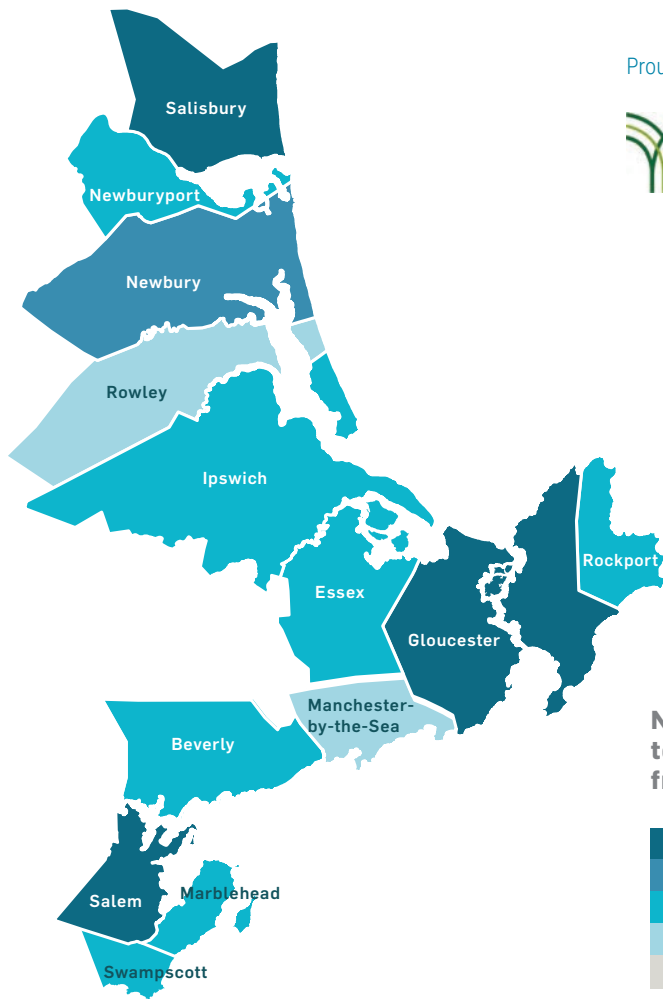
STORM SURGE

www.storm-surge.org/

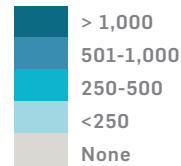
Storm Surge is a volunteer-run Newburyport organization that promotes science-based outreach and education and encourages municipalities to prepare for the impacts of sea level rise.



Proudly sponsored by



Number of buildings projected to flood at surface elevation from 10-year storm in 2050 [CIT. 3]



THE TRUSTEES OF RESERVATIONS

Main Office
200 High Street
Boston, MA 02110

Phone: 617.542.7696
Email: coast@thetrustees.org
Website: thetrustees.org/coast

ACKNOWLEDGMENTS

We would like to acknowledge and thank our interdisciplinary team, without whom the publication of this report would not have been possible. Thanks to **Tom O'Shea**, Trustees Director of Coast and Natural Resources for his vision and leadership in guiding the publication of this report; **Christine Boynton**, Trustees Coastal Communications Manager for assisting in its development as co-project lead; **Eric Nelson**, for lending his expertise as a Senior Environmental Consultant/Coastal Geologist to the foundational research, data compilation, and review for this report; **Woods Hole Group**, and in particular, Data and Mapping Environmental Scientist **Brittany Hoffnagle**, for providing the flood risk modeling and mapping data so integral to this work; award-winning journalist **Pamela Ferdinand** for the many rounds of review and composition, and her invaluable guidance in deftly communicating complicated subject matter; and to **Lily Robles**, **Casey McGee** and the Opus team for their beautiful design and creative vision in crafting the look and feel of this inaugural publication.