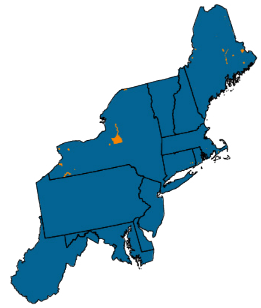
Fifth National Climate Assessment: Chapter 21

Northeast



Chapter 21. Northeast

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Introduction

The Northeast landscape varies from the rural New England coast to the urbanized corridor from Boston to the Mid-Atlantic and inland to the heavily forested Appalachian Mountains. New York, Pennsylvania, Maryland, Delaware, West Virginia, and the District of Columbia all contain parts of the Chesapeake Bay Estuary, the largest estuary in the United States. The Northeast is the homeland of Indigenous Peoples, including 18 Federally Recognized Tribal Nations and many Indigenous Peoples both within the region and who were removed from their lands in the Northeast and relocated to other regions of the United States. Much of the region's employment is in the professional sectors, but jobs related to the natural environment and tourism remain culturally and economically important.[1] Heritage industries tied to resources and agriculture still shape New England and the Mid-Atlantic, including fishing at the coasts, farming in rural areas of Pennsylvania and Maryland, forestry in northern New England, and mining in West Virginia. Seasonal tourism tied to outdoor recreation is particularly important, with summer tourism in coastal communities, fall tourism driven by changing leaves, and winter tourism based on cold-weather sports. Tourism is also important in the cities year-round, with visitors attracted to historical sites, the arts, and the diverse cultures of large cities such as Boston, New York City, Philadelphia, Baltimore, and Washington, DC.

The population of the Northeast has increased by approximately 4.4% since 2010, totaling more than 67 million people. The Mid-Atlantic states experienced the largest increases, with the District of Columbia increasing by 14.6% and Delaware by 10.2%. Some states with larger rural areas—Maine, Pennsylvania, Vermont, and Connecticut—experienced more modest population growth or remained stable. West Virginia was the only state to lose population, declining by 3.2%.[2,3]

Much of the information about the impacts of climate change on the region presented in the Fourth National Climate Assessment (NCA4) remains true today.[4] Urban residents still face increased exposure to extreme heat events, flooding, and episodes of poor air quality. Likewise, rural areas are still susceptible to droughts and floods that affect agricultural productivity and ecosystem function. These events still pose compounding threats to aging transportation, water, and wastewater infrastructure. The communities most vulnerable to climate risks remain those that are historically overburdened and economically disadvantaged in both rural and urban areas. As extreme events continue to occur frequently, these changes are becoming stressors throughout the region—in rural interiors, urban corridors, and the ecosystems supporting coastal communities.

Many early adopters of both mitigation and adaptation action have been in the Northeast. Hurricane Sandy (2012) drove some of this action through programs like the Rebuild by Design effort, which focused on making projects related to disaster rebuilding more resilient to all hazards.[5] In 2014, thirteen projects that won the National Disaster Resilience Competition were located in the Northeast, and by 2022 these projects were in design and construction phases, with some projects substantially complete.[6,7] Northeast cities and states participated in numerous other efforts, from the Rockefeller Foundation's 100 Resilient Cities program to Massachusetts's landmark integration of climate adaptation into its FEMA State Hazard Mitigation Plan.[8] States, Tribal Nations, and local governments are also beginning to fund both planning and project implementation with non-grant public funding, and private-sector actors are increasingly self-funding their own action. Advancements in adaptation and mitigation efforts in the Northeast provide an opportunity to document progress and identify remaining knowledge gaps that constrain or enable climate action.

In the Northeast, both adaptation and mitigation actions are proceeding, particularly in response to repeated impacts from extreme weather events (KM 21.1). Adaptation is also being documented in the ocean and coastal regions (KM 21.2). Human and ecosystem climate change impacts are disproportionately affecting overburdened communities and people, leading to an increased focus on equity in adaptation and mitigation efforts (KM 21.3). Deliberate action plans for both mitigation and adaptation are being completed throughout the Northeast by states, municipalities, and Tribal Nations (KM 21.4), but the progress of action in both the public and private sector will depend on the ability to fund and finance it (KM 21.5).

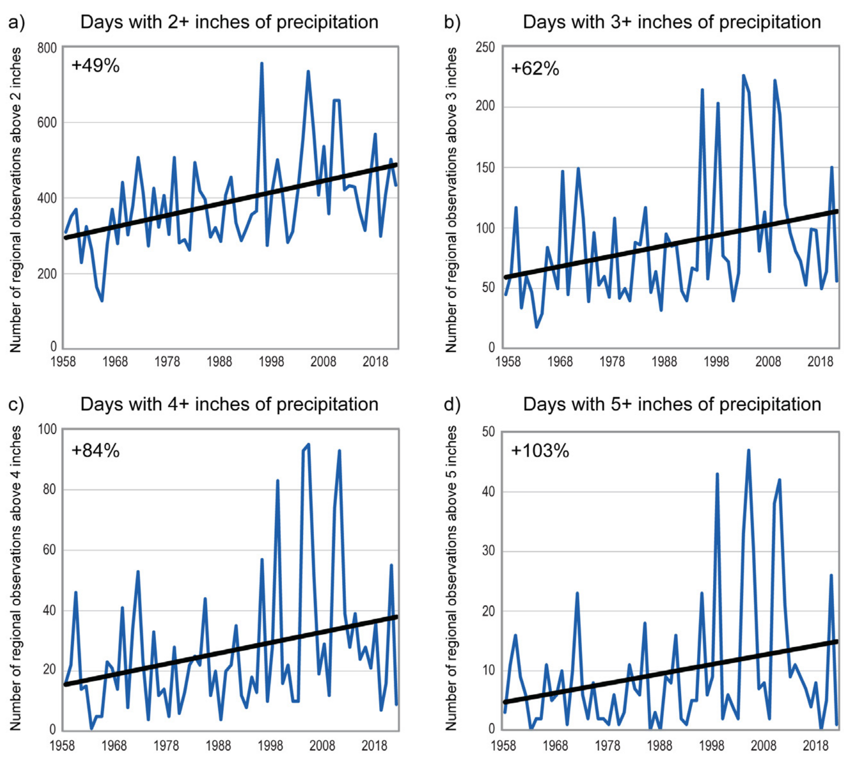
Key Message 21.1

Chronic Impacts of Extreme Weather Are Shaping Adaptation and Mitigation Efforts

The Northeast continues to be confronted with extreme weather, most notably extreme precipitation—which has caused problematic flooding across the region—and heatwaves (*very likely*, *high confidence*). In response, climate adaptation and mitigation efforts, including nature-based solutions, have increased across the region (*high confidence*), with a focus on emissions reductions, carbon sequestration, and resilience building (*medium confidence*).

Precipitation in the Northeast has increased in all seasons (Figure 2.4),[292] and extreme precipitation events (defined as events with the top 1% of daily precipitation accumulations) have increased by about 60% in the region—the largest increase in the US (Figure 2.8; see also Figure 21.1). These changes may be due to an increase in tropical systems during the Atlantic hurricane season in September and October, especially at interior locations as far inland as West Virginia.[9,10,11,12] The increase in extreme precipitation and associated flooding could also be due to the higher overall water availability throughout the region.[13]

Trends in Extreme Precipitation in the Northeast

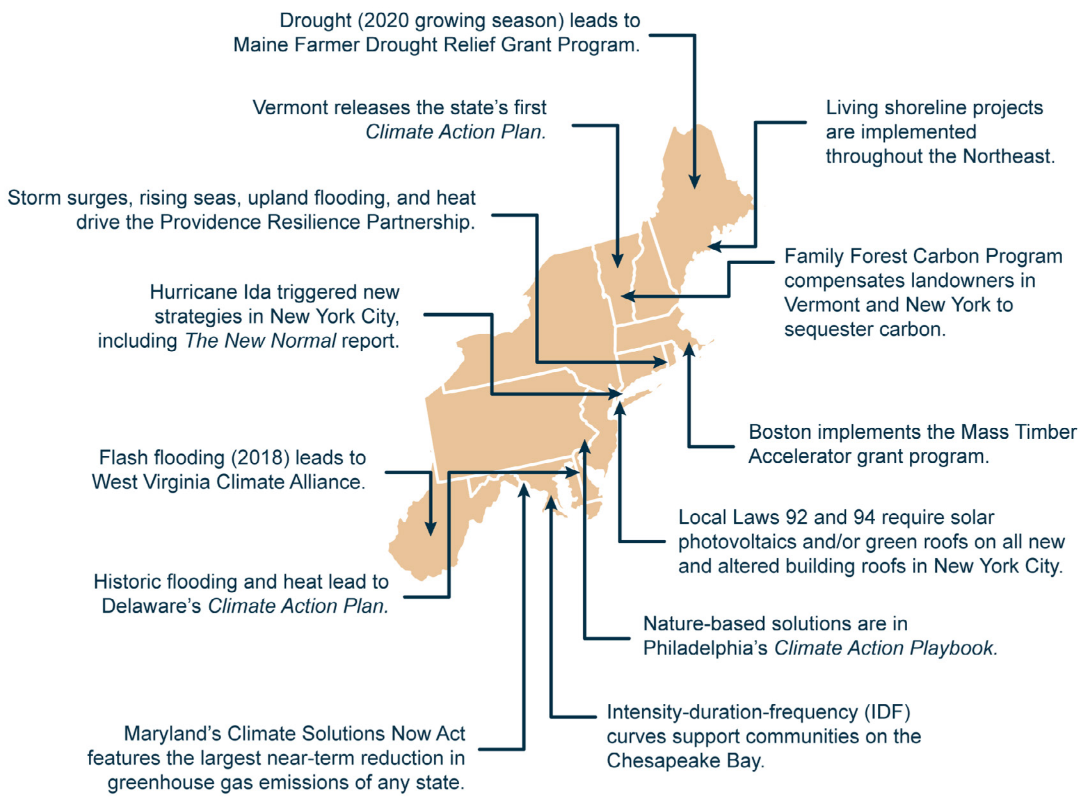


The number of days in the Northeast with extreme precipitation has increased.

Figure 21.1. The four charts show the number of daily events per year with precipitation totals equal to or exceeding 2, 3, 4, and 5 inches from 1958–2022 (blue lines), along with trend lines (black) computed from linear regressions over the full period. Numbers in the top left corner show the percent increase relative to the long-term average, computed as the difference between the end points of the trend lines divided by the 1958–2022 average. The number of daily events is defined as the total number of extreme precipitation accumulations recorded at all stations across the observing network in the Northeast. See the figure metadata for details on the methodology. The trends shown suggest an increase in the frequency of extreme precipitation, with larger increases for the more extreme precipitation events. Figure credit: USDA Forest Service, Drexel University, NOAA NCEI, and CISESS NC.

Urban and flash flooding is typically triggered by short-duration (e.g., sub-daily, sub-hourly), high-intensity, localized "cloudburst" events, often caused by convective thunderstorms. Although historical and forecasted trends in sub-daily precipitation event attributes and frequencies have not yet been evaluated for the region, the occurrence of these events has already begun to motivate action (Figure 21.2). For example, in 2021 after back-to-back storms (Hurricane Henri followed by Hurricane Ida) shattered records for the greatest one-hour rainfall events and resulted in 13 deaths, the City of New York committed to educate, train, and acclimate residents to the potential impacts of extreme weather, expand flood protection to include both inland and coastal communities, and reimagine its drainage system, among other initiatives.[14]

Examples of State and Local Responses to Extreme Weather



Northeastern states and cities have adopted a range of plans, programs, and policies in response to extreme weather, many of which include nature-based strategies.

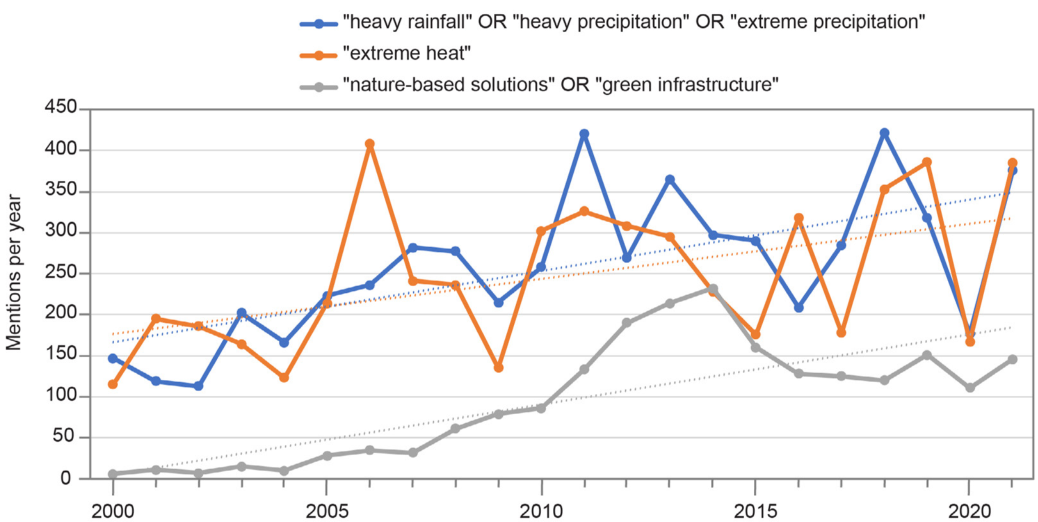
Figure 21.2. This map highlights efforts, many of which are nature-based, that address climate change impacts by building resilience or promoting mitigation measures. In some cases, these efforts are specific programs or projects, such as the Family Forest Carbon Program in Vermont and New York. In other cases, local and statewide plans include broader attention on natural and nature-based strategies. Figure credit: Drexel University and USDA Forest Service.

The frequency of droughts in the Northeast decreased between 1901 and 2015, albeit not as much as would have been expected given the region's increase in average precipitation.[15] Although higher overall humidity can reduce the effect of rising temperatures on how quickly water evaporates from crops,[16] farmers[17,18] and other stakeholders report impacts triggered by highly variable soil moisture. For example, thaw events, extended spring conditions, and longer mud seasons have reduced mobility on unpaved roads that are important for rural travel and logging operations.[19]

As in the rest of the country, the region's heatwaves are lasting longer and are more severe, generally increasing heat stress, especially in densely populated areas (KM 2.3). By midcentury, heat index values over 100°F are projected to increase threefold in the Northeast under an intermediate scenario (RCP4.5).[20]

Extreme weather creates a range of social, economic, and ecological impacts in urban, coastal, rural agricultural, and wild landscapes, as demonstrated by an increase in reporting on extreme weather in the Northeast media (Figure 21.3). Social vulnerability to climate stressors is unequally distributed throughout the region. Individuals who are low income, minority, and/or without high school diplomas are, respectively, 35%, 20%, and 20% more likely than individuals who are not members of those groups to live in areas with the highest projected traffic delays due to high tide flooding. Minorities in the region are 16% more likely than non-minorities to experience property damage or loss due to the highest projected inland flooding damages.[21] In New York City, high levels of social vulnerability to climate change are consistently found in neighborhoods with lower incomes and higher shares of African American and Hispanic residents.[22] Ecosystems are also becoming more vulnerable to extreme weather events as climate change increases stressors such as pests that survive in warmer winter nights.[23]

Northeast US Newspaper Mentions of Extreme Weather and Nature-Based Solutions



Mentions of extreme weather events and nature-based solutions are increasing across Northeast media.

Figure 21.3. As the Northeast continues to experience extreme weather events, news articles highlight the trend in climate action planning. Natural and nature-based features are a common strategy used in these efforts. Solid lines show mentions related to heavy precipitation (blue), extreme heat (orange), and nature-based solutions and green infrastructure (gray) during 2000–2021, with dotted lines showing the estimated trend line for each category. Figure credit: Drexel University and USDA Forest Service.

Future increases in heatwaves are projected to increase mortality rates in the region's major urban areas (KM 15.1).[24] Among workers who are exposed to weather conditions, minorities are 7% more likely than non-minorities to lose labor hours under 2°C (3.6°F) of global warming.[21] Extreme heat is also putting increased pressure on emergency managers and utility corporations, as well as causing human mortality.[25]

High population density, problematic land-use configurations, industry and other pollution sources, contaminated soils, aging infrastructure, and a legacy of buried and/or heavily modified natural drainage systems exacerbate extreme weather impacts in urban areas (KM 12.2).[26] Even under non-extreme weather conditions, impervious surfaces (e.g., sidewalks, roofs, roadways, compacted lawns) generate large quantities of runoff from precipitation, yielding nonpoint source pollution, streambank erosion, habitat degradation, downstream flooding, impaired mobility, and reduced access to services. Extreme weather accelerates and amplifies these phenomena. Localized rainfall flooding can damage homes and businesses with below- or at-grade spaces (e.g., basements, ground floors, subways). Hurricane Ida triggered rainfall flooding that killed 11 people in New York City who could not escape below-grade dwellings[27] and inundated below-grade sections of Philadelphia's Vine Street Expressway. In Baltimore, flooding interrupts basic services, including access to food distribution centers, schools, childcare facilities, health services (e.g., dialysis or methadone clinics); in addition, the city's elderly, poor, mentally ill, mobility-constrained, and those with limited experience of flooding were identified as the most susceptible to flooding effects.[28] More broadly across Maryland, probabilistic flood mapping and recent flood events indicate that flood risks extend beyond the 100-year floodplain in some places, particularly in urban watersheds.[29]

Increased precipitation can also impact less intensively developed areas and along the coasts. Observed and projected increases in precipitation in the Susquehanna River basin, which contributes about half of all freshwater discharges into the Chesapeake Bay, are drivers for flood risk, poor water quality, and changes to habitats in the bay.[30,31] Wetter springs are expected to continue to delay planting, postpone harvests, and reduce crop yields.[23]

Stronger storm surges during tropical systems and nor'easters increase the risk of coastal flooding, also exacerbated by sea level rise.[32,33] Flood hazards for coastal cities are projected to increase in frequency and magnitude in the coming decades in the absence of near-term adaptive measures.[34] In August 2020, Tropical Storm Isaias flooded the Eastwick neighborhood of southwest Philadelphia. This overburdened community is home to one of the largest Superfund sites in the country and also faces coastal and compound flood risks due to sea level rise from the Delaware River.

Governmental and nongovernmental groups are mapping hazards to assist in responding to extreme events. New York City and Boston developed detailed maps of the portions of each city that are at risk of rainfall-induced inland flooding under coincident tidal conditions and sea level rise. Maps of croplands and forests most vulnerable to saltwater intrusion are also being developed.[35] Heat vulnerability maps have been developed for cities (e.g., Philadelphia), counties (e.g., Essex County, New York), and states (e.g., Vermont) throughout the region. Such maps can assist with identifying at-risk communities. Heat risk-reduction strategies tend to emphasize direct assistance to at-risk residents and impacts on energy utilities. Chelsea, Massachusetts, and New York City have distributed air conditioners to reduce the impacts of extreme heat, and Philadelphia recently released a Beat the Heat Toolkit.

States, regional planning commissions, Tribal Nations, and localities are also responding by incorporating climate resilience into FEMA hazard mitigation plans (HMPs; KM 31.4). Many action plans are developed through collaborative public–private processes. Atlantic County, New Jersey, has initiated a Regional Resilience and Adaptation Action Plan through a partnership between the New Jersey Bureau of Climate Resilience Planning and various regional stakeholder groups. The Stafford Act[36] requires that states and Tribes submit approved HMPs to FEMA every five years to be eligible for nonemergency Stafford Act disaster assistance and FEMA hazard mitigation grants. The act also requires each state to establish a process to support development of local HMPs. Climate-resilient HMPs incorporate downscaled climate projections, resident experiences, and local visions. Increasingly, HMPs directly address the goals of other plans developed at the local, regional, Tribal, or state level, including sustainability plans and comprehensive plans (e.g., Nashua, New Hampshire; Springfield and Boston, Massachusetts; Shinnecock Nation; and New York City). In most cases, these efforts are in the planning phase, but some early-adopter locations are beginning to implement their resilience projects. Local and state FEMA hazard mitigation planning guides now encourage climate-informed planning and projects that incorporate resilience.[37,38]

With increased awareness of extreme weather impacts, climate action plans and projects in the Northeast are utilizing natural and nature-based features (NNBFs) more frequently (Figure 21.2). NNBFs restore landscape resilience to disturbances, protect downstream water bodies, and deliver a range of co-benefits that protect public health, reduce flood damage, improve water and air quality, and control ambient air temperatures (KM 9.3). NNBFs utilize plant or soil systems for environmental, economic, and social benefits.[39] Several recent studies focused in New Jersey, New York, and Connecticut emphasize the role of NNBFs in buffering coastal flood losses,[40,41] detaining and retaining runoff,[42,43] reducing combined sewer overflows,[44] alleviating heat impacts,[45,46] and introducing vegetation that is resilient to future floods and droughts.[47] Changes in precipitation can also reduce the stormwater capture performance of NNBFs,[42,48,49] and the adaptation value of NNBFs can depend heavily on unique local conditions.[50] Several Tribal NNBFs are also in place across the Northeast (KM 16.3). For example, the Shinnecock Nation has developed a kelp aquaculture farm and a living shoreline featuring oyster reefs on Long Island, New York.[51] In partnership with the Town of Mashpee, Massachusetts, the Mashpee Wampanoag Tribe also built an oyster reef.[52] The Wampanoag Tribe of Gay Head (Aquinnah), Massachusetts, rebuilt and replanted beach dunes for coastal protection.[53]

Climate mitigation is also a target for NNBFs, including carbon sequestration and greenhouse gas (GHG) emissions reductions.[54,55,56] Local, Tribal, and state planners are moving toward multi-objective approaches when incorporating NNBFs as part of the toolbox for climate adaptation and mitigation, with increasing focus on equitable climate outcomes where co-benefits are needed for heat, flooding, and well-being (Figure 21.2).

Key Message 21.2

Ocean and Coastal Impacts Are Driving Adaptation to Climate Change

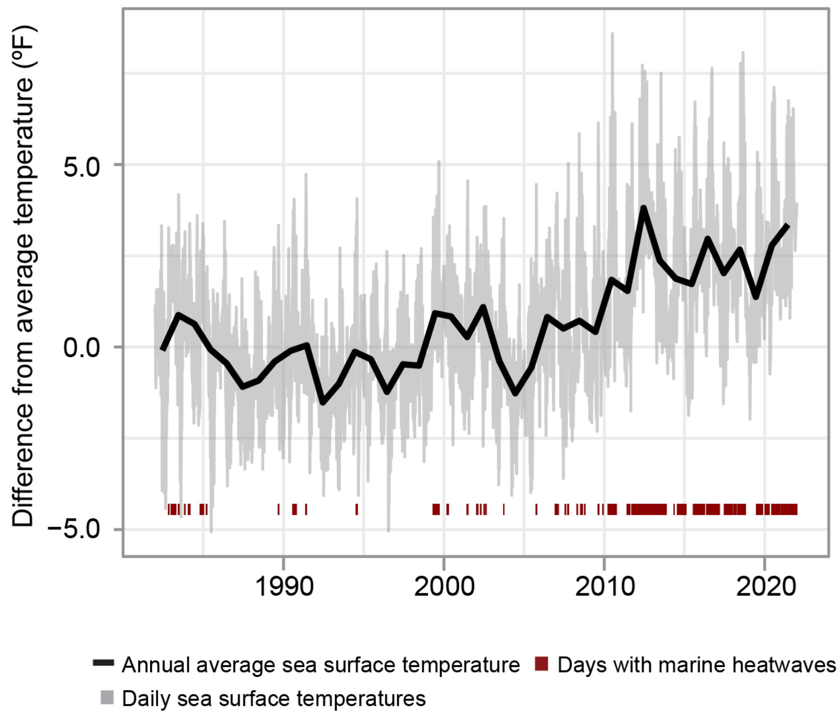
The ocean and coastal habitats in the Northeast are experiencing changes that are unprecedented in recorded history, including ocean warming, marine heatwaves, sea level rise, and ocean acidification (*high confidence*). Changing ocean conditions are causing significant shifts in the distribution, productivity, and seasonal timing of life-cycle events of living marine resources in the Northeast (*high confidence*). These impacts have spurred adaptation efforts such as coastal wetland restoration and changes in fishing behavior (*high confidence*).

Ocean warming, more frequent and intense marine heatwaves, sea level rise, and ocean acidification are harming aquatic ecosystems and ecosystem services, and these impacts are expected to be exacerbated by future climate change (KMs 2.1, 3.4, 9.1, 9.2, 10.1; App. 4.4).[57,58,59,60] Climate-driven shifts in distribution, productivity, and phenology (seasonal timing of life-cycle events) are increasing in prevalence and magnitude across species, from phytoplankton to whales.[59,61]

Ocean temperatures in the continental shelf bottom waters of the Northeast have increased by as much as 0.15°F to 0.7°F per decade (Friedland et al. 2020) due to changes in atmospheric circulation from a persisting positive North Atlantic Oscillation (NAO; a large-scale climatic phenomenon) and a weaker Atlantic Meridional Overturning Circulation.[62] The northward shift of the Gulf Stream increased the salinity and temperature of subsurface waters on the Northwest Atlantic shelf.[63] Several notable marine heatwaves affected the Northwest Atlantic over the last decade (Figure 21.4),[63,64,65] associated with Gulf Stream variability, atmospheric jet stream motions, and the increased presence of masses of warm water formed from the Gulf Stream called warm core rings.[66] Changes in ocean temperature and circulation have also decreased the extent, temperature, and duration of the cold pool, a near-bottom coldwater feature in the Mid-Atlantic and an important habitat for fish productivity.[58,67]

These changes are impacting productivity at the base of the region's ocean ecosystem and changing the composition of the phytoplankton community.[68] The overall diversity and abundance of the zooplankton community has increased,[68] but the biomass of key zooplankton species has declined.[59,69] These changes can restructure communities and have cascading effects throughout the food web. For example, the negative impact of warming on the copepod *Calanus* has been linked to shifts in the distribution of right whales along the Northeast shelf.[70,71]

Ocean Temperatures and Marine Heatwaves

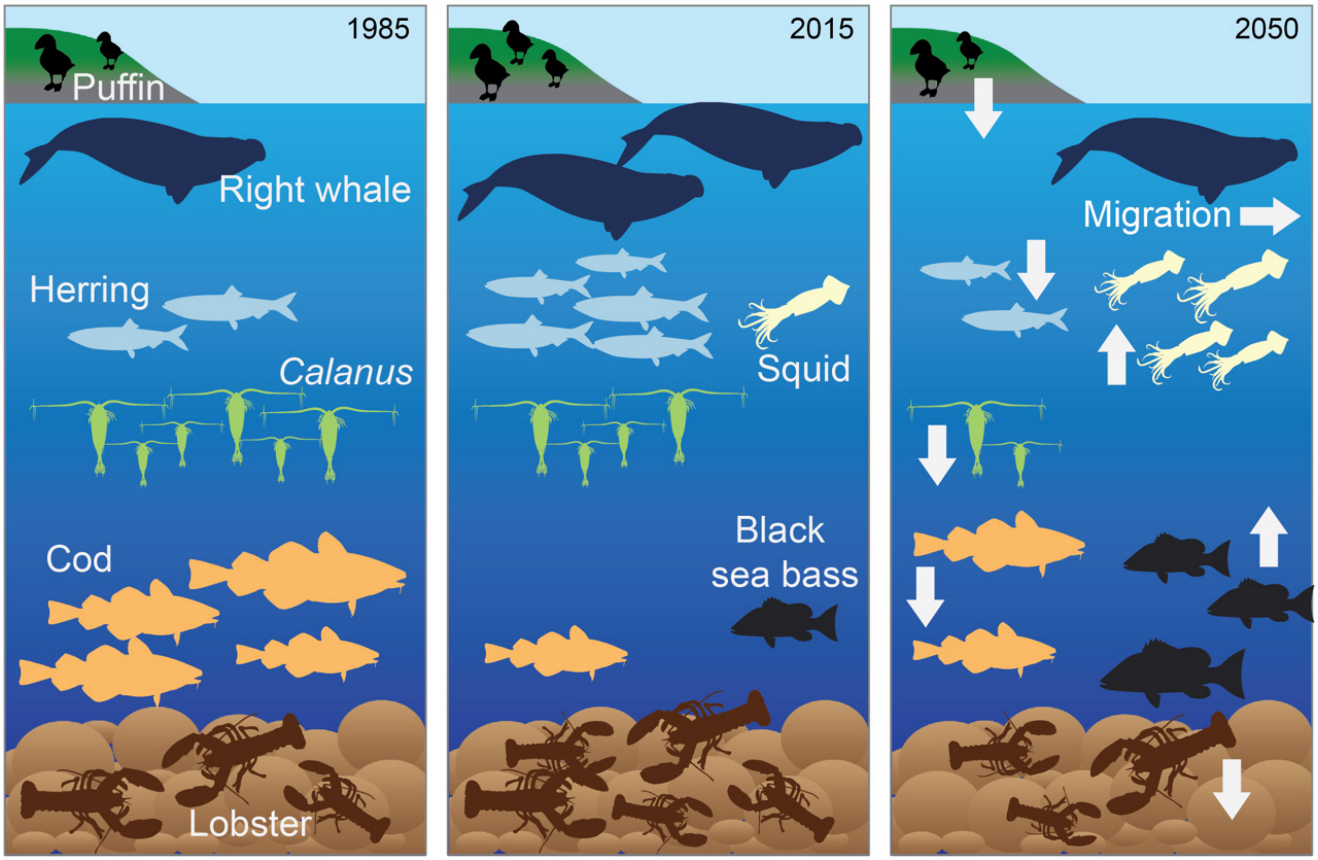


Oceans are growing warmer and marine heatwaves are more frequent, which is impacting marine ecosystems in the Northeast.

Figure 21.4. Annual average sea surface temperature (SST) anomalies (solid black line) and daily SST anomalies (light gray line) for the Gulf of Maine (region defined as ecological production unit, an ecologically distinct ecosystem). Differences from the long-term average are estimated using a 30-year climatology reference period of 1982–2011. Days meeting marine heatwave criteria are noted (red tick marks). Marine heatwave status was determined following the methods of Hobday et al. (2016).[72] The figure shows continued warming of the Gulf of Maine, with 2022 among the warmest years on record. In addition to the warming trend, the periodicity of extreme temperature events (i.e., marine heatwaves) has increased in the region. Adapted from Gulf of Maine Research Institute 2022.[73]

Fish stocks are shifting northeastward along the shelf and into deeper waters.[58] Traditional Mid-Atlantic fish species (e.g., black sea bass)[74,75] are increasing, and subarctic species (e.g., northern shrimp and Atlantic cod)[59] face declines in the Gulf of Maine (Figure 21.5). Warming is changing the distribution of bottom-dwelling species, including American lobster, Atlantic surf clams, and sea scallops (Figure 21.6).[76,77] New research directions focus on the impacts these changes have on early life stages for key species like Atlantic mackerel.[78]

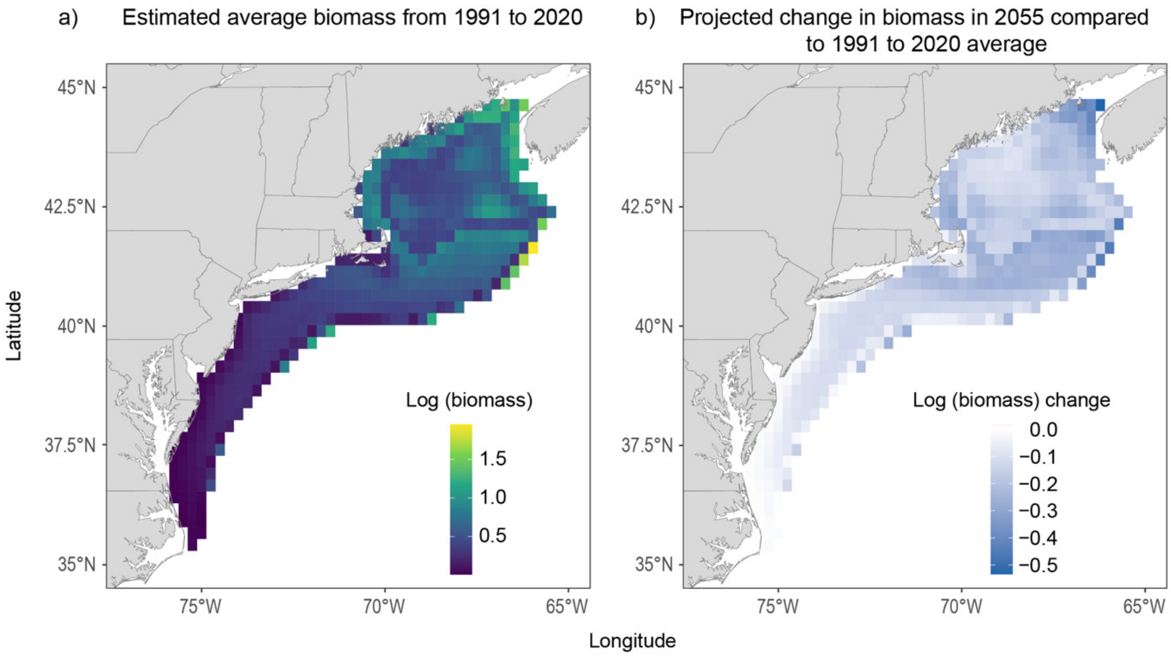
Past (1985), Present (2015), and Future (2050) of the Gulf of Maine Ecosystem



Shifts in the abundance and composition of species in the Gulf of Maine are expected to continue with additional warming.

Figure 21.5. In 1985, conditions in the Gulf of Maine ecosystem were cool, and subpolar species (puffin, right whales, and Atlantic herring) were not abundant due to human activities and natural variability. By 2015, Atlantic cod abundance was low due to overfishing and rising temperatures, whereas temperate species (e.g., black sea bass and squid) became prevalent due to warming. Under an intermediate scenario (RCP4.5), by 2050 many subpolar species (e.g., lobster, Atlantic cod, Atlantic herring, and *Calanus*, a copepod) are expected to decline (down arrows), and temperate species will increase (upward arrows). With better management, Atlantic cod abundance will tend to increase, but it will be counteracted by decreased productivity due to warming. Right whales will increase with better management but are expected to move out of the Gulf of Maine (horizontal arrow) due to the impacts of warming on the distribution and abundance of their prey. Local fishing communities will need to shift effort to harvest species that have become more abundant. Adapted from Pershing et al. 2021[59] [CC BY 4.0].

Changing Distribution of Fishery Resources in the Northwest Atlantic Ocean



The distribution and abundance of American lobster are expected to decrease by midcentury.

Figure 21.6. The figure shows (**a**) predicted changes in American lobster (*Homarus americanus*) distribution and abundance based on the estimated baseline biomass (log-transformed scale) from 1991 to 2020 (the color scale ranges from yellow [high biomass] to purple [low biomass]) and (**b**) future projected change in biomass in 2055 compared to the baseline period (the color scale ranges from no change [white] to a decrease in biomass [darker blue]). Projections suggest a decrease in the future biomass of lobster due to ocean warming. Adapted from Allyn et al. 2020[79] [CC0 1.0].

The timing of important life-history events, such as fish feeding and spawning migrations, is shifting in the Northeast. Spring and autumn phytoplankton blooms occurred later in recent decades.[80] Larval fish occurrence and fish migration are both happening earlier.[81,82,83] Warmwater fish remain longer in Rhode Island's Narragansett Bay, while coldwater species stay for shorter periods,[84] changing when species can be fished. Warming seas are linked to increased cold-stunning events for Kemp's ridley sea turtles in the northwest Atlantic, in which turtles acclimated to warm water become motionless when subjected to sudden cold water.[85]

Increased temperatures make some diseases more prevalent in aquatic organisms, affecting the availability of seafood and increasing seafood-borne diseases. Shell disease in American lobster is associated with changing molting patterns due to spring warming and increased exposure to summer heat.[86] Climate change is expected to cause higher mortality of blue crabs due to infection by *Hematodinium*[87] and *Callinectes sapidus* reovirus 1.[88] Harmful algal blooms occur more often in the Northeast.[89] Evidence links climate change to an increase in the potential growth rates and bloom-season duration of *Margalefidinium polykrikoides*, which kills finfish and bivalve mollusks,[89,90,91] and in the number of blooms of *Prorocentrum minimum*.[92,93] Increasing temperature is linked to increases in the occurrence of pathogens (e.g., *Vibrio* species),[60] which are among the most important causes of seafood-borne diseases.[94]

Increasing water temperature is expected to alter fish and shellfish community structure in estuaries.[95] Significant declines in the relative habitat usage of several economically important finfish species (e.g., Atlantic croaker, spot, and summer flounder) were observed in the Chesapeake Bay from 2008 to 2019,[96] driven in part by the NAO.

The abundance of subtropical species such as pinfish and white shrimp is expected to increase in the Chesapeake Bay and coastal lagoons, whereas more temperate species, such as soft clam and sand shrimp, might decrease.[97,98] In the Chesapeake Bay, an observed increase in the abundance of white shrimp[99] was related to favorable environmental conditions, including rising temperatures. Projections of shorter winter periods and warmer winter temperatures in the Chesapeake Bay suggest that by 2100, blue crabs will grow faster and improve their overwinter survival, increasing the productivity of the population.[100]

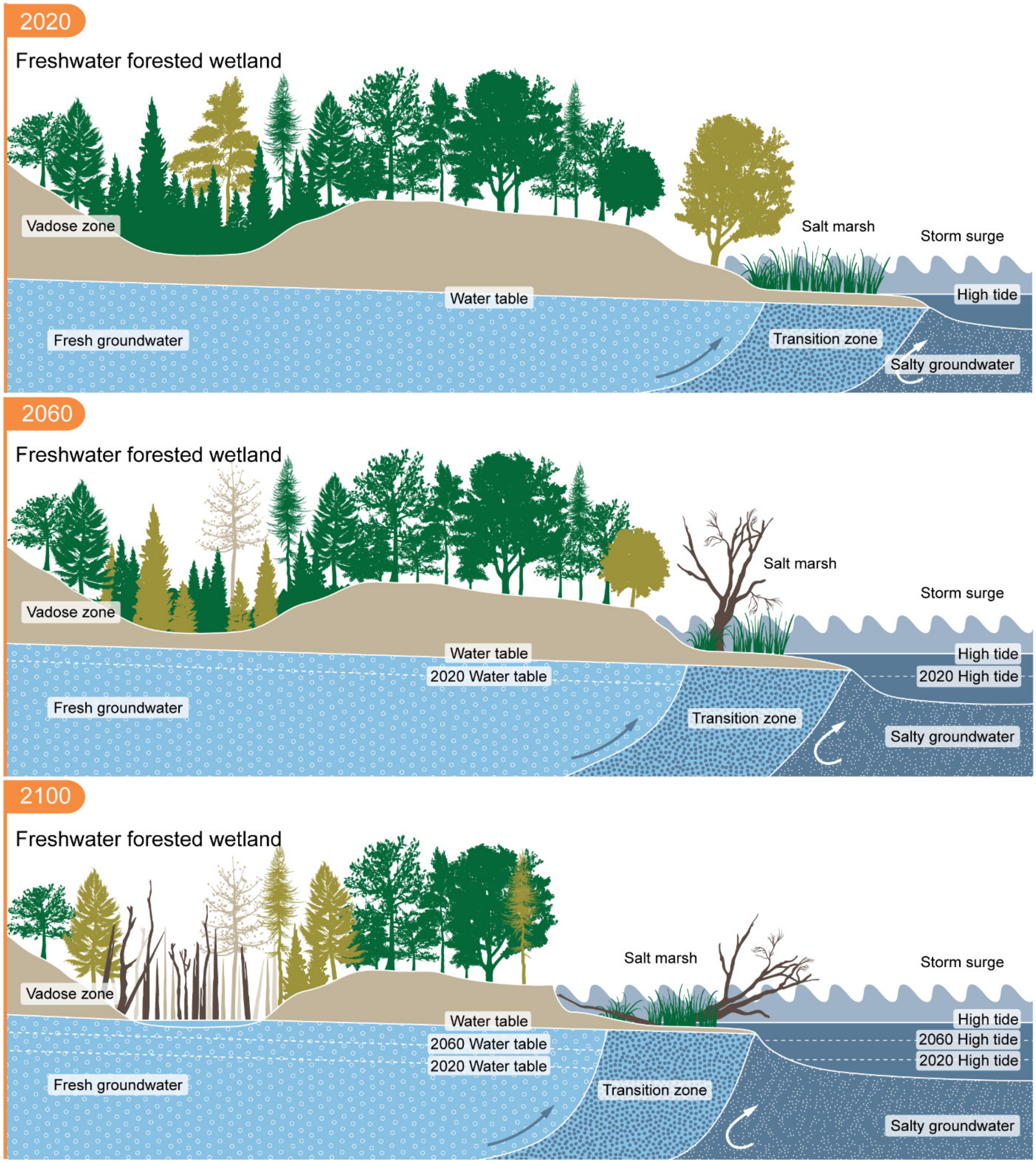
Combined with changes in salinity, ocean acidification exerts stress on shell-building organisms in the region (KM 2.3). The Mid-Atlantic Bight is acidifying faster than other Atlantic coastal regions and the open ocean.[101] Ocean acidification may impact fishery resources, including American lobster, scallops, oysters, clams, and mussels.[102] For example, projections of sea scallop biomass suggest a potential decrease of more than 50% by the end of the century under a very high scenario (RCP8.5) and 13% under an intermediate scenario (RCP4.5).[103] Scallops are one of the most lucrative fisheries in the Northeast, and acidification will have socioeconomic ramifications.

Oxygen loss in ocean and coastal areas, which is correlated with water temperature and nutrient enrichment, is also an important driver of marine ecosystem change (KM 2.3). The rate of change varies by region, with coastal waters of the Northeast showing a drop in oxygenation that outpaces that of the global ocean and broader North Atlantic.[104,105,106] Projected increases in precipitation discussed in Key Message 21.1 will lead to increased runoff and nutrient loading into coastal waters. Estuaries such as the Chesapeake Bay that receive significant amounts of nutrients from the watershed that stimulate algae production experience low oxygen levels (hypoxia),[107] especially during the summer months. Furthermore, temperatures are rising in the region, and in the Chesapeake Bay this is driven by increases in air temperature and in reflected longwave radiation, as well as by warming of the continental shelf.[108] Marine heatwaves are also increasing in frequency, number of days per year, and yearly cumulative intensity in the Chesapeake Bay, which is projected to reach a semipermanent marine heatwave state by 2100, relative to present day.[109] Under such a condition, extreme temperatures will occur for more than six months in a year. Increases in the temperature and intensity of marine heatwaves are expected to decrease the dissolved oxygen content of water and worsen the hypoxic conditions, with consequent negative effects on fish, shellfish, and other living organisms.[110,111]

Sea level rise, tropical and extratropical cyclones, storm surges, and flooding are changing natural coastal wetlands and forests and the species that inhabit them (Figure 21.7; Ch. 9).[112] Impacts of rainfall and riverine floods on coastal areas include shoreline erosion,[113] damage to infrastructure and agriculture, and the degradation and loss of coastal ecosystems, including tidal wetlands and forests (KMs 9.1, 9.2).[114,115] Coastal inundation poses increased risks to aquifers and buried structures, such as septic tanks and pipes, which would degrade water quality.[116] Coastal zone groundwater supplies (such as in Long Island, New York, and Cape May County, New Jersey) are also vulnerable to saltwater intrusion from sea level rise.[117,118]

Coastal forests in the Northeast, such as the Lower Eastern Shore of Maryland and other areas of the Delmarva Peninsula, have been affected by saltwater intrusion and salinization of the soils.[119,120] When coastal forests are invaded by salt water, they transform into tidal marshes, leaving behind standing dead trees, called ghost forests,[121,122] and promoting the growth of *Phragmites australis*, an invasive reed grass that provides less suitable habitats for fishes, crustaceans, and other invertebrates.[123]

Projected Changes in Coastal Forests



Rising sea levels kill trees and transform coastal forests into marshes, damaging vital ecosystems and the services they provide to the community.

Figure 21.7. As sea level rises, the water table also rises; the vadose zone (which is between the ground surface and the groundwater table) becomes thinner, bringing the water table closer to the surface; and tidal flooding and storm surges reach farther inland, resulting in forest dieback and conversion of forested wetlands to standing-water wetlands. Over time, these changes result in permanent habitat shifts. Adapted from Sacatelli et al. 2020.[122]

Advancements in predictive modeling of coastal and marine resources[59,79,124] are informing expectations of future climate-driven changes in the thermal habitat of species, such as American lobster (Figure 21.6) and sea scallops, and enabling marine resource managers to anticipate risks to these fisheries. Projections of habitat changes in the Northeast suggest that sea scallops will undergo a northward shift, while American lobster will move farther offshore over the next 80 years.[125] Information on expected shifts in the distributions of marine resources is important for adaptive actions that can support livelihoods and local economies reliant on these resources.

Adaptation responses to sea level rise and shoreline erosion include the use of natural and nature-based features, such as eco-engineered oyster reefs (e.g., oyster castles), and management and restoration[126,127] of coastal wetlands.[128,129,130] Collaborative learning and exchange of ideas among multidisciplinary groups, including salt marsh professionals, is facilitating salt marsh management and restoration in the region; techniques include using drone technology to monitor living shorelines and constructing and evaluating runnels (shallow, narrow channels used to drain water from the marsh surface at low tide).[131,132,133,134] Other measures are aimed at managing stormwater and reducing carbon dioxide (CO_2) emissions to mitigate ocean acidification.[135]

New England and Mid-Atlantic fishing communities are particularly vulnerable to climate impacts and face declining fishing opportunities unless they adapt, either through catching new species or fishing in new locations.[136] Actions undertaken to reduce potential climate change impacts to Northeast fisheries range from individual actions to changes in federal governance.[137] Fishing patterns such as location and timing have altered in response to shifting species distributions (e.g., summer flounder). Effective adaptation strategies include diversifying species targeted for harvest in response to changing availability and improving fleet mobility, so fishers can follow their target species.[138] Marine heatwaves led to an early influx of molted lobsters, prompting the lobster industry to implement changes throughout the supply chain to avoid price drops should another warm year with early and intense landings occur.[139] However, key barriers to adaptation efforts include fisheries specialization and dependency, fishery access, working waterfront and workforce issues, and management system responsiveness.[140] Furthermore, interactions with threatened and endangered aquatic mammals can complicate adaptation efforts. Changes in right whale patterns due to warming have increased concern about the risk of vessel strikes. This has prompted calls for increased fishing gear regulations, with possible ramifications for the lobster industry.[141]

Key Message 21.3

Disproportionate Impacts Highlight the Importance of Equitable Policy Choices

Extreme heat, storms, flooding, and other climate-related hazards are causing disproportionate impacts among certain communities in the Northeast, notably including racial and ethnic minorities, people of lower socioeconomic status, and older adults (*very likely*, *very high confidence*). These communities tend to have less access to healthcare, social services, and financial resources and to face higher burdens related to environmental pollution and preexisting health conditions (*very likely*, *high confidence*). Social equity objectives are prominent in many local-level adaptation initiatives, but the amount of progress toward equitable outcomes remains uneven (*very likely*, *high confidence*).

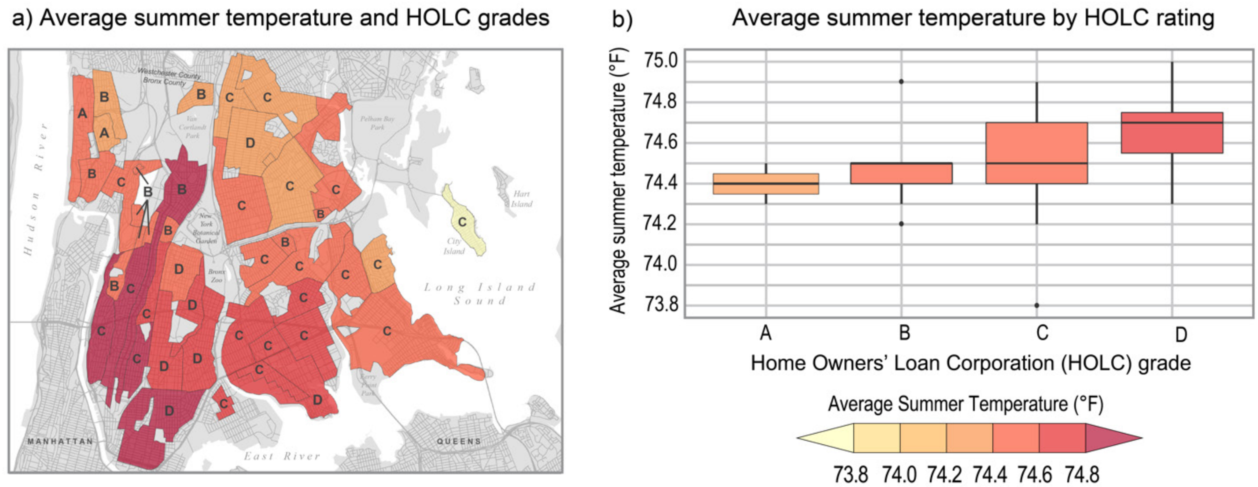
Across the Northeast, the disproportionate impact of climate change and extreme weather on racial and ethnic minorities and low- and moderate-income communities has provided focus to new advocacy and policy work to advance equity and environmental justice.

Climate impacts—including extreme heat, stronger storms, flooding, and pollution—compound the environmental, health, and socioeconomic burdens on some communities (KMs 12.2, 15.2). These burdens include historical racially based injustices such as redlining (a discriminatory practice by which financial products such as loans and insurance were refused or limited in specific geographic areas),[142,143,144,145,146] land dispossession and forced migration of Indigenous Peoples, and disinvestment in poor communities and communities of color. In response, local, Tribal, and state governments are increasingly working directly with community organizations, Indigenous Peoples, and environmental justice groups to develop new approaches to these challenges.

Analyses of summer land surface temperature and sociodemographic data reveal heat exposure disparities across Northeast neighborhoods. Specifically, neighborhoods with higher proportions of racial and ethnic minorities, people of lower socioeconomic status, and households without automobile access experience higher temperatures.[147]

Relative to non-redlined neighborhoods, historically redlined areas in the Northeast show consistent city-scale patterns of elevated land surface temperatures.[148] For instance, Figure 21.8 shows higher average summer temperatures in redlined neighborhoods in the Bronx, New York. People of color tend to live in census tracts with higher surface urban heat island intensity than non-Hispanic Whites, and this difference is particularly pronounced in the Northeast.[149] Across the United States, higher heat is experienced by racial and ethnic minorities in metropolitan statistical areas more segregated from Whites and in census tracts with lower socioeconomic status and higher percentages of Black and Asian residents.[150]

Summer Temperature Differences by Neighborhood in the Bronx, New York



Average summer temperatures are generally higher in historically redlined neighborhoods in the Bronx, New York.

Figure 21.8. Historically redlined areas, defined by lower Home Owners' Loan Corporation (HOLC) grades that deprived certain areas of federal loans and insurance, typically show higher temperatures relative to non-redlined neighborhoods, leading to greater likelihood of heat exposure for areas with lower socioeconomic status and higher percentages of racial and ethnic minorities in the Bronx, New York (1981–2010). The letters A, B, C, and D on the figure correspond to the four categories used by the HOLC: "Type A (Best), Type B (Still Desirable), Type C (Declining), and Type D (Hazardous)."[143] Figure credit: Union of Concerned Scientists, RAND Corporation, Columbia University, NOAA NCEI, and CISESS NC.

Compared with the historic territories of Indigenous Peoples, present-day Tribal lands experience nearly two additional extreme heat days per year and a decrease of nearly 23% in annual average precipitation.[151] For some members of Tribal Nations across the Northeastern US, climate change impacts on Tribal reservation or trust lands, which in some Tribal Nations have been reduced to 1 square mile or less, pose serious threats to Tribal cultures. One of the greatest threats will be the shifting of ecosystems and species migration beyond Tribal lands or regions.[152] Loss of access to culturally significant locations harms the physical and mental health of Indigenous Peoples (KM 15.2).[153]

Temperature extremes are related to a larger fraction of cardiorespiratory deaths in the Northeast and industrial Midwest (compared with other regions), particularly in areas with higher urbanization, more older people, fewer White residents, and lower socioeconomic status (Zhang et al. 2019).[154] Reasons for the regional differences are unclear. Nationally, health impacts of temperature extremes often cluster in neighborhoods that are also poor, racially segregated, historically disinvested, and suffer other environmental problems such as air pollution.[155]

As extreme events become more frequent or severe in the Northeast, both rural and urban fenceline communities (those adjacent to industrial facilities) are expected to face increased health burdens from exposure to toxic pollution and stress related to potential chemical releases (KM 20.3).[156] In rural Pennsylvania, fenceline communities near oil and gas extraction activities show higher pediatric asthma and genital and urinary problems in non-elderly women; increased asthma is related also to industrial animal pollution.[157] Power sector carbon mitigation policies focusing on aggregate emissions reductions (e.g., Regional Greenhouse Gas Initiative) may not redress disparities in pollutant burdens.[158]

Energy insecurity is a complex problem influenced by social determinants of health and the changing climate. Energy burden—the fraction of household income spent on energy costs—varies among racial groups, depending on energy type, end-use demand, and region, given differences in climate and households' socioeconomic characteristics. The cold Northeast climate leads to higher household energy burdens (compared with the Midwest, West, and South) based on residential energy consumption.[159] African American households had a heavier energy burden than others, but their energy poverty rate (the share of households paying a disproportionate share of income on the cost of energy use) decreased over time, whereas the rate for White households increased. Despite the substantial impact that energy burden can have on population health, links with climate change have been understudied.[160]

Continued warming in the Gulf of Maine ecosystem (KM 21.2) threatens access to species and locations of cultural significance. Some Tribal Nations and other coastal communities may have to shift their economic or subsistence harvests to new species that are migrating to the region, but the loss of other species or places is expected to result in a loss of cultural lifeways that will harm physical and mental health and well-being.[161]

Managed relocation from flood-prone areas is still relatively uncommon (KM 20.3), but initiatives such as the New Jersey Department of Environmental Protection's Superstorm Sandy Blue Acres Buyout Program are combining federal and state funding to support community relocation. Demand for buyouts (where homeowners sell properties to the government and the land is restored to open space) along the Mid-Atlantic seaboard relates to household-level perceptions of risk and confidence in ability to adapt to changing conditions.[162] Buyouts by local governments tend to be more common in counties with larger populations and income.[163] However, bought-out properties tend to be concentrated in areas of greater social vulnerabilities within the counties (i.e., relatively poorer, less densely populated areas with lower levels of education and English language proficiency and with greater racial diversity). The reasons underlying this pattern are unclear, but the finding highlights the need for evaluating the equity of buyout implementation and outcomes (KM 22.1).[164]

Social equity objectives that address challenges facing low-income communities and communities of color are prominent in local-level adaptation plans and initiatives.[165] These groups are less likely to have access to socioeconomic or healthcare resources to mitigate climate change impacts and are more likely to have preexisting health concerns, greater sensitivity to environmental changes, and higher exposure to pollution.[166]

Three dimensions of social equity are important in understanding uneven climate-related burdens. Distributive equity refers to the fair distribution of risks and benefits across groups; procedural equity focuses on the inclusion of affected groups prior to and during decision-making processes; and contextual equity reflects the preexisting structural, political, and socioeconomic conditions.[167,168]

Distributive equity has been a prominent theme in New York City's planning initiatives (e.g., OneNYC 2050). These plans cited the disproportionate health impacts of extreme temperatures on certain populations and focused heat mitigation investments on developing green space in underserved neighborhoods.[169] Local legislation mandated that city agencies work together and with local environmental justice leaders (addressing procedural equity) to publish more data on local environmental conditions, study environmental justice concerns, and publish a first-ever environmental justice plan that embeds a new approach to decision-making to counter historic injustices.[170,171] When representatives of frontline communities are included in the decision-making process (which helps address procedural equity), more attention is paid to the equitable distribution of benefits and burdens.[165]

Innovative sea level rise adaptation strategies developed by Tribal Nations, such as the WAMPUM Indigenous adaptation framework (Box 21.2), reflect Indigenous Knowledge typically not evident in other existing sea level rise adaptation frameworks in the Northeast.[172] Nonetheless, even when Tribal Nations work across jurisdictions to address climate change impacts, some adaptation plans do not take into account Tribal Nations' interests in natural resources and areas of cultural significance. Tribal Nations face difficulties if adaptation strategies require relocating or reacquiring lands with access to cultural resources.[153] Relocation is a profoundly sensitive concern for Tribal Nations, given the history of forced migration and loss of homeland access. These past injustices highlight the importance of the United States' meeting trust and treaty obligations to Tribal Nations and ensuring that rights and access to original homelands, waters, and coasts are maintained and protected, even if these places become submerged.[152]

Key Message 21.4

Climate Action Plans Are Now Being Implemented

In recent years, there have been substantial advances in the magnitude and scope of climate action across all jurisdictional scales (*high confidence*). Almost every state in the region has conducted or updated a climate impact assessment, developed a comprehensive climate action plan, and enacted climate-related laws since 2018 (*high confidence*). Innovative approaches to transparent, inclusive, and equitable processes around climate action are being embraced by Tribes, municipalities, and states (*high confidence*). Although ambitious emissions reduction targets have been put forward, meeting these goals is expected to be challenging (*medium confidence*).

The landscape of climate action in the United States has been dynamic in recent years. The United States' withdrawal from and rejoining of the Paris Agreement raised questions among international and subnational constituencies about America's ability to meet its mitigation targets—and, as a consequence, catalyzed substantial climate action at state, city, business, and Tribal levels.[173,174] Moreover, the increase in public concern about community climate risks has led to a proliferation of vulnerability assessments and resilience plans among these subnational jurisdictions.[175]

A compilation of recent state-level climate impact assessment reports, climate action plans, and relevant laws and executive orders for the 12 states (plus Washington, DC) of the Northeast is shown in Table 21.1. For a more comprehensive assessment, see, for example, Dalal and Reidmiller (2023),[176] the US Climate Alliance inventory of member state policies particularly around mitigation,[177] the Georgetown Climate Center's State Adaptation Progress Tracker,[178] and the Northeast Region reports section of NOAA's Climate Resilience Toolkit.[179] The intent in presenting the information in this Key Message is to provide the ever-growing regional workforce (and related volunteer efforts) focusing on climate action planning and implementation with a concise, accessible source of information and inspiration as these workers develop, refine, and/or update their own assessments, plans, and climate-related laws. It endeavors to be a decision-support tool. An analysis of individual vulnerability assessments, climate action plans, or climate laws and executive orders is beyond the scope of this chapter; rather, the utility comes from providing—for the first time ever—a single resource compiling all of the Northeast's state- and Tribal-level information in one place. For a more comprehensive look at state-level climate mitigation policies across the entire country, see Key Message 32.5.

The Regional Greenhouse Gas Initiative (RGGI) is the largest regional climate coordination effort in the Northeast. RGGI includes every state in the Northeast region except West Virginia, but as of this writing, Pennsylvania's membership is undergoing a legal challenge. Established in 2005, RGGI was the Nation's first mandatory, market-based cap-and-trade program aimed at reducing CO_2 emissions from the power sector. RGGI issues a limited number of tradable CO_2 allowances with member states, which are then able to distribute the allowances through quarterly auctions. The revenue generated through these auctions goes toward investments in energy efficiency, renewable energy, and other consumer benefit programs. Although there have been critiques of RGGI for, among other things, not adequately integrating environmental justice considerations (e.g., Declet-Barreto and Rosenberg 2022[158]), it has also been estimated that the program is responsible for an annual reduction of almost 5 million metric tons of CO_2[180] across the regulated states—roughly equivalent to the annual residential CO_2 emissions from Rhode Island and Maine combined.[181,182]

There has been strong cross-jurisdictional collaboration between the federal and state governments to advance climate resilience in the past few years. An example of this is the Federal Highway Administration's Resilience and Durability to Extreme Weather Pilot Project. Under this effort, departments of transportation and metropolitan planning organizations from eight states in the Northeast (ME, MA, CT, NY, NJ, PA, DE, and MD) are performing detailed vulnerability assessments to understand the condition of their transportation-related assets and the risks they face from climate change (KM 13.1).

In many Northeast states, particularly in New England, mitigation and adaptation action has been solidified in state law. Many states in the region have legally mandated greenhouse gas emissions reductions by midcentury, consistent with the goals of the Paris Agreement, and require state agencies to integrate the best available science (e.g., sea level rise projections) into land-use planning and zoning, building codes, and regulation development. Seven states in the region (ME, VT, MA, RI, CT, NY, and NJ) have laws requiring emissions reductions of at least 80% by 2050 (usually against a 1990 baseline). Several go even further in calling for economy-wide carbon neutrality before midcentury. Most of these laws have been passed by state legislatures since 2018. In other Northeast states, much of the action has been promulgated through executive order.[176]

Below are some novel climate actions employed by states in recent years that reflect increased attention to economic risks; equity considerations; and transparent, inclusive engagement processes (e.g., Molino et al. 2020;[183] Powell et al. 2019;[184] Reckien and Petkova 2019[185]). The list is illustrative, not exhaustive, but provides practitioners with examples of the latest innovative ways of advancing climate action at the state level.

- In Maine, the work of the Maine Climate Council and its Maine Won't Wait climate action plan was informed by a collection of economic impact and opportunity reports,[186] as well as an equity assessment conducted by an external team of experts.[187]
- In Massachusetts, a climate bill was passed that mandates that all new vehicles sold be zero emissions by 2035, as well as pilots a program allowing municipalities to ban fossil fuel connections (such as natural gas lines) to new construction.[188]
- Among other provisions, Rhode Island's H5445 requires the integration of environmental justice into climate action planning efforts to reduce impacts on vulnerable communities and create an equitable transition.[189]
- A Connecticut law allows municipalities to create stormwater authorities charged with developing stormwater management and public outreach.[190] Connecticut also enacted a first-in-the-Nation climate risk provision requiring the state insurance commissioner to submit a report on progress toward addressing climate-related risks, monitoring greenhouse gas levels, and bolstering resilience of insurers to the physical impacts of climate change.[191]
- In New York, the Climate Leadership and Community Protection Act established a Climate Justice Working Group to support the Climate Action Council in mainstreaming environmental justice considerations.[192] The New York State Common Retirement Fund released a Climate Action Plan Progress Report highlighting the fund's recent efforts to address climate risks and opportunities.[193]
- In New Jersey, a study was commissioned to better understand the integration of the needs and challenges of underrepresented and socially vulnerable populations into coastal hazards planning.[194]

- Maryland launched a Climate Leadership Academy in 2018, providing standardized climate training and support to state and local government officials, citizens, the private sector, and nonprofit organizations.[195]

Table 21.1. Recent Climate Planning and Action Among States and Tribal Nations in the Northeast

The table is a compilation of state and selected Tribal climate impact assessments and action plans, alongside illustrative climate-related laws, since 2018.

State	Climate Impact Assessment	Climate Action Plan	Climate-Related Laws
Maine	Scientific Assessment of Climate Change and Its Effects in Maine[196] Maine Climate Science Update 2021[197]	Maine Won't Wait[198]	An Act to Analyze the Impact of Sea Level Rise[199] An Act to Implement Agency Recommendations Relating to Sea Level Rise and Climate Resilience[200] An Act to Establish a Pilot Program to Encourage Climate Education in Maine Public Schools[201]
New Hampshire	New Hampshire Climate Assessment 2021[202]	N/A (The state has a pre-2018 climate action plan[203])	An Act Establishing a Coastal Resilience and Economic Development Program[204]
Vermont	Vermont Climate Assessment 2020[205]	Initial Vermont Climate Action Plan[206]	Global Warming Solutions Act[207]
Massachusetts	Massachusetts Climate Change Assessment[208]	Massachusetts Clean Energy and Climate Plan for 2025 and 2030[209] Massachusetts State Hazard Mitigation and Climate Adaptation Plan[8]	An Act Creating a Next-Generation Roadmap for Massachusetts Climate Policy[210] An Act Driving Clean Energy and Offshore Wind[188]
Rhode Island	Resilient Rhody: The Statewide Climate Resilience Action Strategy[211] Rhode Island 2022 Climate Update to the 2016 GHG Emissions Reduction Plan[212] Executive Climate Change Coordinating Council (EC4) to deliver "2025 Climate Strategy" by Dec 31, 2025	Resilient Rhody: The Statewide Climate Resilience Action Strategy[211] Rhode Island 2022 Climate Update to the 2016 GHG Emissions Reduction Plan[212] Executive Climate Change Coordinating Council (EC4) to deliver "2025 Climate Strategy" by Dec 31, 2025	2021 Act on Climate[189]
Connecticut	Connecticut Physical Climate Science Assessment Report[213]	Taking Action on Climate Change and Building a More Resilient Connecticut for All[214]	An Act Concerning Climate Change Adaptation[190] A provision to address climate-related risk to insurance[215]

State	Climate Impact Assessment	Climate Action Plan	Climate-Related Laws
New York	Observed and Projected Climate Change in New York State[216]	Draft Scoping Plan[217] New York State Climate Action Council Scoping Plan[218]	Climate Leadership and Community Protection Act[192] Soil Health and Climate Resiliency Act[219] Green CHIPS[220] Environmental Bond Act[221]
Pennsylvania	Pennsylvania Climate Impacts Assessment 2021[222]	Pennsylvania Climate Action Plan[223]	N/A
New Jersey	New Jersey's Rising Seas and Changing Coastal Storms[224] 2020 New Jersey Scientific Report on Climate Change[225] Climate Change Impacts on Human Health and Communities[226]	2021 New Jersey Climate Change Resilience Strategy[227] 2019 New Jersey Energy Master Plan[228] New Jersey's Global Warming Response Act 80x50 Report[229]	An Act Concerning the Reduction of Greenhouse Gases[230] An Act Requiring New Jersey to Join the U.S. Climate Alliance and Uphold the Paris Climate Accord[231]
Delaware	An Economic Analysis of the Impacts of Climate Change in the State of Delaware[232]	Delaware's Climate Action Plan[233]	Renewable Energy Portfolio Standards Act[234]
Maryland	Sea Level Rise Projections for Maryland 2018[235]	2030 Greenhouse Gas Emissions Reduction Act Plan[236] 2021 Annual Report and Building Energy Transition Plan[237] Maryland Ocean Acidification Action Plan 2020[135]	Climate Solutions Now Act[238] Sea Level Rise Inundation and Coastal Flooding—Construction, Adaptation, and Mitigation[239]
West Virginia	N/A	N/A	N/A
Washington, DC	N/A (DC has a pre-2018 impact assessment[240])	Clean Energy DC[241] Sustainable DC 2.0 Plan[242] Resilient DC[243] Climate Ready DC[244]	Clean Energy DC[241] Sustainable DC 2.0 Plan[242] Resilient DC[243] Climate Ready DC[244]
Saint Regis Mohawk Tribe	Climate Change Adaptation Plan for Akwesasne[245]	Climate Change Adaptation Plan for Akwesasne[245]	N/A
Shinnecock Indian Nation	Shinnecock Indian Nation Climate Vulnerability Assessment and Action Plan[51]	Shinnecock Indian Nation Climate Vulnerability Assessment and Action Plan[51]	N/A
Mi'kmaq Nation	Thirteen Moons Climate Change Adaptation Plan[246]	Thirteen Moons Climate Change Adaptation Plan[246]	N/A

Box 21.1. Innovative Approaches to Climate Action at the Municipal Level

To complement the aforementioned focus on state-level planning and implementation—a jurisdictional level that was feasible to assess within the scope of this chapter—this box highlights examples of innovative approaches to climate action within mid-sized cities of the Northeast region. While extensive climate action planning and implementation has occurred within the major metropolitan areas of the Northeast region (e.g., Boston,[247] New York City,[169] and Philadelphia[248]), the focus here is on a geographically, economically, and politically diverse sampling of mid-sized cities that have different capacities (e.g., specialized staff, funding) to commit to the issue. Their efforts generally receive less visibility, but the need among similarly sized cities in the region—to learn about best practices and lessons learned in developing and implementing climate action plans to inform their own efforts—can be significant.

Cross-Jurisdictional Climate Action Planning in Portland and South Portland, Maine

The cities of Portland and South Portland, Maine, are jointly producing assessments and plans to address climate change. The Climate Change Vulnerability Assessment report highlights the ways climate change is projected to affect Portland and South Portland, and the Our Contributions to Climate Change report contains data about their greenhouse gas emissions sources.[249,250] Informed by these foundational reports, the *One Climate Future* climate action and adaptation plan commits the two cities to reduce their greenhouse gas emissions by 80% from the 2017 level by 2050,[251] with municipal operations running on 100% renewable energy by 2040. Both city councils prioritize implementing the plan, working closely with municipal staff, business leaders, nonprofit organizations, and concerned citizens to ensure equitable and transparent progress is being made.

Pittsburgh Climate Action Plan 3.0 and State of Sustainability Reports

Pittsburgh places climate action at the forefront of its municipal agenda through executive orders and planning efforts. Mayor William Peduto signed Executive Order 2017-08, in which the City of Pittsburgh endorsed and expressed its commitment to the "principles" of the Paris Agreement.[252] An executive order in April 2021 commits Pittsburgh to achieve carbon neutrality by 2050.[253] The city released an updated Climate Action Plan 3.0 in 2017, showcasing progress and adding new mitigation and adaptation measures.[254,255] The update process included multiyear civic engagements bringing together residents, the business community, the nonprofit sector, and local, state, and federal government partners.[256] The plan recognizes that climate-related stressors disproportionately affect some of the city's most vulnerable residents and focuses on co-benefits including improved equity. The city tracks progress through its Pittsburgh Equity Indicators report and produces annual State of Sustainability reports, highlighting progress on the Climate Action Plan.[257] The city's recently updated stormwater code requires new developments to reflect a future-climate-projected 10-year rainfall event instead of historically derived estimates.[258]

Morgantown, West Virginia, Municipal Green Team Strategic Plan

While West Virginia has no formalized state-level mitigation or adaptation plan, the city of Morgantown committed to the Paris Agreement goals in August 2017. The Green Team, established in 2007, recommends actions to achieve the emissions-reduction goal,[259] advises the city council on environmental sustainability, and produces annual reports on the status of team projects.[260] In 2018, the Green Team released the Morgantown Municipal Green Team Strategic Plan (2018–2022), which contains a framework of goals and objectives that it plans to accomplish, including creating a climate action plan.[261] Lastly, the team has an energy policy guide, which contains recommendations to reduce the cost of energy and also highlights the costs of fossil fuel extraction and combustion on the environment, human health, and national security.[262]

Box 21.2. Tribal Nations Leading and Setting an Example

WAMPUM Adaptation Framework

The WAMPUM Adaptation Framework is a culturally responsive approach developed by Shinnecock Indian Nation citizen Dr. Kelsey Leonard for Northeast Indigenous Peoples impacted by sea level rise. This framework provides adaptation actions drawing from coastal Tribal Nations' Indigenous Knowledge systems. WAMPUM is an acronym for Witness (climate change warnings), Acknowledge (cultural relationships with land and water), Mend (areas damaged by sea level rise), Protect (cultural sites for future generations), Unite (with other Tribal Nations), and Move (to places out of harm's way but with cultural connections). The framework connects to wampum (carved quahog and whelk shells), which Tribal cultures in the Northeast have used for millennia for establishing diplomatic relations, documenting kinship, recording treaties, and negotiating the economic systems of settler European nations as currency. The WAMPUM framework acknowledges that sea level rise may force some Tribal nations and communities to relocate; however, the framework insists on Tribal self-determination in movement and continued rights, access, and cultural connections with areas inundated by sea level rise.[172]

Climate Change Adaptation Plan for the Akwesasne/Saint Regis Mohawk Tribe

The Saint Regis Mohawk Tribe was the first Tribal Nation in the Northeast to formally draft a climate change adaptation plan, which was published in 2013. The plan was initiated by the Tribal Nation's Environment Division to investigate the local impacts of climate change and to provide recommendations for adaptation actions. This plan continues to be implemented and is noted for its grounding in the cultural framework and priorities of the Saint Regis Mohawk Tribe.[245]

Shinnecock Indian Nation Climate Vulnerability Assessment and Action Plan

Shinnecock translates to "People of the Stony Shore." The Shinnecock Indian Nation, located on eastern Long Island, completed a climate change adaptation plan following Hurricane Sandy and updated it in 2019. The Shinnecock Indian Nation has a 1-square-mile reservation with more than 600 residents; it is vulnerable to sea level rise, storms, flooding, and coastal erosion. Other climate change concerns include water quality issues from increasing temperatures, salinity changes, and acidification. The Shinnecock are closely tied to the coast, and fish and shellfish have been a staple of traditional diets for thousands of years.[51] The updated Shinnecock Indian Nation Climate Vulnerability Assessment and Action Plan includes several steps, including evaluation of adaptation actions, habitat restoration, green infrastructure projects, land conservation, and outreach and education on climate change.

Mi'kmaq Nation: Thirteen Moons Climate Change Adaptation Plan

The Mi'kmaq Nation is one of several Tribal Nations of the Wabanaki Confederacy ("People of the Dawn"). The Mi'kmaq Nation (formerly known as the Aroostook Band of Micmacs) live in northern Maine in Aroostook County. In February 2022, the Tribal council approved its Thirteen Moons Climate Change Adaptation Plan. The primary concern for the Mi'kmaq Nation is warming winters, which are encouraging the spread of invasive species that damage forest health (e.g., emerald ash borer) and harming animal populations (e.g., winter tick impact on moose). The plan calls for proactive efforts to address climate change, such as the development of solar energy, community education and outreach on climate change, and forest and wildlife health monitoring.[246]

Key Message 21.5

Implementation of Climate Plans Depends on Adequate Financing

Options for financing mitigation and adaptation efforts have expanded in recent years, providing households, communities, and businesses with more options for responding to climate change (*high confidence*). Flood insurance allows individuals and communities to recover following extreme flooding events, but many at-risk homeowners lack adequate coverage (*high confidence*). Although the public sector remains the primary source of funding for adaptation, private capital has started to invest in a variety of mitigation and adaptation projects, including services for monitoring climate risks and community-based catastrophe insurance (*high confidence*).

Climate adaptation plans and resilience projects ultimately need financing to come to fruition. Although finance is just one piece of the climate adaptation puzzle, progress and innovation in recent years have expanded the options available to businesses, communities, and Tribal organizations to cover the cost of building resiliently for the future.[263] Implementing adaptation plans also requires meeting prerequisite conditions. Political leadership and local trust must be built among all stakeholders to ensure a common vision and successful outcome, and technical expertise is needed to execute the plan.[264] Sources of private capital also look for transparency, well-defined risk metrics, and an adequate return on investment.[265]

Successful projects often require a mix of funding sources, and financing via a mixed or stacked approach becomes increasingly necessary as project size grows (KM 31.6).[266] A stacked approach also helps spread the burden and benefits across multiple parties to achieve mutually beneficial mitigation and adaptation goals, improved distribution of risk management functions, and increasing private equity participation in climate adaptation activities.[265]

Currently, access to private funding of climate mitigation and adaptation remains primarily limited to large businesses and institutional investors, as their focus remains on protecting corporate investments and limiting potential liability, not the equitable distribution of climate mitigation and adaptation funds.[267] Federal and state public funding of climate mitigation and adaptation—whether via grants, loans, or tax assessments—is currently available to a wider array of stakeholders and is more readily accessible to over-burdened communities (e.g., EPA 2023[268]).

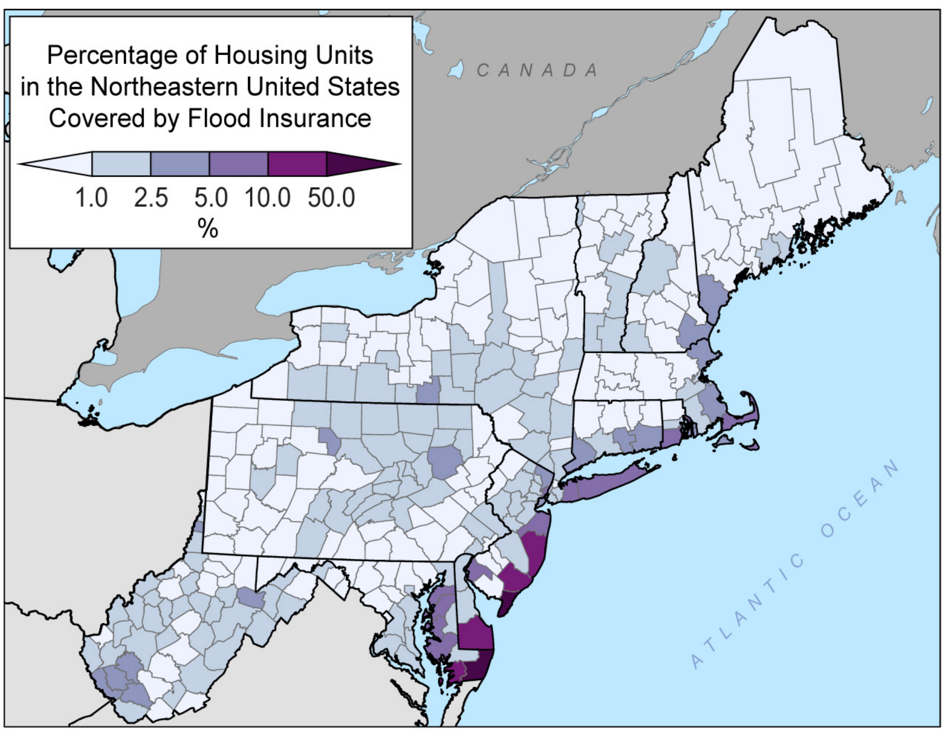
For households and businesses, property insurance remains one of the most effective risk financing mechanisms for protection from both natural catastrophes and the impacts of climate change.[269] Insurance provides individuals, businesses, and communities a source of financial resilience from natural disasters, annually providing billions of dollars in recovery funds to devastated communities across the United States.[270] Despite paying approximately $661 billion (in 2022 dollars) in insurance claims from natural disasters between 2012 and 2021, the US property and casualty insurance industry remains very well capitalized, with a record $978 billion (in 2022 dollars) in policyholder surplus to pay claims from future catastrophic events.[271]

However, insurance take-up rates (the percentage of households who purchase insurance) vary greatly by natural hazard. While about 50% of fire and wind damage in the United States is covered by insurance, only 12%–14% of flood damage is insured by the federally run National Flood Insurance Program (NFIP).[272] This "gap" in flood insurance coverage leaves millions at risk of financial hardship as the frequency and severity of coastal and rainfall flood events across the Northeast are expected to increase (KM 21.1).[273] In 1978–2015, 6 of the top 17 states with the highest NFIP payouts were in the Northeast, with New Jersey and New York ranked third and fourth, respectively.[274] Currently only two counties in the Northeast have flood insurance take-up rates above 50%. No other northeastern county exceeds 20% take-up, averaging 6.5% along the coast and 1.3% inland (Figure 21.9).

Lack of flood insurance coverage is driven by affordability issues and the underestimation of flood risk by individuals. Misperceptions around FEMA flood maps play a significant role here, as most individuals are unaware that the maps are not holistic in their assessment of flood risk. While FEMA is updating maps, some are still decades old and unrepresentative of total flood risk. Additionally, the maps do not consider flood risk along smaller catchments, nor do they consider the potential for localized flooding from intense rainfall events.[275] Flood risk data for overburdened and Tribal communities have historically been underrepresented in flood mapping as well (KMs 16.1, 20.1). Since flood insurance is not required by mortgage lenders outside of mapped FEMA-designated Special Flood Hazard Areas (SFHAs; locations with an annual probability of flooding of 1% or more), many homeowners in non-mapped SFHAs or prone to flash flooding believe that they are not at risk and thus forego coverage.[276]

Even for those who purchase NFIP coverage, policy limits are capped by law at $250,000 for residential structures, well below the current median value for an existing single-family dwelling in the Northeast ($366,000), potentially leaving policyholders financially exposed if their homes are completely destroyed.[277,278] Enforcement of flood insurance requirements is another issue, as lenders often do not continue to verify coverage in locations where flood insurance is required; as a result, about one-third of policyholders stop purchasing coverage after three years.[279]

Flood Insurance Take-Up Rates by County



Many Northeast households and communities risk financial hardship from a lack of flood insurance coverage.

Figure 21.9. The figure shows flood insurance take-up rates by county in the northeastern United States, based on 2020 Census housing units and active National Flood Insurance Program policy counts at the end of 2021. Almost half of the counties in the region have less than 1% market penetration, while only two counties (Cape May, New Jersey, and Worchester, Maryland) have more than 50% of their housing units insured for flood. The lack of coverage, particularly inland, leaves both individuals and communities at risk of major financial hardship after a flood event. Figure credit: Munich Reinsurance America Inc.

Because of major flooding events associated with hurricanes—including Irene, Sandy, and Ida in the Northeast—NFIP remains more than $20 billion in debt to the US Treasury, despite $16 billion in debt forgiveness by the federal government in 2017. This debt is driven by the program's concentration of vulnerable risks along the coast and subsidized premiums that were unable to cover the claims volume from multiple large flood events.[280] In response, the NFIP has developed a new pricing methodology, Risk Rating 2.0, with a goal of making premiums better reflect the level of flood risk at individual locations.[281] Additionally, the NFIP started purchasing catastrophe reinsurance in 2017 and catastrophe bonds in 2018, which together can provide more than $1 billion in claims-paying capacity if losses to the NFIP exceed $10 billion from an extreme flood event.[282]

Under the new Risk Rating 2.0 system, the majority of NFIP policyholders were projected to see only a nominal change in premiums, with only 4% of policyholders expected to see larger increases.[281] However, the move toward risk-adequate rates exacerbates affordability issues, especially for vulnerable individuals and communities (KM 9.3). To address rising costs, some states have used public funds to help individuals in vulnerable communities afford flood insurance. For example, in 2019, the state of New York reduced property taxes for lower-income households to make flood insurance more affordable.[263] Private insurers, who mostly stopped underwriting flood insurance for homeowners and small businesses in 1968, are also starting to reenter this market as more sophisticated flood risk assessment tools become available.[283]

Beyond flood insurance, private-sector financing of climate mitigation and adaptation has increased by 13% globally since 2018, with an annual average expenditure of $332 billion (in 2022 dollars). Of that total, about $85 billion (in 2022 dollars) has been invested annually in the United States and Canada. However, the vast majority of this private capital, nearly 98%, is currently being spent on mitigation, focused on solar and onshore wind energy development, electric vehicle infrastructure, and increasing adoption of electric vehicles.[264]

The current dearth of private-sector investment in climate adaptation, despite ample capital available for such projects, is the result of several business obstacles, including a lack of localized climate data on which to make sound investment decisions, a lack of well-defined performance metrics, and the perception that returns on investment from adaptation projects are insufficient.[265] It also can be challenging for private investors to identify climate adaptation projects that might be financially attractive to them, and, similarly, communities might not know how to find sources of private capital.[264]

Although the private sector's direct investment in climate adaptation remains small, the sector is playing an increasing role in enabling adaptation. Over the past four years, dozens of companies have started providing climate adaptation services, including high-resolution risk assessments, the deployment of sensors for risk monitoring, and innovative finance and risk transfer mechanisms.[265] This private sector investment in adaptation not only helps others but also ultimately makes businesses' own supply chains more resilient to potential climate shocks (Focus on Risks to Supply Chains).[265]

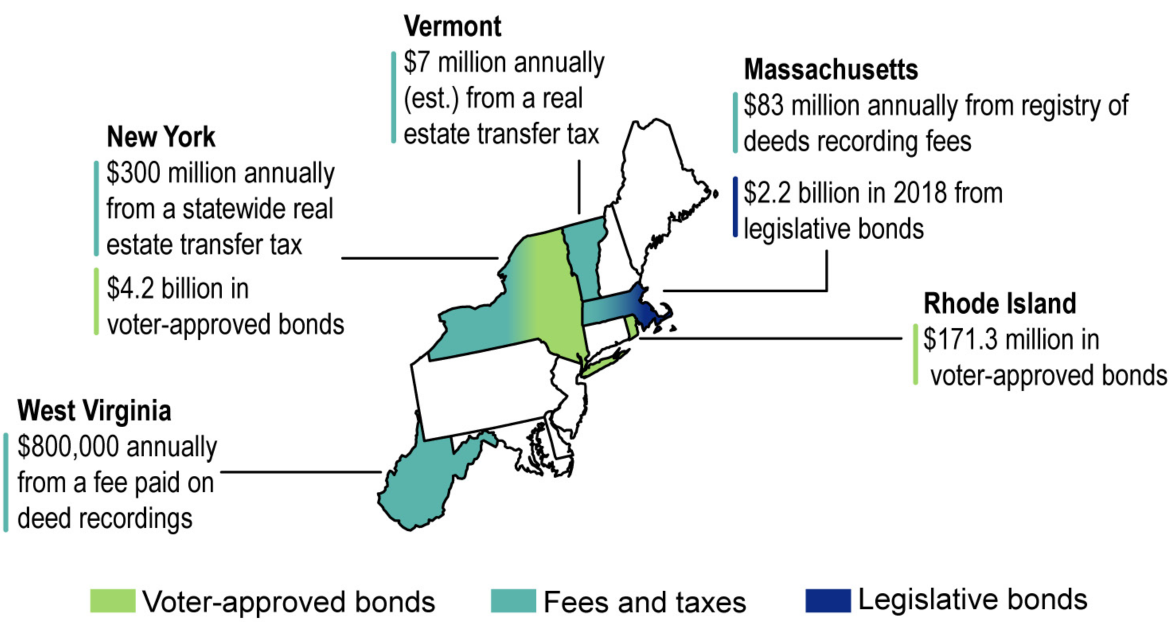
Recent innovations around the financing of climate adaptation by the private sector include community-based catastrophe insurance (CBCI), climate adaptation as a service, and climate investment intermediaries. A CBCI is a community institution (it does not have to be governmental) that helps its members access and afford insurance. The level of involvement by the community institution can vary, from purchasing a group policy on behalf of its members, to creating its own risk-bearing entity, to simply facilitating access to insurance for its members.[263] Climate adaptation as a service allows for the longer-term financing of climate adaptation projects for businesses and communities, with investors repaid over time with interest. Climate investment intermediaries are entities that facilitate matching asset owners with investors interested in climate adaptation projects.[284]

The public sector has historically shouldered the costs related to investments in the built environment.[285] State and local governments are the primary owners and operators of transportation and water systems, spending $216.5 billion on projects in 2019, substantially more than federal spending at $173.3 billion (both amounts in 2022 dollars).[286] The investments represent the responsibility of local entities to ensure continuous operation and services provided to taxpayers.

Providing these services becomes increasingly difficult when dealing with an aging and inefficient infrastructure coupled with climate change. This challenge is highlighted in the American Society of Civil Engineers' 2021 America's Infrastructure Report Card, in which no Northeast state received a grade higher than C.[287] Additionally, state and local officials are finding it challenging to proactively address resilience planning due to limited staff and inconsistent budgeting.

Historic levels of federal funding directed to states, counties, Tribes, and communities through pandemic relief provide access to needed capital for climate resilience. The Infrastructure Investment and Jobs Act of 2021 provides funding through low-interest loan programs such as the Clean Water and Drinking Water State Revolving Funds.[288] Capacity barriers exist to accessing federal funds, especially for Indigenous Peoples (KM 16.2). Increased capacity across these state-administered loan programs and access to grants create opportunities for Northeast states to address deferred maintenance and accelerate project implementation. Additionally, states in the Northeast continue to issue general obligation bonds through statewide ballot measures to finance climate resilience projects (Figure 21.10). Success of voter-approved bonds requires diverse stakeholder engagement. For example, land trusts are uniquely positioned in the Northeast to be effective in quickly generating support from landowners to elected officials for climate adaptation and mitigation funding and projects.[289]

Public Funding for Resilience



Northeastern states provide funding for resilience efforts in a number of ways.

Figure 21.10. Northeastern states fund planning and implementation of resilience projects through multiple public financing mechanisms. Examples of voter approved bonds, taxes and fees, and legislative bonds established and ongoing since 2018 are highlighted. The most common source of state funding originates from annual fees and is largely directed to conservation and natural and working lands. Infrastructure projects and capital investments are most often funded through voter-approved general obligation bonds, with Rhode Island being the most active issuer of bonds for climate-resilience projects. Figure credit: Rhode Island Infrastructure Bank.

While access to infrastructure financing is increasing, the public sector's ability and willingness to repay debt financing is a common challenge. This is heightened by the influx of federal stimulus funding, as well as local governments waiting for potential grant funds. New and innovative financing models that spread credit risk across multiple payors and focus on outcomes have moved from concept to reality. Most deals have focused on stormwater investments to increase installation of nature-based solutions and address regulatory compliance. For example, the Buffalo Sewer Authority financed nature-based solution projects through a $54 million environmental impact bond to support the city's Rain Check 2.0 initiative.[290] Buffalo Sewer will utilize bond proceeds for the design, engineering, and construction of stormwater projects that should reduce combined sewer overflows, improving water quality and community resilience.

As Northeast states plan investment priorities, a pipeline of climate-resilience projects often does not exist. However, there have been recent examples of leadership in Massachusetts, Maine, and Rhode Island to create programs focused on identifying and prioritizing resilience projects. These programs have generated more than $130 million (in 2022 dollars) in state-directed funding for planning and resilience projects from 2018 to 2022. The overall need identified through these planning programs far outweighs the grant funding available and highlights the opportunity to link these priorities with other financing programs.

Traceable Accounts

Process Description

Chapter leadership compiled a list of previous Fourth National Climate Assessment (NCA4) authors and those provided to chapter leadership through the USGCRP author nomination process. They defined potential themes for the region based on their own and potential author expertise, NOAA engagements over a decade in the region via Regional Climate Services, and a literature review. They prioritized invitations to author candidates based on their ability to address potential themes and a desire for diversity based on a mix of regional distribution, career stage, gender, sector, discipline, race, and ethnicity. Where gaps existed, chapter leadership identified additions to the candidate list through professional networks, research into departments at key regional institutions, and searches on several databases of experts from frontline communities. Introductory conversations were pursued to gauge interest and answer questions. In some cases, when author candidates indicated they could not participate, chapter leadership asked them for recommendations of additional candidates.

Author meetings were held on a weekly basis throughout the process, with a Gantt chart used to track tasks and interim milestones. Authors were divided into teams based on expertise and Key Message, and some held team meetings in addition to the full chapter meetings. The author team used productivity tools to gain consensus on key themes for the Zero Order Draft. A public workshop on January 26, 2022, was held virtually, with productivity tools used to synthesize public input provided. Key Message teams then used workshop input and literature review to further develop their Key Messages and develop figures.

Key Message 21.1

Chronic Impacts of Extreme Weather Are Shaping Adaptation and Mitigation Efforts

Description of Evidence Base

Literature reviewed (gathered by using tools such as the Web of Science) discussed an increase in extreme events in the region and the impacts caused by these events.[10,11,12,21] Authors anchored their understanding of climate trends, likelihood, and confidence in climate data analysis through discussions with the Chapter 2 author team and the Technical Support Unit (TSU) science team. Authors frequently referenced descriptive statistics and graphs from the NCA Figure and Climate Data Generator, developed by the TSU, and from NOAA NCEI's Climate at a Glance. Cost data for recovery from incidents were used as a metric for impacts. For each state and Tribe in the region, the author team searched for the following types of documents and reviewed any that were found: heat vulnerability maps, climate action plans, hazard management plans, flood maps, and weather-relevant toolkits. The team also searched state and Tribal websites for information about responses to large storms that had recently occurred in the region. Most states and some Tribes and local governments have documented some evidence of climate planning, but the methods and types of documentation widely varied. It was rarer to find clear links to recent weather events, but comprehensive understanding of the planning process illuminates these events as motivators for climate adaptation and mitigation efforts. For example, an increase in public planning meetings and changes in funding allocations can be tracked to follow a particularly impactful storm event.

Major Uncertainties and Research Gaps

Our understanding of changes in extreme precipitation is largely based on analyses and descriptive statistics showing observed and projected changes of daily precipitation time series. Research into trends in sub-daily and sub-hourly precipitation patterns in the region is ongoing but still inconclusive. The comprehensive body of state, local, and regional-level responses to climate change is continuously evolving and has not been summarized in any one place. This makes it difficult to quantitatively evaluate trends in climate action at different levels of government and to determine whether specific types of climate action can be generally attributed to the occurrence of specific extreme events.

Description of Confidence and Likelihood

High confidence in ongoing increases in the frequency of extreme weather, specifically precipitation, is based on both published literature analyzing daily weather trends through time and current NOAA data. These increases in extreme weather frequency were deemed *very likely* based upon evidence on precipitation and heatwaves presented in Chapter 2, with this likelihood determined to maintain consistency across chapters. The conclusion that problematic flooding is *very likely* due to extreme precipitation was determined through actual event tracking based on knowledge of storms, NOAA NCEI's database (https://www.ncdc.noaa.gov/stormevents/), and newspaper searches. Efforts to address climate change through adaptation and mitigation are also determined through web searches that show both news reports and multiple efforts that include mitigation planning. *High confidence* regarding the increase of adaptation and mitigation activities across the region, including natural and nature-based features, comes from less formal web searches, personal knowledge, and author team discussions. *Medium confidence* in the influence of extreme events on adaptation and mitigation efforts is based on the balance of evidence discovered when searching for attribution of reasons for planning and implementing these efforts.

Key Message 21.2

Ocean and Coastal Impacts Are Driving Adaptation to Climate Change

Description of Evidence Base

There has been a significant growth of peer-reviewed literature since NCA4 on climate change impacts on ocean and coastal environments in the Northeast. Ocean temperatures have increased,[291] and several marine heatwaves[65] have occurred in the region. These changes have impacted the marine ecosystem from phytoplankton to whales, with consequent effects on fisheries and the fishing community.[59] Coastal forests in some parts of the region have been affected by saltwater intrusion due to sea level rise, transforming them into tidal marshes.[122] Documentation on climate adaptation has come through formal reports and peer-reviewed literature in the field.

Major Uncertainties and Research Gaps

The responses of the coastal and marine food webs to the effects of multiple stressors (e.g., warming, marine heatwaves, loss of oxygen, and acidification) in the Northeast are currently not well understood. Additional research would help to fill knowledge gaps on the relative severity of these stressors on estuarine coastal ocean ecosystems and to evaluate the effectiveness of nature-based solutions with regard to ameliorating the impacts of sea level rise in coastal environments.

Description of Confidence and Likelihood

Confidence in the statements that the coastal ocean is warming, sea levels are rising, and ocean acidification is increasing is assessed as being *high* based on a synthesis of the published literature and formal reports. For marine heatwaves the confidence level is *high* based on peer-reviewed papers that covered limited data over a shorter time period. The statement on the existence of shifts in distribution, productivity and seasonal timing of life-cycle events of some marine species is made with *high confidence* based on information contained in several peer-reviewed publications. For adaptation actions, the confidence level is *high* based on actions taken across state, local, and federal scales.

Key Message 21.3

Disproportionate Impacts Highlight the Importance of Equitable Policy Choices

Description of Evidence Base

Reports of statistically significant relationships among sociodemographic variables and health and well-being outcomes related to heat, flooding, and storm events are published in peer-reviewed journals.[147] There is a growing body of literature that supports the conclusion that racial and ethnic minorities and low- and moderate-income communities are disproportionately impacted by climate extremes while having less access to the resources needed to mitigate those impacts.[148,151,159] Evidence of social equity as a priority in local climate adaptation planning is provided in publicly available plans published by government agencies and nongovernment organizations.[165] Specific actions to address environmental justice challenges are provided in the plans.[172]

Major Uncertainties and Research Gaps

The complex relationships among the changing climate, sociodemographic characteristics of communities, and health and well-being outcomes are multifaceted, and no single study can capture all aspects of these relationships. Moreover, longitudinal studies are rare, but they would help capture evolving patterns of impacts and responses within individuals and to evaluate the effectiveness of communities' adaptation initiatives. There are gaps in knowledge about the equity impacts of alternative adaptation options.

Description of Confidence and Likelihood

Confidence in the statement that climate-related hazards are causing disproportionate impacts among racial and ethnic minorities and low- and moderate-income communities in the Northeast is assessed as being *very high* because it is based on the synthesis of many peer-reviewed papers and formal reports. Confidence in the statement that these disproportionately impacted communities tend to have less access to resources and face higher environmental and health burdens is assessed as being *high* because it is based on the synthesis of many peer-reviewed papers, but the relationships are hard to tease apart. The assessment of *high confidence* in the statement that social equity objectives are prominent in many local-level adaptation initiatives but that progress toward equitable outcomes remains uncertain is based on the availability of several example plans, as well as insufficient time to permit robust assessment of equity outcomes. The likelihood of observed changes and events is assessed as *very likely* based on observations of extreme weather events and official actions and the synthesis of peer-reviewed papers and formal reports.

Key Message 21.4

Climate Action Plans Are Now Being Implemented

Description of Evidence Base

The evidence base assessed for this Key Message includes formally adopted reports, plans, executive orders, and laws addressing climate risks and vulnerabilities, sources of greenhouse gas emissions, and response options from state, municipal, and Tribal governments, including the Dalal and Reidmiller (2023)[176] assessment of state-level climate actions. While state-level differences in impacts are revealed through state-specific climate impact assessments (see references in Table 21.1), broadly speaking the observed and projected climate impacts are similar across states in the Northeast region. The state-by-state assessment of climate action revealed that most states in the region have taken ambitious, aggressive climate action through both the legislative and executive branches of government, with Pennsylvania (legislative inaction) and West Virginia (legislative and executive inaction) standing out as distinctly different. The reader is directed to Table 21.1 for a suite of state-specific resources describing climate impacts, sources of greenhouse gas emissions, and various state-government-level climate actions.

Major Uncertainties and Research Gaps

While the statements in the Key Message do not contain traditional research uncertainties, there are unknowns, including the following: Have jurisdictions adequately and comprehensively assessed their climate-related risk exposure? How much uncertainty is associated with the greenhouse gas emissions inventories that have been conducted? Are there cascading impacts or interacting stressors that are not yet accounted for? Several major unknowns will persist in any such analysis: Will the jurisdiction achieve the targets that have been set forth? What future level of warming will these jurisdictions experience? Will the anticipated impacts manifest as projected? Will jurisdictions be able to overcome nonfinancial barriers to adaptation? Will adaptation actions prove to be effective against realized impacts?

Description of Confidence and Likelihood

Confidence in most of the statements in the Key Message is assessed as being *high* because they represent an assessment of many stand-alone reports, plans, and laws. The exception to this is the final statement regarding whether mitigation targets will be met, which is assessed as having *medium confidence*, as the authors were unable to identify literature analyzing projections of emissions for each of the states in the region. Likelihood is not assessed in this Key Message because the nature of the content being assessed does not lend itself to a probabilistic assessment of the uncertainty associated with the statements.

Key Message 21.5

Implementation of Climate Plans Depends on Adequate Financing

Description of Evidence Base

Currently, the quality of the information is high and comes from reliable academic sources, federal agencies, and nongovernmental organizations. Data regarding FEMA and the National Flood Insurance Program (NFIP) are sourced directly from those entities based on the most recent data available.[280,281] However, most private risk financing and public funding information is not found in peer-reviewed literature but rather in gray literature, white papers, and case studies.[264,265] Unlike the public sector, the private sector typically does not announce adaptation work they might be financing or investing in.[264] However, the concepts behind public- and private-sector mitigation and adaptation projects are available from reliable academic and NGO sources.[263,284]

Major Uncertainties and Research Gaps

The literature searches for the draft of this chapter unfortunately did not produce any specific examples of private-sector adaptation investment in the Northeast, for the reasons stated in the previous section. Community-based catastrophe insurance is a new financial risk transfer concept. Few extant in-force examples exist, and ultimately the concept may not gain widespread use (see Bernhardt et al. 2021[263]). Similarly, climate investment intermediaries are also a new business concept but ultimately may not achieve long-term success.[265] The recent increase in federal funding through the Infrastructure Investment and Jobs Act[288] provides opportunity to pay for climate resilience projects, but the public sector's ability and willingness to repay debt financing is uncertain.

Description of Confidence and Likelihood

This section primarily discusses human financial systems and adaptation to mitigate physical climate change risk. Confidence around impacts of the flood insurance gap is *high*, based on the low market penetration of flood insurance across the Northeast (Figure 21.9) and the fact that the NFIP policies are currently capped by law at $250,000 for structural damage,[277] far below the median cost of a single-family home in 2022.[278] The confidence around demand for climate resilience investment is *high*, as numerous Northeast states have established programs to develop a project pipeline and pass voter-approved general obligation bonds to fund project implementation (Figure 21.10). Confidence around climate impacts is *high*, based on a literature search similar to that for Key Message 21.1.[13,20,23]

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