THE *NEW* NEW ENGLAND

HOW CLIMATE CHANGE JEOPARDIZES THE NORTHEAST'S ECONOMY AND ENVIRONMENT

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NATURAL RESOURCES
COMMITTEE • DEMOCRATS
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EXECUTIVE SUMMARY

For centuries, the experience of being a New Englander has been shaped by the region's climate and unique environment. Winds and waves carried the first Pilgrims to its shores, where Native Americans showed them which crops to plant and how to care for them. Perennially cool fall weather has illuminated forests with brilliant colors. Harsh winters that once took lives now enrich them with winter sports. New England's climate has shaped traditions and helped bring a sense of community across the region.

The creeping effects of global warming in New England will test her citizens like never before, as warming temperatures and more extreme weather changes the face of the region. Global warming caused by the emission of heat-trapping gases into the atmosphere from human activities is increasing temperatures, raising sea levels, altering precipitation patterns, and acidifying the oceans. These effects could have extensive impacts on New England's economy and will worsen if current rates of carbon pollution continue. Failure to address climate change could cost Massachusetts $9 billion in GDP and nearly 38,000 jobs between 2010 and 2050.[1] All together New England could see a $22 billion hit to GDP and almost 100,000 jobs lost.[2]

Global warming is already creating a "new" New England with more changes expected, including the following:

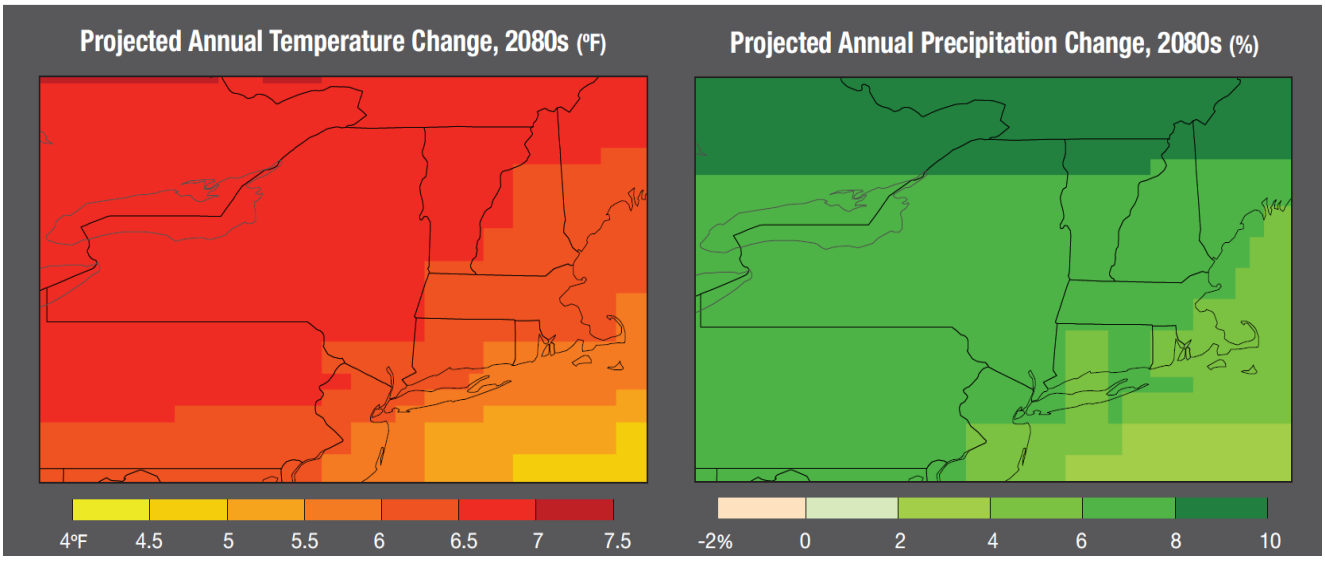
- The Northeast is heating up rapidly. January to August 2012 set a new record for high temperatures both on land and in the ocean. Without action to curb carbon pollution, this warming is expected to continue.
- Rates of sea-level rise from North Carolina to Massachusetts are two to four times faster than the global average. Many of the region's population centers, economic engines, and historical landmarks will be inundated.
- Precipitation in New England is becoming increasingly erratic – extreme rain and snowfall events are on the rise, making damaging floods more likely.
- Snow and ice are an integral part of New England's culture, from ice hockey to Frost's "Stopping by Woods on a Snowy Evening", yet New England has lost 9 snow days every decade since 1965 and will continue to lose snow as winter temperatures rise.
- Warm winters lower the percentage of sugar in maple tree sap so syrup producers must process more sap to get the same amount of syrup. In 2012, New England syrup production was down 27 percent from the previous year, leading to an approximately $17 million loss to the industry.
- By 2100, Maine will likely be the only state cold enough to sustain ski resorts, putting thousands out of work and losing billions of dollars for the New England economy.
- Drought will dull the iconic palette of fall colors that New Englanders – and countless tourists – have delighted in for centuries.
- Climate change represents a critical threat to several of New England's iconic species, like maple trees and the lynx. Ocean acidification and warming oceans will make New England's waters inhospitable to some of the region's most valuable species, including cod and lobster.
- Many of New England's streams will become uninhabitable for species that are important to recreational anglers, including brook trout and Atlantic salmon. In Massachusetts alone, freshwater angling supports 3,500 jobs and provides hundreds of millions of dollars in revenue.
- Climate change will leave New England vulnerable to invasion by invasive species known to inflict millions of dollars in damage elsewhere in the country.

CHANGES IN NEW ENGLAND'S ENVIRONMENT ARE WELL UNDERWAY

New England is already experiencing the impacts of climate change: warming temperatures, ocean acidification, rising sea levels, changes in the seasons, and more extreme weather.

The average annual temperature in the Northeast has been increasing by 0.5°F per decade,[3] with January to August 2012 setting a record for the hottest eight month period since record keeping began in 1895.[4] By the end of the century, climate change could make summer in Massachusetts feel like summer in North Carolina.[5] Boston could go from an average July temperature of 73°F to over 86°F by 2100.[6,7] Winter temperatures are also setting record highs; in fact, winter temperatures in the Northeast have been rising more than twice as fast as the annual averages.[8] According to scientists at the University of New Hampshire, New England winters have become 4°F warmer on average since 1965. In other words, Boston now has Philadelphia's winter weather.

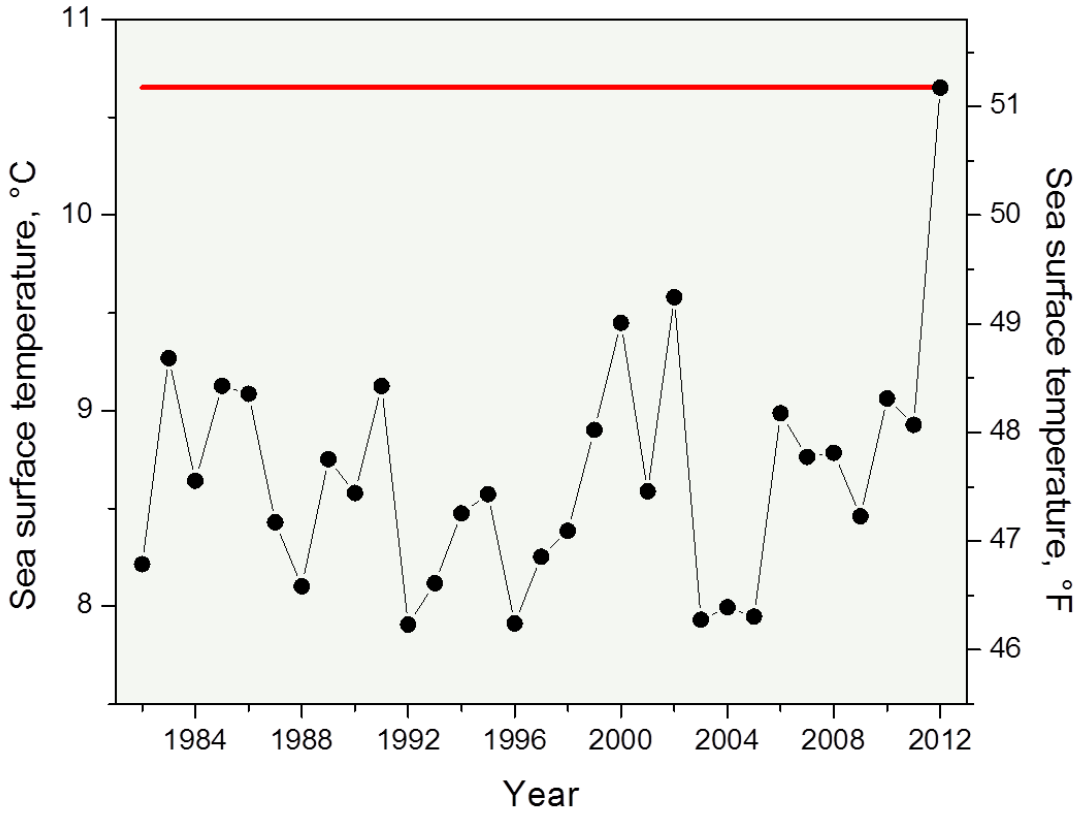
FIGURE 1: WARMER, WETTER WEATHER Predicted changes in temperature and precipitation by 2080, assuming continued high emissions of carbon pollution. By 2080, New England will be much hotter and will see significantly more precipitation, mostly because winters will become rainier. Source: Rosenzweig et al. (2011)



Carbon dioxide (CO_2) and other heat-trapping gases have increased the temperature and acidity of the oceans. The average sea surface temperature in the Northeast for the first half of 2012 was the highest since record keeping began in 1854.[9] It was above 51°F in 2012 while it has typically been below 48°F in the past three decades according to satellite remote sensing data (Figure 2).

The world's oceans absorb a significant amount of CO_2. From 1800-1994, the oceans absorbed more than 260 trillion tons of anthropogenic CO_2.[10] The added CO_2 changes the chemistry of the ocean, causing ocean acidification. If current emissions trends continue, ocean water is expected to become five times more acidic than it was before the industrial revolution.[11]

Figure 2: A Warming Ocean Ocean temperatures in the Northeast during the first half of 2012 were the warmest on record. It was 51°F in 2012 (denoted by the red line) but has typically been below 48°F in the past three decades. Source: NOAA Northeast Fisheries Science Center



Sea level is also rising around the globe from the expansion of seawater as the temperature increases and from the addition of water from melting glaciers. However, from North Carolina to Massachusetts, sea level is rising two to four times faster than the global average due to changes in ocean circulation patterns that slow the flow of water along the coast, essentially piling up water along the coastline.[12,13] Massachusetts loses an average of 65 acres (2.8 million square feet) to rising sea levels each year. Much of this loss occurs along the south-facing coast between Rhode Island and the outer shore of Cape Cod, including Nantucket and Martha's Vineyard.[14]

Weather in New England is getting more extreme and variable. Extreme downpours and snowfalls have increased by 85 percent since 1948.[15] While precipitation is falling in more intense intervals, there are also longer stretches where water is scarce, creating "feast or famine" dynamics when it comes to water.[16] And,

while extreme snowfalls are increasing, the overall amount of snow is declining. Since 1965, New England lost 9 more days of snow cover each decade because less snow falls overall and because warmer springs cause snow to melt earlier.[17]

The timing of the seasons is also changing. In the continental United States, autumn now arrives 10 days later than it did in the early 1980s.[18] In Massachusetts and most of New England, spring is "sprung" 5 days earlier on average than it did in the latter part of the 20th century.[19] Around the iconic Walden Pond, plants now flower 10 days earlier on average than they did in the 1850s based on the careful record kept by Henry David Thoreau of what was blooming when.[20]

IMPACTS ON NEW ENGLAND'S LAND-BASED RESOURCES

Rising temperatures will dramatically alter the New England landscape by reducing snow cover; diminishing the iconic fall foliage; driving out iconic species like the maple tree and the lynx; and increasing invasive species like the emerald ash borer beetle, which is capable of killing all North American ash trees, and kudzu, an invasive plant known as "the vine that ate the south".

Warmer winters translate into less precipitation falling as snow, which directly harms New England's snow-based economy and the thousands of people whose jobs depend on it. If current levels of carbon pollution continue, only western Maine will be able to maintain a reliable ski season.[21] This could mean billions of dollars and many thousands of jobs lost from Massachusetts to New Hampshire. Skiing and other winter sports are an important source of revenue and jobs for New England. In the state of Vermont alone, direct spending at ski resorts (e.g. lift tickets, ski rentals) amounts to $750 million, with an additional $700 million in indirect spending (e.g. hotel and fuel costs).[22] What's more, the resorts themselves spend $280 million a year on services (e.g. food, electricity), most of which they draw from other local businesses.[23]

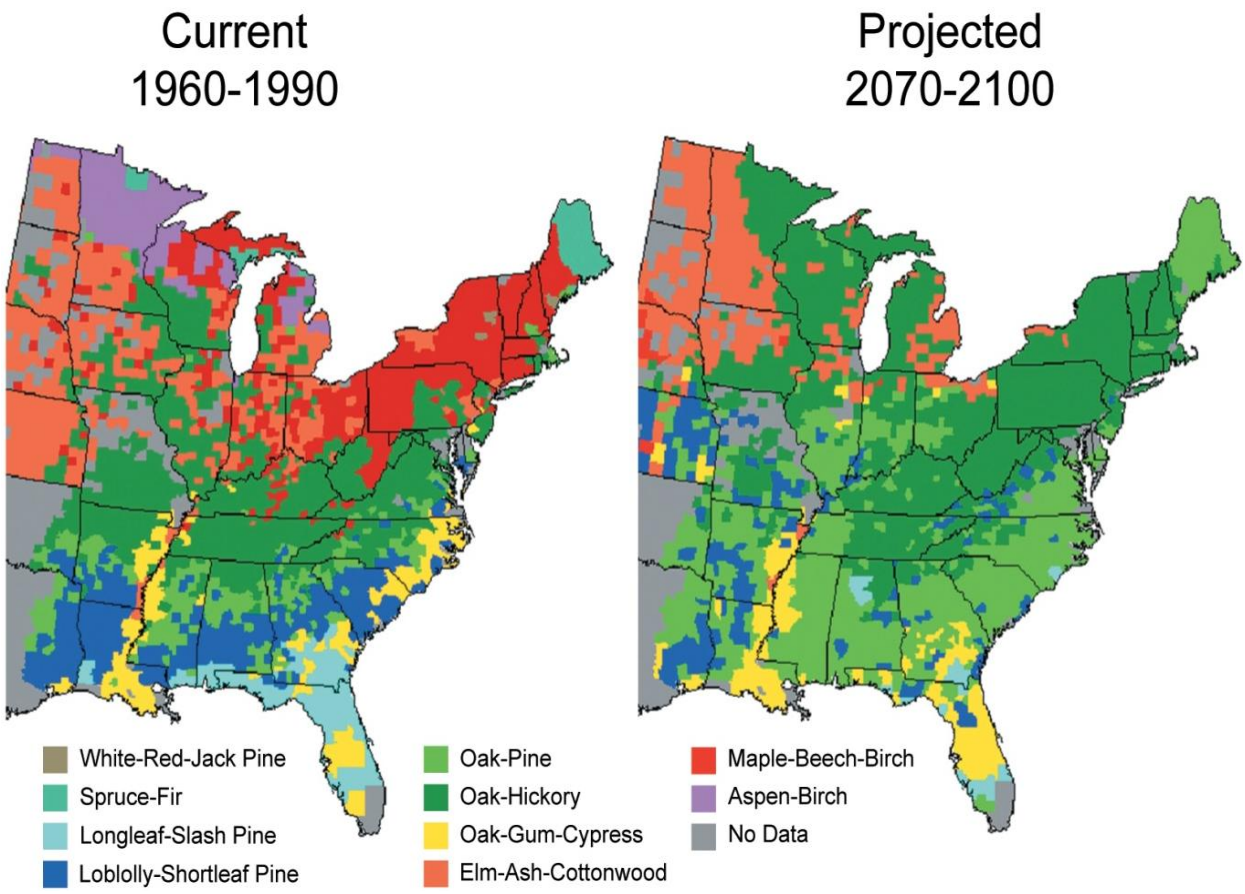
Lost revenues due to warming temperatures are already inflicting harm on ski resorts. A recent survey from the National Ski Areas Association found that the 2011-2012 winter – one of the warmest on record – saw a 16 percent reduction in the number of visitors compared to the year before. The warmer winter also meant a shorter ski season, as 51 percent of resorts opened late and 49 percent closed early.[24] In addition, a study from New Hampshire found that "low snow" winters cost 3,000 jobs across the state, mostly from skiing and other tourist-based industries.[25]

Each fall New Englanders delight in a striking palette of fall foliage – and in the influx of tourists that the vibrant landscape brings. Yet the attractive blazes of maple, beech, and birch leaves will fade away as climate change takes hold. The trees will become increasingly drought-stressed and their autumn colors will lose their vibrancy.[26] This will hurt the vibrancy of the New England tourism economy too. Fall foliage tourism is estimated to add $1 billion dollars to New Hampshire's economy alone.[27] Drought-stress will also make forests more vulnerable to fire. While forest fires have historically been rare in New England, the last few decades have seen substantial increases in the frequency and extent of fires, a trend in keeping with increased temperatures and a changing precipitation regime.[28,29] Eventually forests in New England will shift to oak, hickory and pine. By the end of this century, there could be no maple-beech-birch or spruce-fir habitat left (Figure 3).[30]

Changes in forest species composition could compromise jobs in the pulp, paper, and forest products industry, as these industries will have to adapt to an increasingly unreliable resource base. For example, the sugar maple, a cornerstone of New England's culture and economy, is predicted to move north as climate change continues. Maple trees are already shifting northward from increasing temperatures and could almost completely disappear from New England by the end of this century.[31,32] Moreover, those trees that remain will produce

dramatically less syrup. Warm winters lower the percentage of sugar in maple tree sap so syrup producers must process more sap to get the same amount of syrup. New England's maple syrup production is already variable - production in 2012 was down 27 percent from a near record high in 2011.[33] Based on the 2011 price per gallon, this equates to an industry loss of $17 million.[34] As winters continue to warm, the extra effort needed to make syrup will sour many producers on staying in the business.

FIGURE 3: AN UNRECOGNIZABLE LANDSCAPE Climate change will cause dramatic changes in the species composition of Northeastern forests. The maple-beech-birch forest that covers most of the region today will shift to oak and hickory by the end of the century. Source: T.P. Karl et al. (2009)



Increased temperatures also mean that insects that were kept in check by cold winters will be able to expand northward. Insect pests from Asia such as the emerald ash borer beetle and the hemlock wooly adelgid will pose significant threats to New England's forests as the climate warms.[35] The emerald ash borer, an aphid-like insect, was recently discovered in Massachusetts.[36] This insect could destroy all native North American ash trees, as they have no evolutionary history with this insect.[37] Ash trees are a mainstay of urban and suburban landscapes across the Northeast and the costs of dealing with dead trees can be substantial. A study from Illinois, Indiana,

Michigan, and Wisconsin estimated that the total cost of removing and replacing dead ash trees would be between $13.4 and $26 billion.[38]

The hemlock woolly adelgid has the potential to kill off New England's hemlocks, which are important trees for wildlife. Hemlocks are evergreen trees that grow along stream banks. They keep water clean, offer shade in the summer and provide habitat over the winter.[39] Hemlock wooly adelgid infestations can cost up to $20,000 per acre in lost property value.[40] Recognizing the substantial threat that these insect pests pose, the Massachusetts State Legislature has allocated $60,000 to a pilot program to control the hemlock wooly adelgid using predatory ladybugs.[41]

As temperatures rise, unwanted plants will move in.[42] For example, kudzu, known as "the vine that ate the South", is currently confined to eastern Massachusetts because it cannot survive cold winters.[43] However, shorter and milder winters will open a path for this invader, which smothers trees and can reduce the value of timber and the overall health of a forest.[44] Economic losses in the southeastern United States amount to more than $500 million per year in control costs and lost forest productivity.[45] Power companies also struggle with this plant; they spend 1.5 million a year to keep it off power lines.[46] In addition, a study from kudzu-infested areas in Georgia found that kudzu can change soil chemistry, releasing a gas called nitric oxide that contributes to ozone pollution. Areas with dense infestation could push local ozone pollution levels to exceed air quality standards as many as seven days a year.[47]

Changes in New England's tree species composition mean that suitable habitat will be moving or shrinking, requiring wildlife to move as well. The lynx, emblematic of the snowy forests of New England, is already listed as threatened in the continental United States, including in Maine—the only place in New England it is still found.[48] Climate change will likely drive this big cat out of the United States entirely. The lynx's prey, like snowshoe hare and red squirrels, are strongly associated with spruce-fir habitat and will have no place in the oak-pine forest that will dominate by the end of the century.[49] Like the lynx, Bicknell's thrushes live exclusively in spruce-fir forests and will have to migrate with their habitat.[50] The Bicknell's thrush is already rare. In fact, it is currently under review by the Fish and Wildlife Service to determine if it may be threatened or endangered.[51] The loss of its forest habitat will mean one less song in the summer chorus of birds found in the New England mountains.

Climate change also could have dramatic effects on New England's streams, threatening valuable species such as brook trout and Atlantic salmon. Trees are a critical component of stream habitats because they prevent erosion, cool streams in the summer, and provide materials for food sources and nesting grounds. Losing riparian trees due to temperature changes or pest outbreaks could significantly degrade habitat quality for all stream-dwelling animals.[52] In addition, changes in New England's precipitation regimes will affect the timing and extent of stream flows. The life cycles of brook trout and Atlantic salmon depend on abundant, cool water from spring snowmelt. Already, scientists have observed that spring snowmelts are happening earlier in New England. It is unclear whether trout and salmon will be able to adapt to these changes.[53]

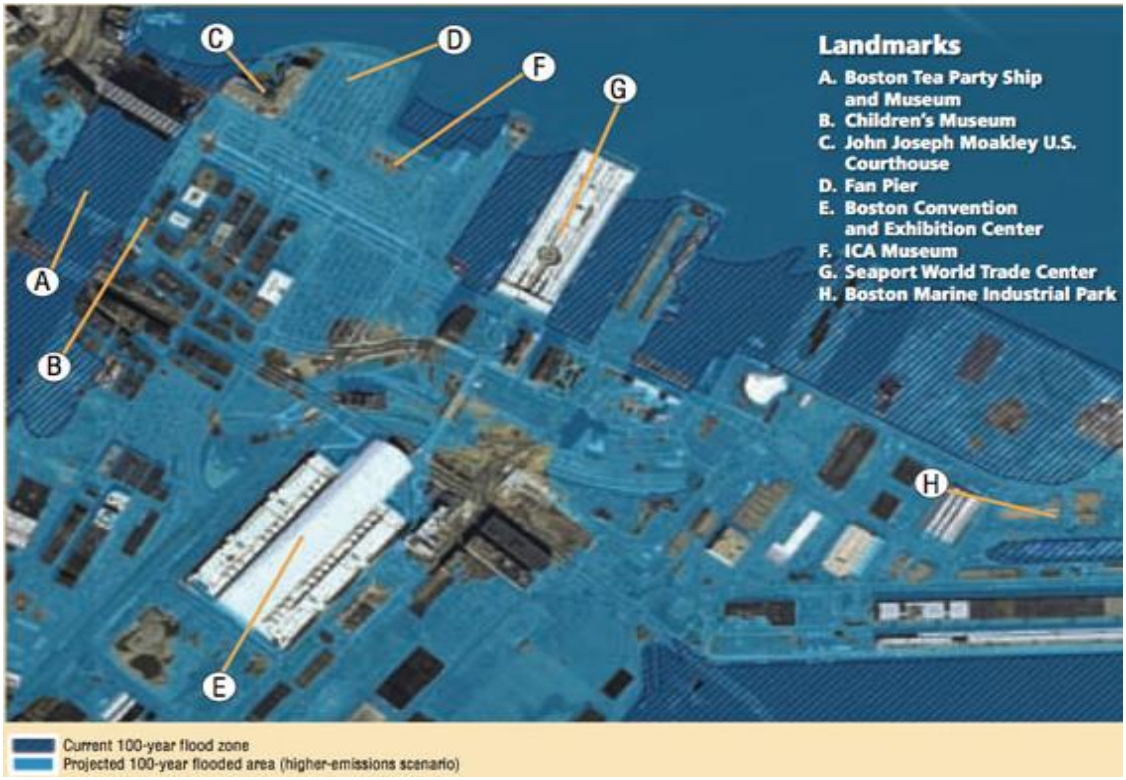
Loss of brook trout and Atlantic salmon could adversely affect freshwater fishing, which is an important component of the New England economy. Just in Massachusetts, freshwater anglers spend $270 million a year on fishing-related products and more than 3500 jobs are directly related to freshwater fishing.[54] Each year, angling-related activities in the state generate $32 million and $38 million in state and federal tax revenues, respectively.[55]

IMPACTS ON NEW ENGLAND'S COASTAL AND MARINE-BASED RESOURCES

Sea level rise could devastate coastal communities and destroy treasured landmarks. Climate-driven changes to ocean temperature and acidity will cause many marine species to decline, including cod, lobster, and right whales. Some mid-Atlantic species are expected to shift north.

Massachusetts' densely populated coastal region is highly susceptible to flooding and the effects of extreme weather. Home to one third of the state's population, insurance companies have already refused coverage to thousands of homeowners in the region.[56] As sea levels rise and storms become more severe, many of Boston's best-known landmarks will be threatened, including Faneuil Hall, Quincy Market, North Station, Fan Pier, Copley Church, John Hancock Tower and the Public Garden (Figure 4).[57] By 2050, sea level rise could cost Boston $463 billion in damages.[58] Cape Cod National Seashore, which attracts thousands of tourists to its 55 miles of pristine beaches, thereby supporting nearly 1,900 jobs, will see many of its unique barrier islands destroyed and much of its beaches degraded.[59] As sea level rise continues, hundreds of the seashore's freshwater wetlands will be inundated, and critical habitat for wildlife will be washed out.[60] Coastal wildlife won't be the only ones forced from their homes - properties would be ruined all along New England's coast. For example, homes in two of Portland, Maine's most affluent neighborhoods, East Deering and Baxter Boulevard, would be wrecked, representing an estimated $70 million worth of damage.[61]

FIGURE 4: LOSING LANDMARKS Sea level rise over Boston under a high carbon emissions scenario will inundate landmarks of cultural and economic importance, in many cases causing irreparable damage. Source: P.C. Fromhoff et al. (2007)

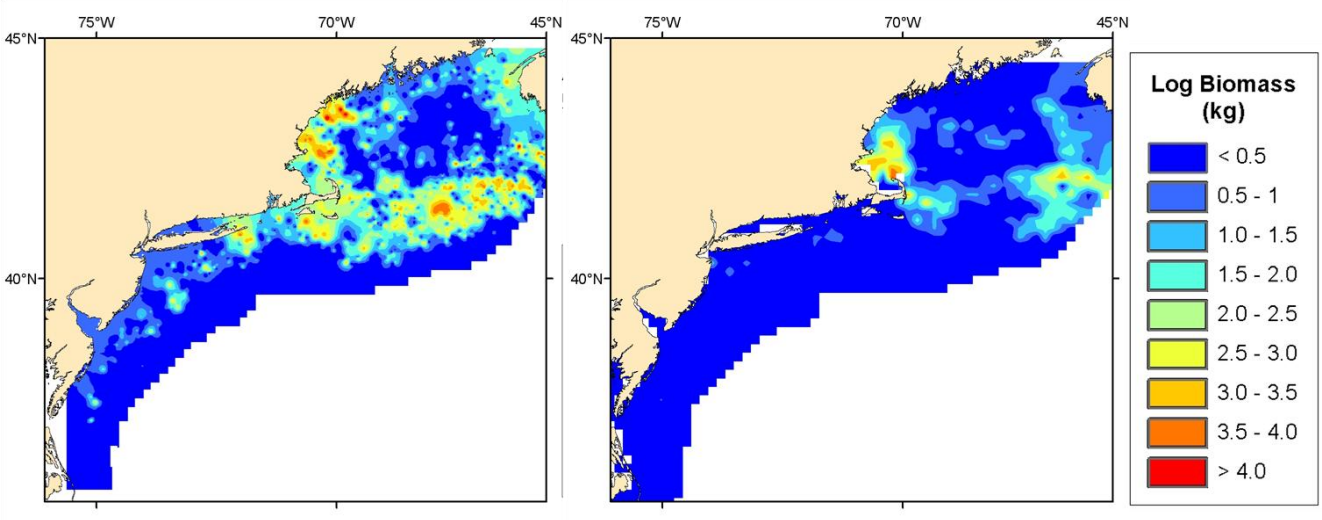


Sea level rise will inundate marshlands, which act as a buffer against waves, filter pollutants, and provide irreplaceable habitat for wildlife. New England's marshlands act as nurseries for commercially important species such as lobsters, clams, scallops and herring, and they provide hunting grounds for bluefish and striped bass.[62] In Massachusetts alone, the combined value of these marsh-dependent fish topped $400 million in 2011.[63]

Many of New England's marine animals, including cod and the endangered right whale, depend on a tiny crustacean called *Calanus finmarchicus* for food.[64,65] Temperature strongly influences the distribution of *Calanus finmarchicus,* whose range is expected to shift dramatically over the next century.[66] The critically endangered North Atlantic right whale is expected to decline as climate change pushes out *Calanus finmarchicus* and other species it needs for food.[67] Cod stocks in the Gulf of Maine and Georges Bank are highly sensitive to warming temperatures, as they are at the southern-most extent of their range. These stocks have been shifting to the northeast as oceans warm (Figure 5).[68,69] Lobsters have also been impacted by the increasing temperatures off of the coast of New England. The southern New England stock, which includes Cape Cod, is now critically depleted and its recovery is in jeopardy.[70] Warm waters can also cause the opposite problem – too many lobsters. This year warm waters meant an early appearance and then an overabundance of lobsters in Maine, which sent the price of lobster plummeting and lobstermen scrambling to make a living.[71]

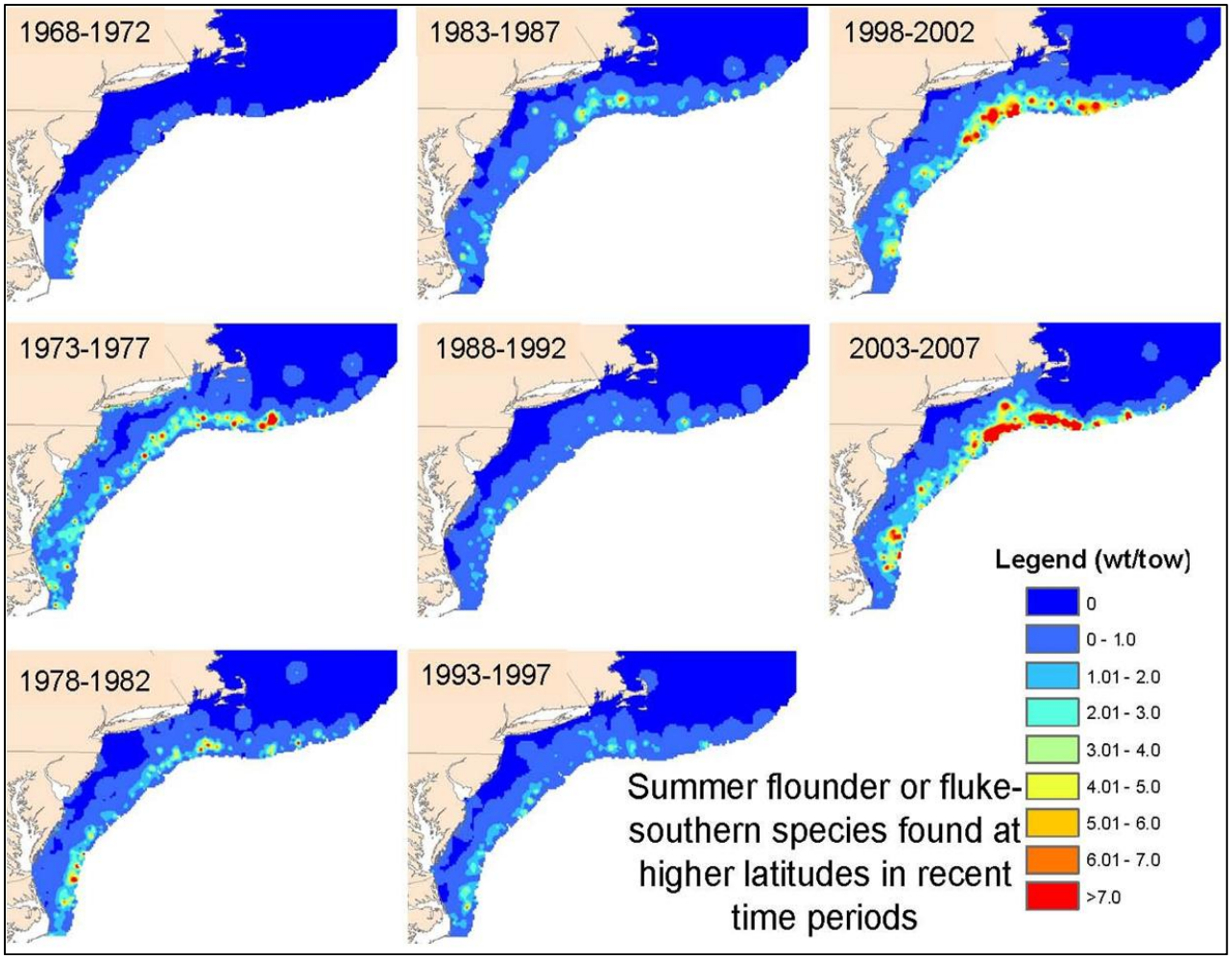
Several studies show that fishing and climate change act synergistically, making overfished species even more sensitive to climate than they would otherwise be.[72,73,74] This means that cod and other overfished species are particularly vulnerable to the effects of climate change. It is likely that as cod decline, species like Atlantic croaker, summer flounder, and red hake will become more common (Figure 6).[75] While many factors have contributed to the decline of the iconic, once abundant cod and right whales, climate change is likely to be the final harpoon in their backs.

FIGURE 5: COD MOVING NORTH TO COOLER WATER Trawl surveys conducted off the coast of New England during the spring from 1968-1972 (left) saw considerably more cod than surveys done from 2008-2012 (right). This trend is expected to continue. Source: NOAA Northeast Fisheries Science Center



Many marine species are vulnerable to ocean acidification. Higher concentrations of CO_2 in seawater can lead to thinner scallops, which could threaten New England's most lucrative fishery.[76] Cod larvae reared in conditions with increased CO_2 show severe tissue damage in the liver, pancreas, kidney, gut, and eye.[77] Other fish develop behavioral and sensory abnormalities,[78] and a recent experiment showed that 78 percent of fish reared in acidified waters died within 10 days of hatching. Although the extraordinarily warm waters off the coast of Maine have led to an overabundance of lobster this year, increasing CO_2 emissions are a potential threat to their existence in the long term. Lobster larvae grown in acidic waters are significantly smaller than animals reared in normal water.[79] Scientists currently estimate that 99.9 percent of lobsters die as larvae.[80] Acidic waters will increase larval mortality further, putting the entire population at potential risk.[81] Perhaps most importantly, ocean acidification reduces marine plant life,[82] so even those animals that escape physical or behavioral maladies will likely face severe disruptions to their food chains.

FIGURE 6: NOT JUST A FLUKE – FISHERMEN SEE MORE FLOUNDER From 1968 to 2007 scientists and fishermen saw more flounder in New England waters. This trend is expected to continue. Source: NOAA Northeast Fisheries Science Center



CONCLUSION

If heat-trapping emissions continue at current rates, New Englanders will see drastic changes to their economy, culture, and environment. Yet even with an accelerated transition to low-carbon energy sources, New England and the world is certain to face some degree of climate change due to the forty percent increase of atmospheric CO_2 concentrations that has already occurred since the beginning of the Industrial Revolution. We must develop comprehensive adaptation strategies to deal with the effects of climate change already under way and prepare for those anticipated in the future. Continued funding of scientific research will be critical to understanding the extent and consequences of climate change.

Taking action to reduce carbon emissions in the near-term will help avoid untold economic and environmental damage associated with climate change over the long-term. Fortunately, the solutions to reduce global warming pollution are available and are already being deployed. Renewable energy sources like wind, solar, geothermal, and hydropower are being harnessed affordably to generate electricity. Vehicles powered by biofuels, natural gas, and electricity are rapidly becoming viable alternatives to the petroleum-based fuels that have had a monopoly on the transportation sector for a century. But we're just beginning to scratch the surface of clean energy's potential. State, federal, and international policies that incentivize clean energy deployment and require fossil fuels to internalize the cost of their carbon pollution will accelerate the transition to low-carbon economy. This transition is achievable and will come with overwhelmingly positive benefits in terms of job creation, global economic competitiveness, and human and environmental health. New England in particular—as an innovation-oriented, entrepreneurial economy with strong universities and technology companies—is well positioned to benefit economically from a transition to cleaner energy sources.

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